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# Sea ice forecasting for optimised Arctic ship routing

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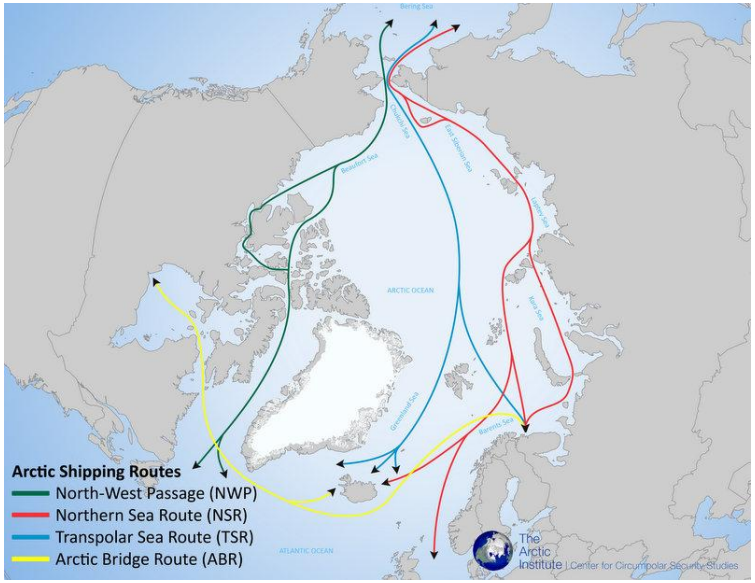
# Project IRO-2

- www.iro-2.de
- 6 + 1 project partner
- 2011 to 2014
- National Masterplan for Maritime Technologies
- German Federal Ministry for Economic Affairs and Energy

# General mission

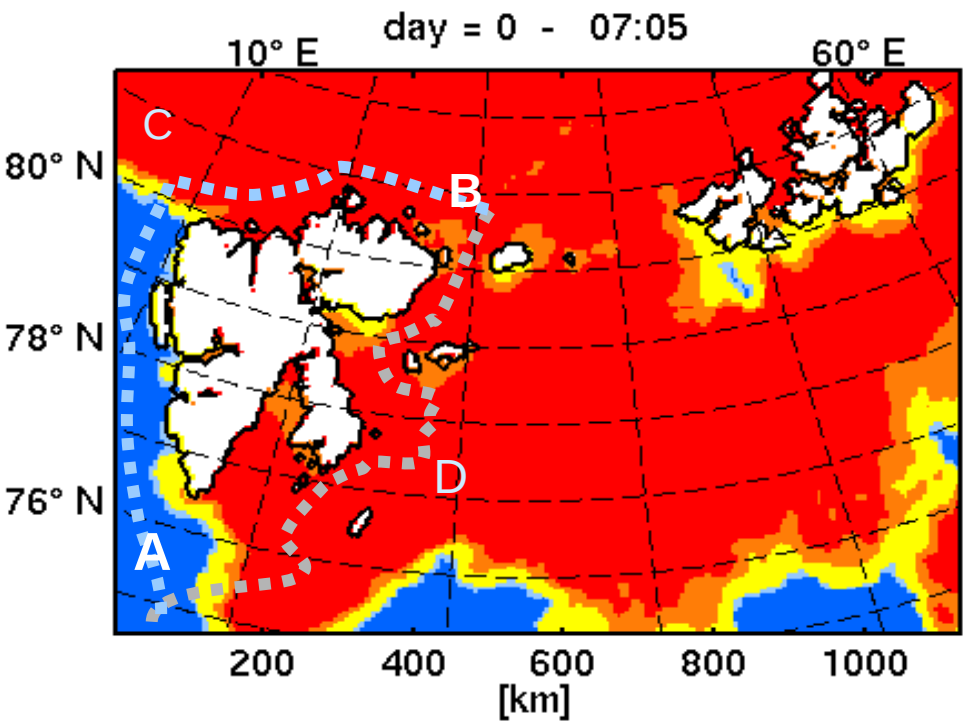
- **Goals**
  - Safe and economic Arctic shipping
    => Ship routing based on current and forecasted sea ice conditions
  - Responsible operation of platforms
    => Forecasts for offshore industry
  - Arctic engineering and product design
    => Virtual reality for ship design, classification, insurance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

