BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Operational ocean forecasting for German coastal waters

Overview

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

- Introduction
- Model system (at BSH)
- Validation
- Results of actual events
  - Elbe flood 2013
  - Xaver
- Outlook

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Introduction

Introduction
Why do we run operational models?

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

BSH provides daily forecasts for a variety of customers and applications

Main applications:

- water level prediction and storm surge warning service
- drift calculations for oil, other substances & SAR
- offshore industry & coastal engineering
- German navy
- fisheries
- tourism

Introduction
Model history at BSH

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- Operational modelling (BSHcmod) since the early 80s
- One BSHcmod version has been sent to SMHI -> HIROMB
- Another version has been sent to DMI -> DMIcmod
- Within MyOcean DMIcmod + BSHcmod => HBM

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Model system

(at BSH)

Operational model system at BSH

Meteorological Models
(GME + COSMO-EU)
forecasts up to 7 days

wind, air pressure, air temperature, cloud coverage, specific humidity

Wave Model
(EWAM)
forecasts up to 84 hrs

wave data

Other forcing data:
tidal predictions, external surges (BSHsmod.na), river input (BfG, SMHI)

external surge, tidal constituents, river runoff

Circulation Model
(BSHcmod => HBM)
for North Sea and Baltic Sea
(3D, baroclinic) + biochemistry

Circulation + Wave Model
(BSHcmod.w => HBM+CWAM)
for North Sea and Baltic Sea
(3D, baroclinic)

Surge Model
(BSHsmod => HBM)
for North Sea
(2D, barotropic)

Model data archive: currents, water levels, eddy coefficients, salinity, temperature, ice data, wave data, meteo. data

surge data

Lagrangian Drift and Dispersion Model (BSHdmod.L => SeatrackWeb)
for oil, drifting objects and conservative substances

Eulerian Dispersion
(BSHdmod.E)
for conservative substances, suspended matter and biochemistry

Local Circulation Models
(HBM, UnTRIM)
for estuaries
(Elbe, Weser, Ems)

Circulation model: BSHcmod V4 => HBM

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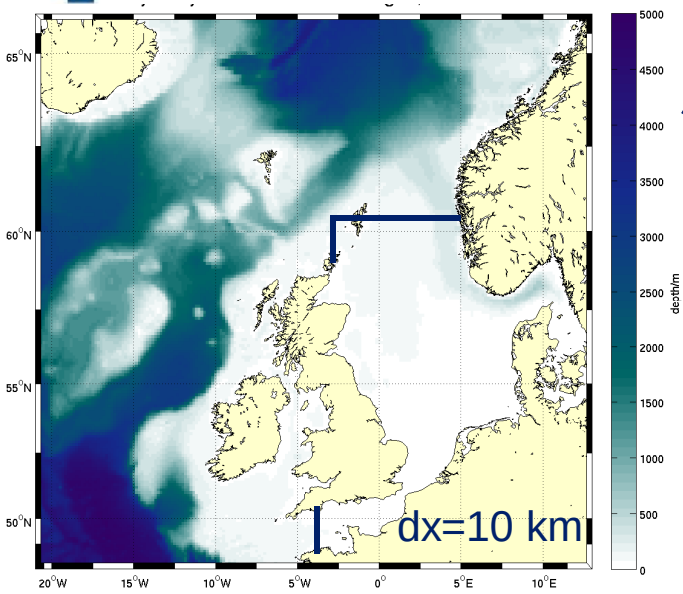
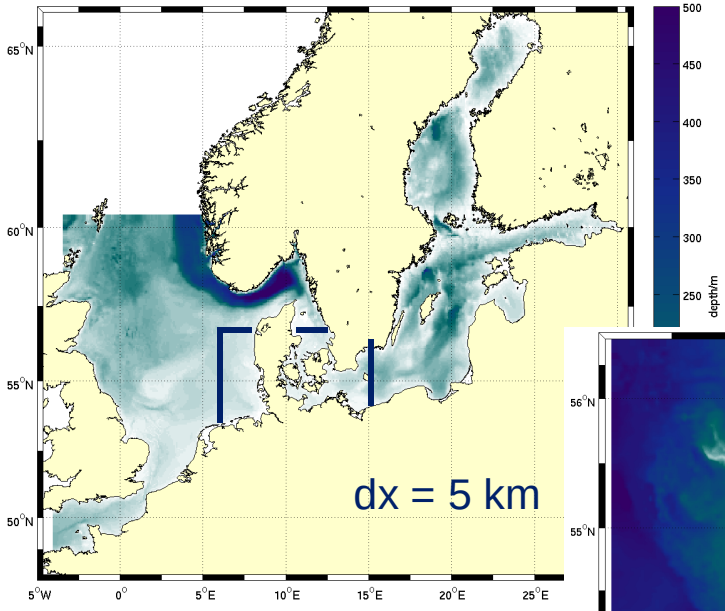
- 3D baroclinic, prognostic
- generalised, adaptive vertical co-ordinates (Kleine, 2004); optionally z-co-ordinates with free surface could be chosen
- 2-way fully dynamical nesting
- k-omega turbulence model
- drying and flooding of tidal flats
- sea ice dynamics (Hibler, 1979 ⇒ going to be replaced by BSH in-house development) and thermodynamics
- driven by meteo. forecasts of DWD, tides (14 constituents) and river inputs
- obc (T+S sponge layer)