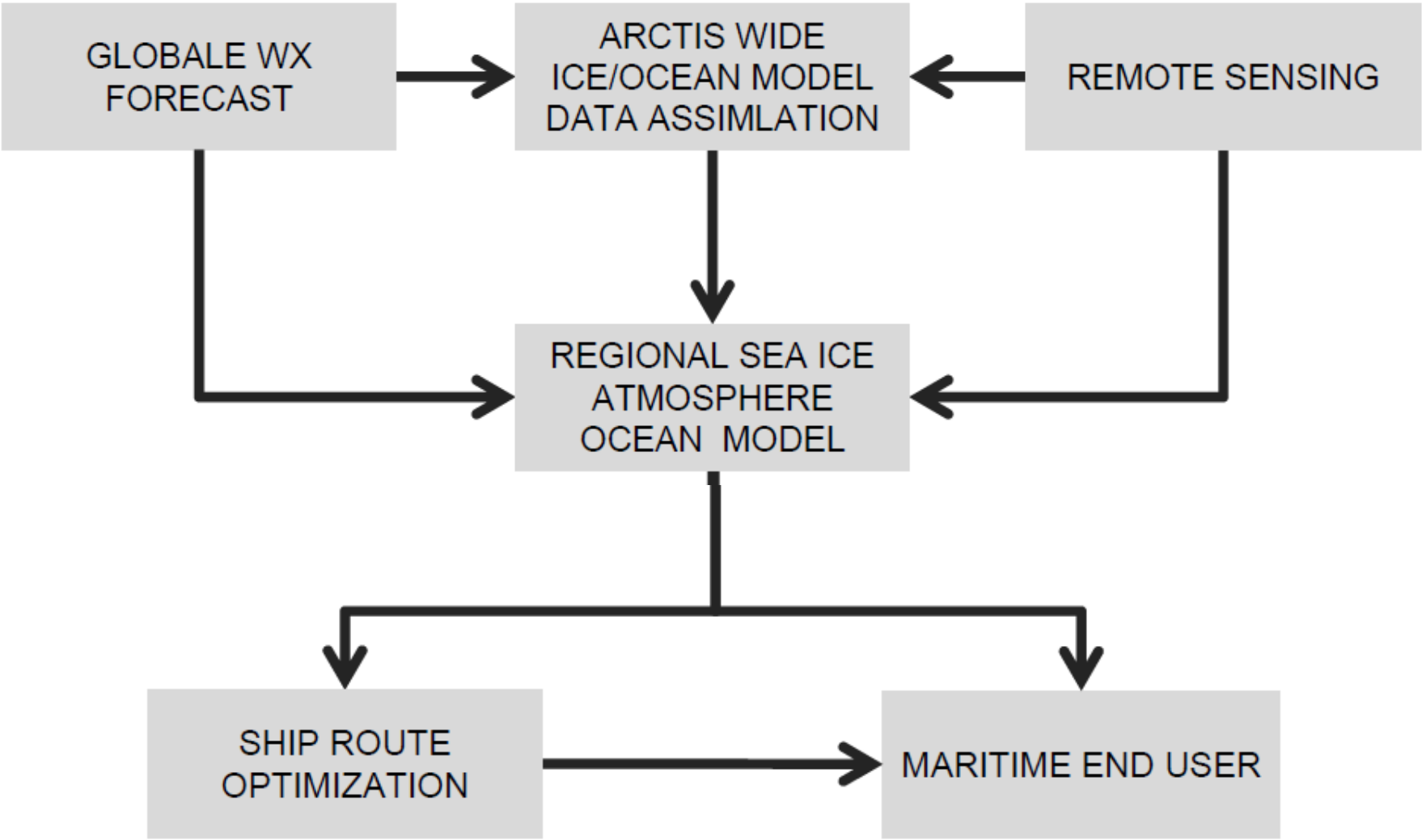


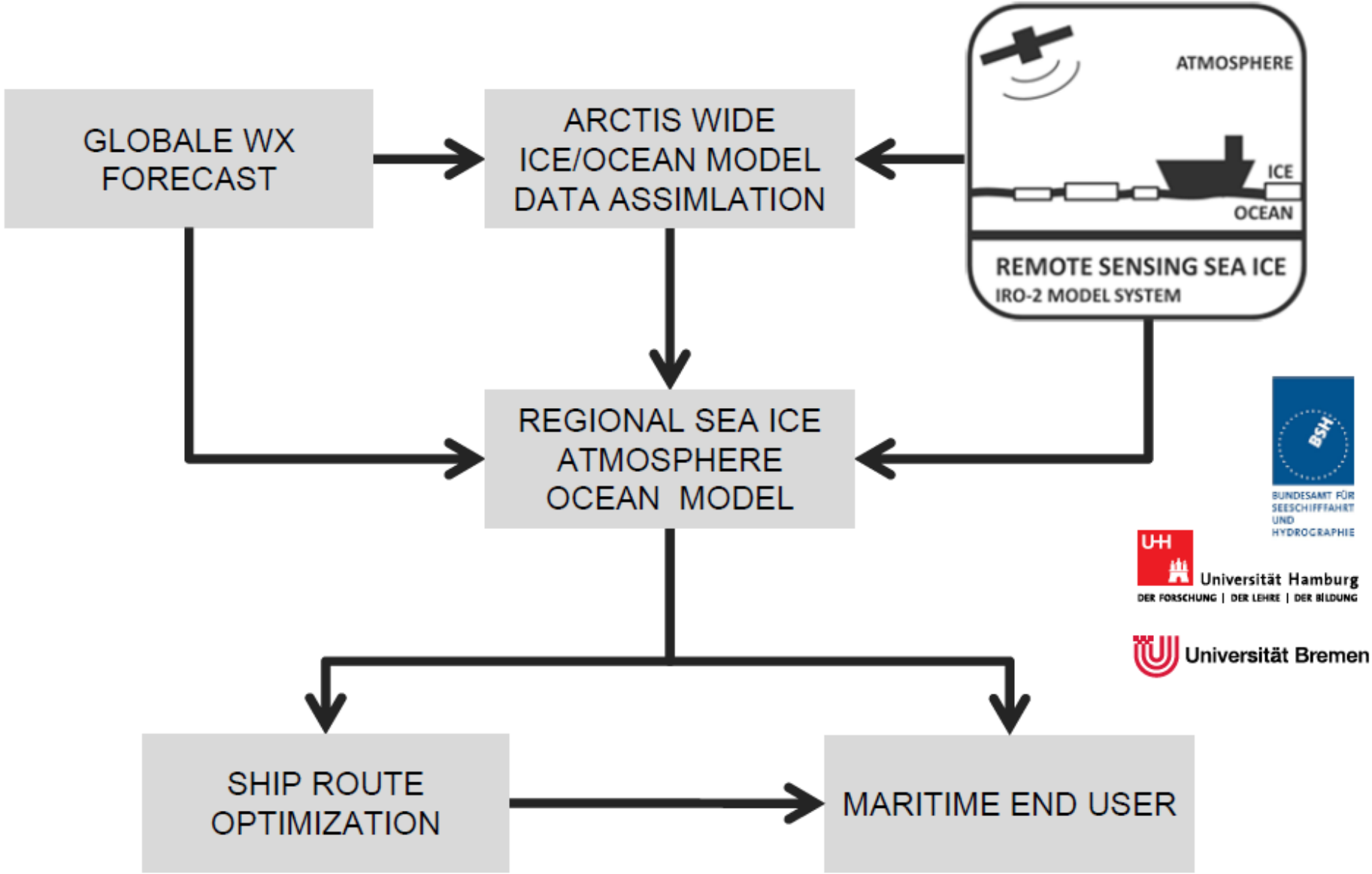

**Humpert, M. and Raspotnik, A. (2012):** The future of Arctic shipping. The Arctic Institute. http://goo.gl/9Bja3

# 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?




GLOBALE WX FORECAST
ARCTIS WIDE ICE/OCEAN MODEL DATA ASSIMLATION
REMOTE SENSING
REGIONAL SEA ICE ATMOSPHERE OCEAN MODEL
SHIP ROUTE OPTIMIZATION
MARITIME END USER


GLOBALE WX FORECAST
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ATMOSPHERE
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BSH
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE
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Universität Bremen
SHIP ROUTE OPTIMIZATION
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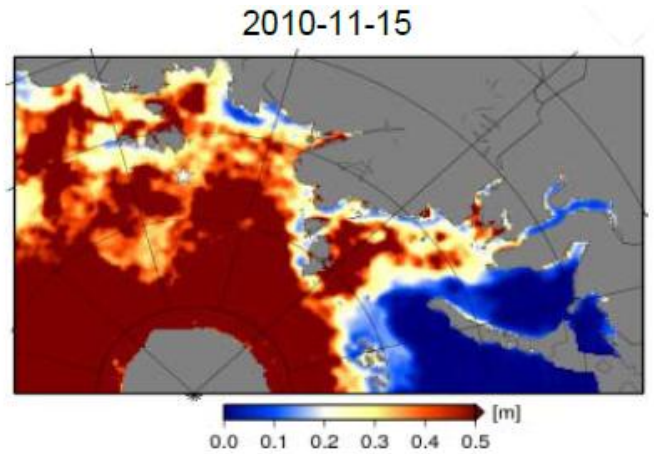
# Sea ice initialization

- **Sea ice thickness – SMOS [1]**
  - 1.4 GHz allows to detect the ocean-ice interface for not too thick ice
  - Brightness temperature related to sea ice thickness for thin ice
  - Daily coverage with 35 km resolution
  - http://icdc.zmaw.de/smosice.html