Grid nesting V4 – part 1

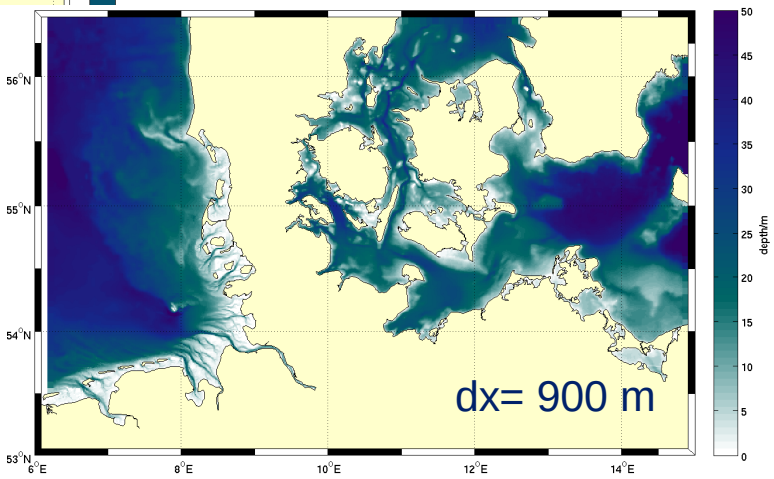
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE