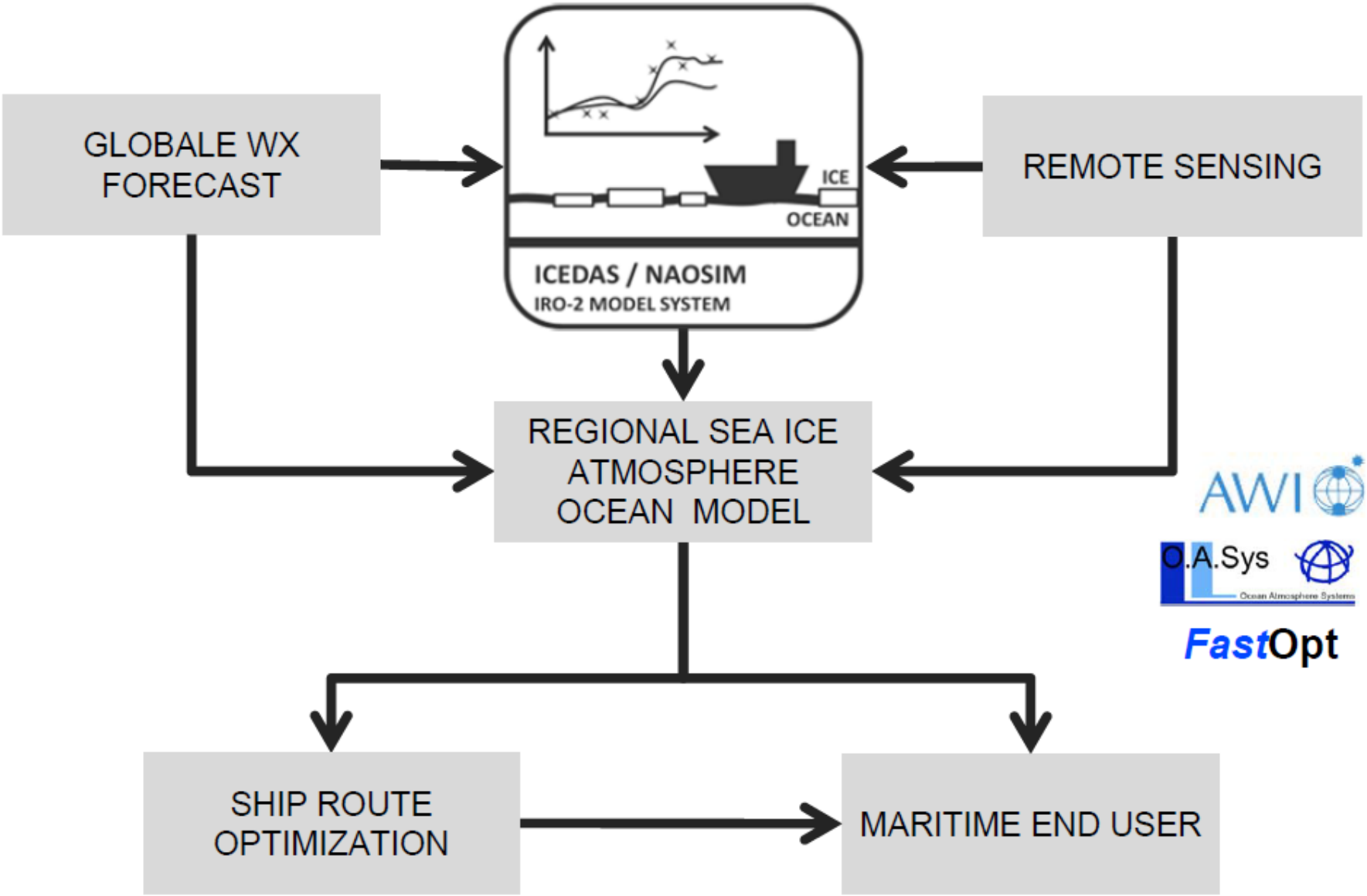



**Kaleschke, et al. (2012):** Sea ice thickness retrieval from SMOS brightness temperatures during the Arctic freeze-up period, Geophys. Res. Lett. http://doi.org/mqv

- **Sea ice Concentration – AMSR2 [2]**
  - First re-forecast tests with SSMIS (dx = 12 km)
  - Updating to AMSR2 / AMSR-E (dx = 3.125 km, 4-5 km footprint)

**[1] Beitsch A, Kaleschke L and Kern S (2014):** Investigating High-Resolution AMSR2 Sea Ice Concentrations during the February 2013 Fracture Event in the Beaufort Sea. Remote Sensing. 6: 3841-3856. http://dx.doi.org/10.3390/rs6053841

**[2] Tian-Kunze X, Kaleschke L, Maaß N, Mäkynen M, Serra N, Drusch M and Krumpen T (2014):** SMOS-derived thin sea ice thickness: algorithm baseline, product specifications and initial verification. The Cryosphere. 8: 997-1018. http://dx.doi.org/10.5194/tc-8-997-2014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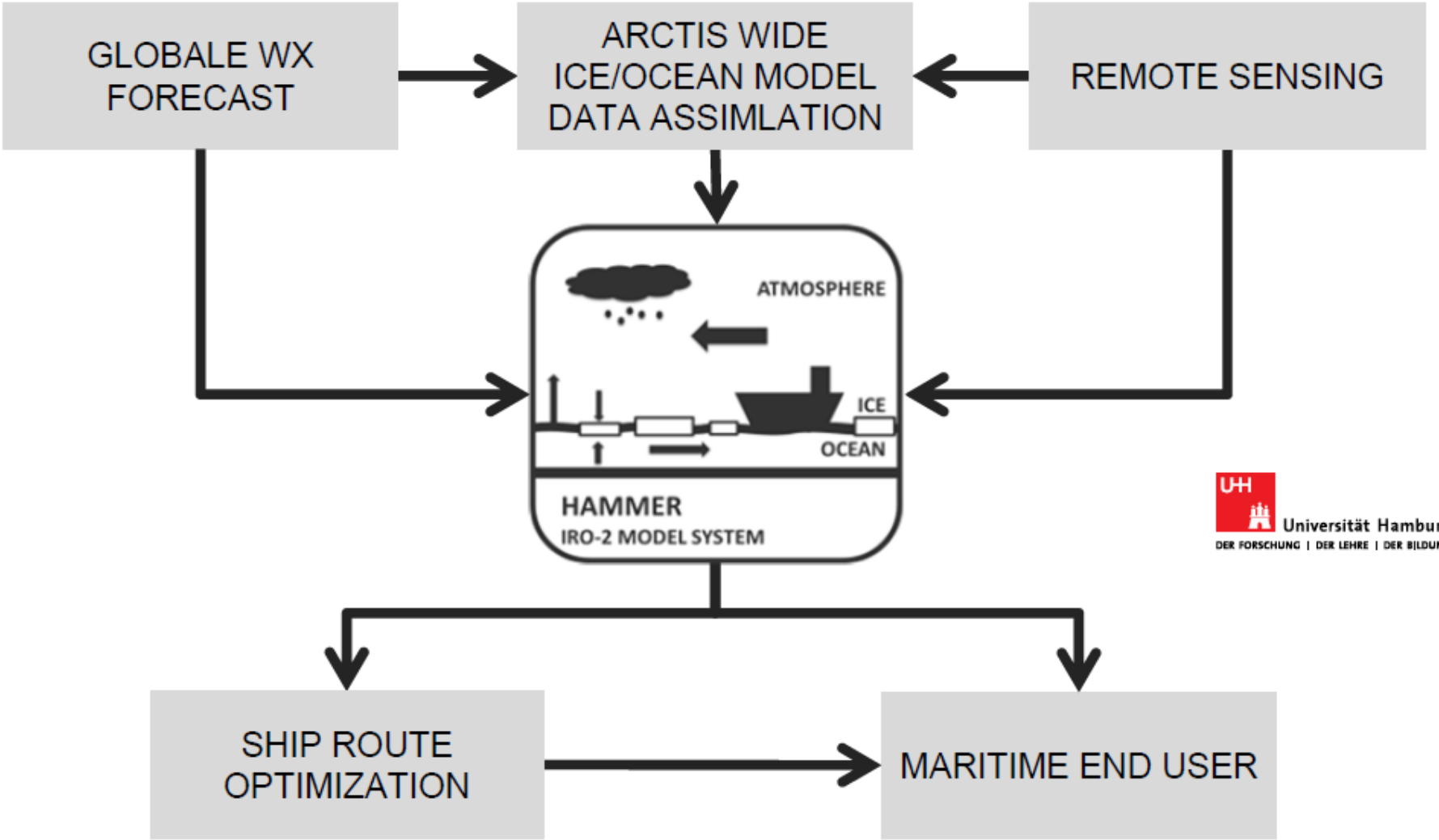
ICE
OCEAN
ICEDAS / NAOSIM
IRO-2 MODEL SYSTEM
REMOTE SENSING
REGIONAL SEA ICE ATMOSPHERE OCEAN MODEL
AWI
O.A.Sys
Ocean Atmosphere Systems
FastOpt
SHIP ROUTE OPTIMIZATION
MARITIME END USER

# Ice data assimilation system - ICEDAS

- Arctic wide sea ice – ocean data assimilation system
- Developed by O.A.Sys and FastOpt based on NAOSIM [1] and NAOSIMDAS [2]
- Process validation and improvement in forecast model NAOSIM by AWI

**[1] Gerdes R, Karcher M J, Kauker F, Schauer U 2003:** Causes and de- velopment of repeated arctic ocean warming events. Geophysical Research Letters 30 (19). http://dx.doi.org/10.1029/2003GL018080

**[2] Kauker F, Kaminski T, Karcher M, Giering R, Gerdes R and Voßbeck M (2009):** Adjoint analysis of the 2007 all time Arctic sea-ice minimum. Geophysical Research Letters. 36: L03707. http://dx.doi.org/10.1029/2008GL036323

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# Regional model - HAMMER

- **Model components**
  - Sea ice: Multiclass sea-ice model MESIM [1], directly coupled to atmospheric model METRAS, originally ported [2] from an AWI sea ice model
  - Atmosphere: Anelastic, Boussinesq approximated non hydrostatic mesoscale model METRAS [1]
  - Ocean: Shelf ocean model HAMSOM [2], free surface including equations for temperature and salinity
  - Tide: Pre calculated with FES2004 [3]
- **Infrastructure**
  - Coupling with OASIS
  - Workflow with ecFlow

**[1] Schlünzen KH, Flagg DD, Fock BH, Gierisch A, Lüpkes C, Reinhardt V and Spensberger C (2012a):** Scientific documentation of the multiscale model system M-SYS (METRAS, MITRAS, MECTM, MICTM, MESIM). http://goo.gl/9WWFf accessible 2014-06-05.

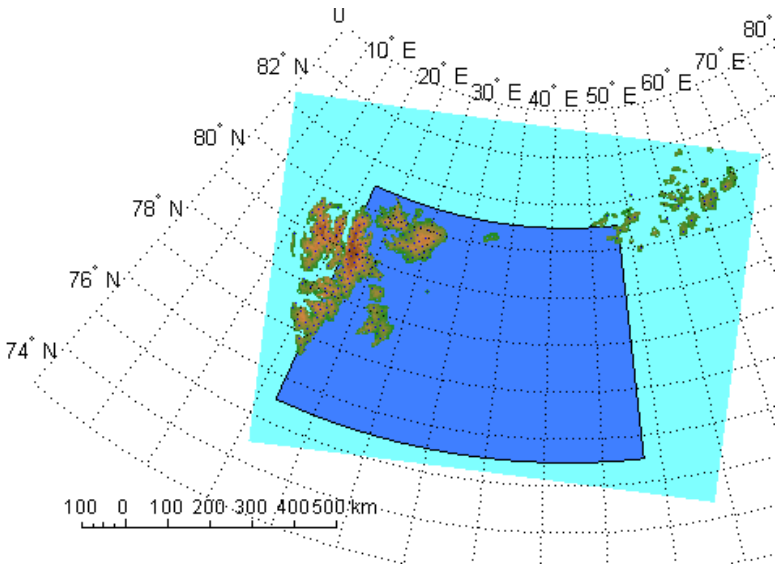
**[2] Birnbaum G (1998):** Numerische Modellierung der Wechselwirkung zwischen Atmosphäre und Meereis in der arktischen Eisrandzone. Berichte zur Polarforschung

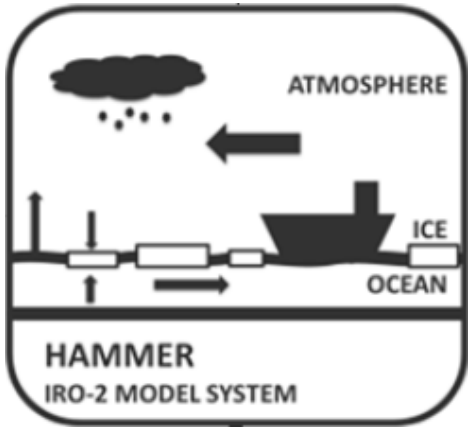
**[3] Pohlmann T (2006):** A meso-scale model of the central and southern North Sea: Consequences of an improved resolution. Continental Shelf Research. 26: 2367–2385. http://dx.doi.org/10.1016/j.csr.2006.06.011

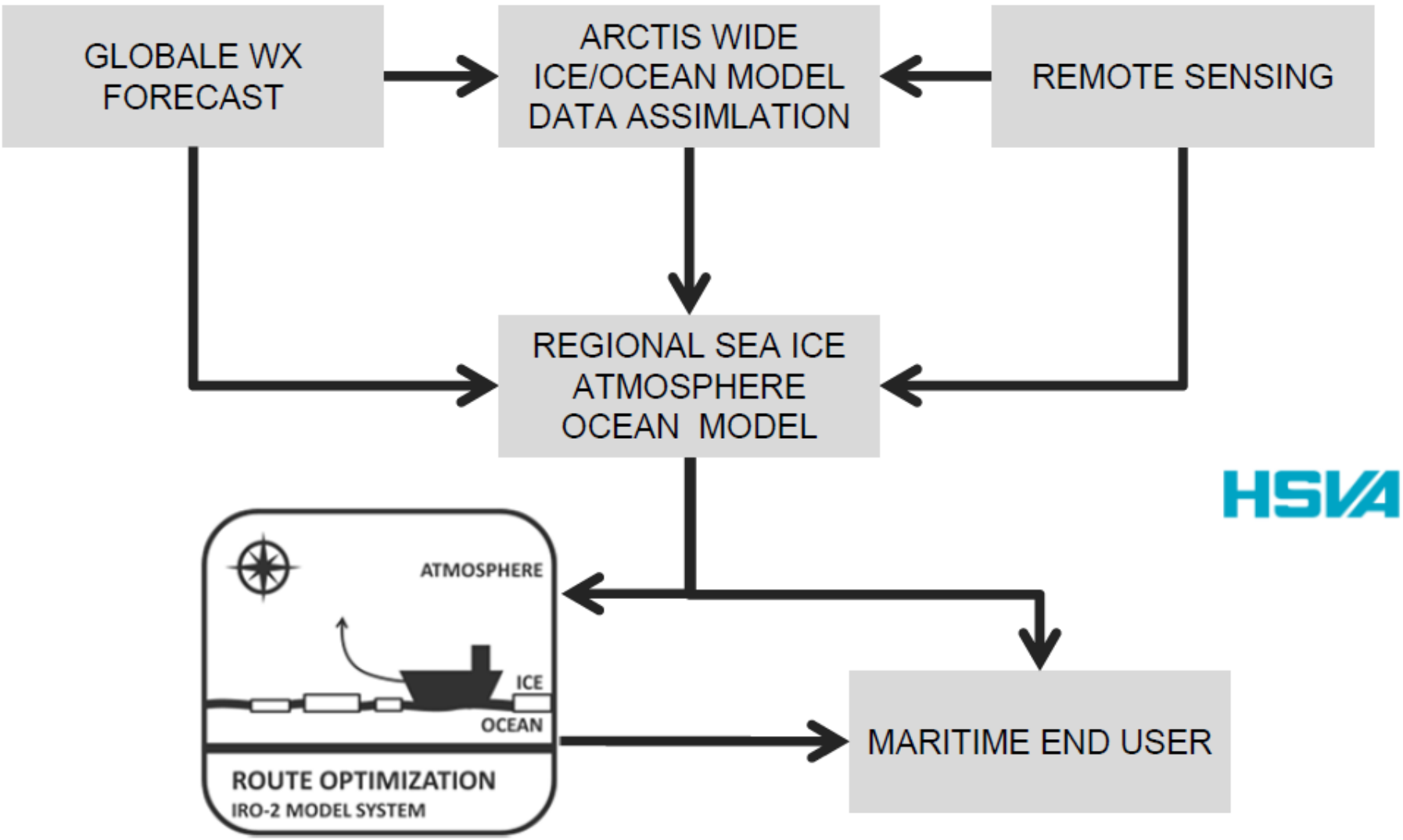
**[4] Lyard F, Lefevre F, Letellier T and Francis O (2006):** Modelling the global ocean tides: modern insights from FES2004. Ocean Dynamics. 56: 394-415. http://doi.org/fkq7sx

# Regional model

- **Regional IRO- setup in short**
  - Test region Barents sea
  - 830 x 1125 km
  - Few days forecasts
  - Running IBM Power 6 @DKRZ
  - Atmospheric forcing ECMWF HRES
  - Sea ice initial conditions from satellite
  - Additional boundary conditions from ICEDAS/NAOSIM
  - Coupling regional models for sea ice - atmosphere - ocean

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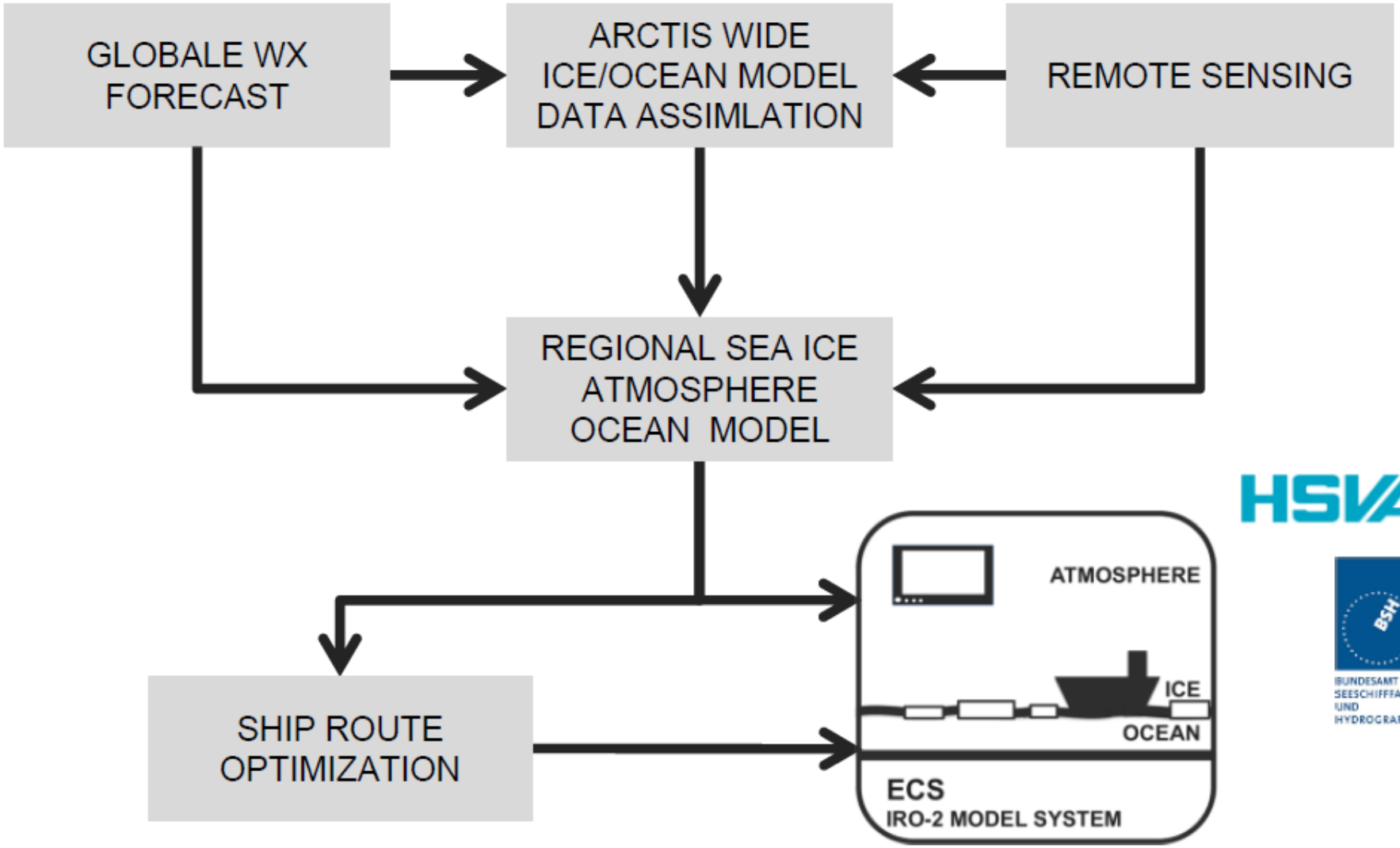
# Route optimisation with ship speed model

- **Input**
  - Environmental data
  - Ship parameters
  - Route constrains
- **Output**
  - Travel time and ship position
  - Fuel consumption and travel cost

→ **Speed optimised route**

Ice tank at HSVA (78 x 10 x 2.5 m), www.hsva.de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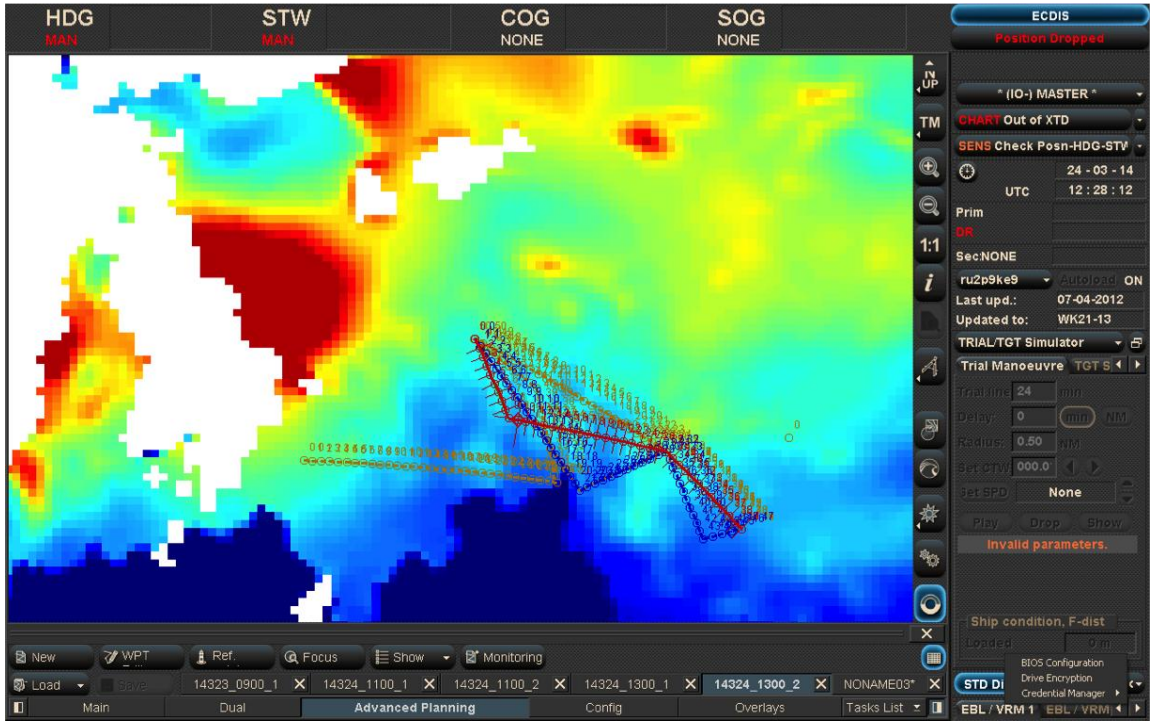
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

# Ice forecast and route product for nautical end user

- **Forecast charts**
  - Ice concentration
  - Ice thickness
- **Route**
  - On board selection of waypoints
  - On shore calculation of optimised route




Ice thickness and routes displayed in Electronic Chart System

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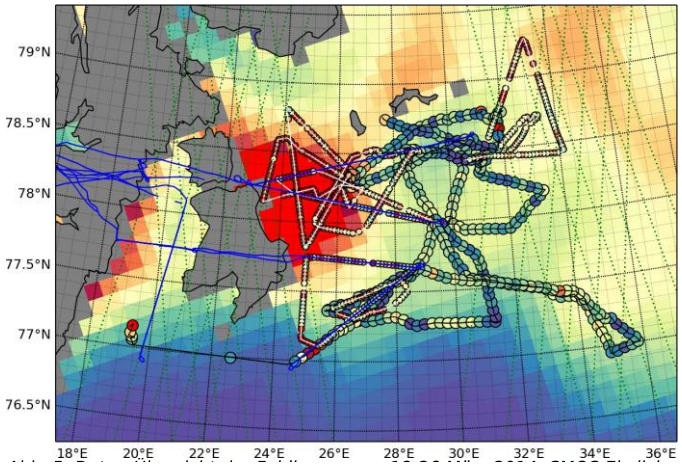
Ice concentration and routes displayed in Electronic Chart System

# Forecast and field experiment, 2014-03-14/29

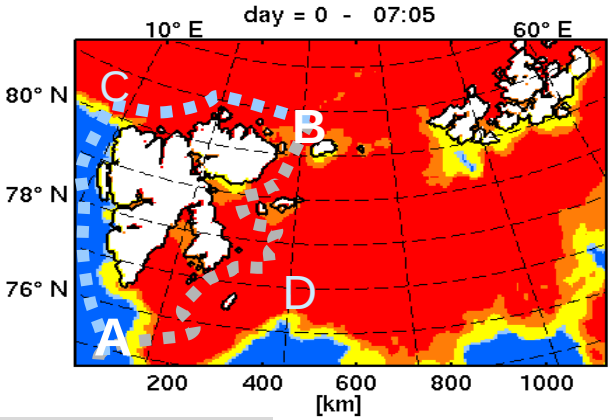
- **Live test of system**
  - 0 Z + 12 Z deterministic forecast
  - Use of forecast + route on RV Lance
- **Observation**
  - Sea-ice thickness measurements with EM
  - Observation of sea-ice concentration
  - Met Ocean measurements
  - Ship course and speed
  - Additional parallel campaigns
    - Aircraft (SMOS ice, ESA)
    - Helicopter (Norwegian Polar Institute)
    - Buoy array (Universität Hamburg)




Ice thickness (0 - 1m), SMOS vs. EM
Kaleschke (2014): Internal report

# Sea-ice forecasting for optimised ship routing

- **Project outcome**
  - Prototype model system for optimised ship routes through sea ice
  - Improved algorithmn for remote sensing of sea ice
  - Data from two week field and forecasting experiment
- **Open points**
  - Further analysis of field and forecast experiment
  - Development of an operational service




**Further reading**


Jochmann P, Reimer N, Kaleschke L, Müller G, Fock BH, Kauker F, Asseng J, Holfort J. (2014): Ice Routing Optimization IRO-2 Validation Trial. HSVANewswave 2014/1: 2-5. http://www.hsva.de/files/newswave2014_1.pdf

Gierisch AMU (2015): Short-range sea ice forecast with a regional coupled sea-ice–atmosphere–ocean model. Dissertation Universität Hamburg. http://ediss.sub.uni-hamburg.de/volltexte/2015/7477/

Dobrynin M, Fock BH, Gierisch AMU, Pohlmann T, Kaleschke L, Schlünzen H (2015): Prediction of Arctic Sea Ice for Ship Routing: Forecast Experiment and Ship Cruise. http://dx.doi.org/10.4043/25479-MS