1-way nesting

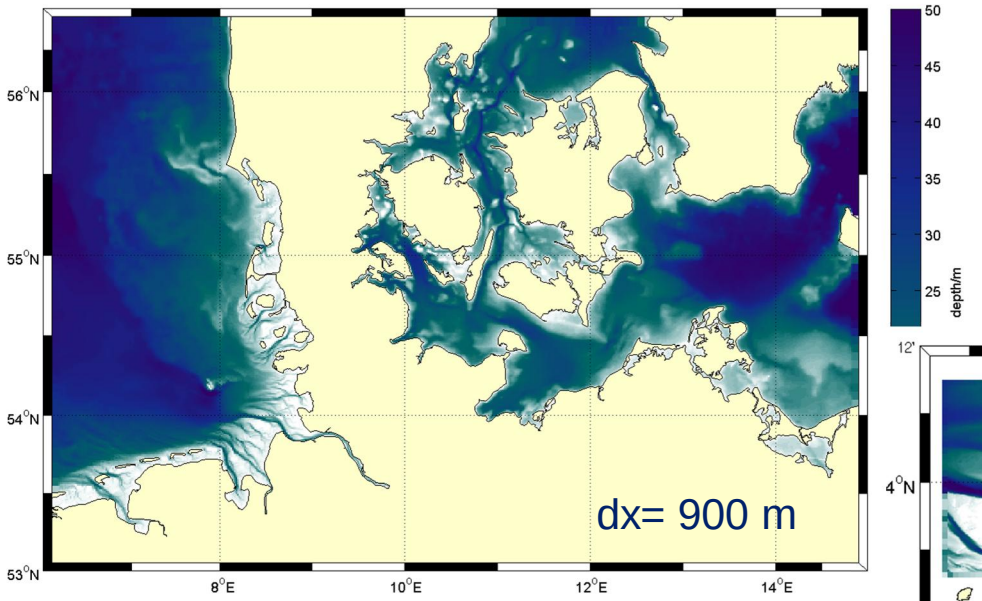


2-way nesting

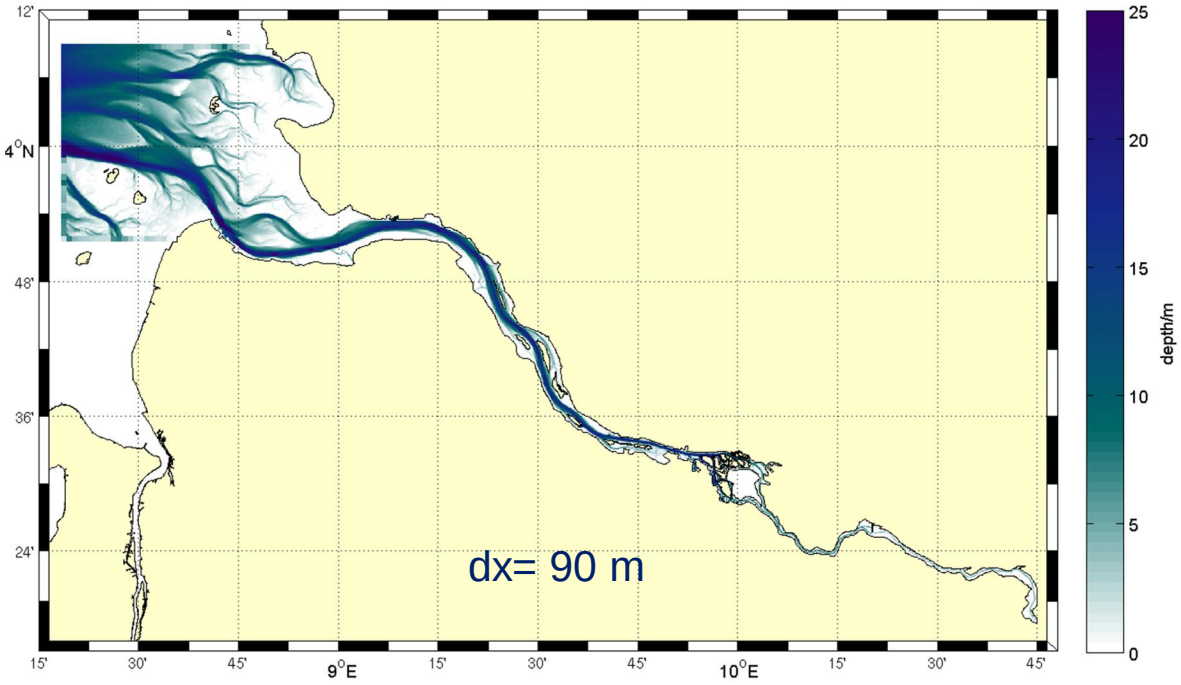


Grid nesting V4 – part 2

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE



1-way nesting



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Validation of BSH-HBM

(period 1.1.2008 – 1.1.2009)

Validation – water levels

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

- North Sea
  - Tides
  - High water / Low water (only peaks)
- Baltic Sea
  - Total water level

Validation - Tides in the North Sea

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

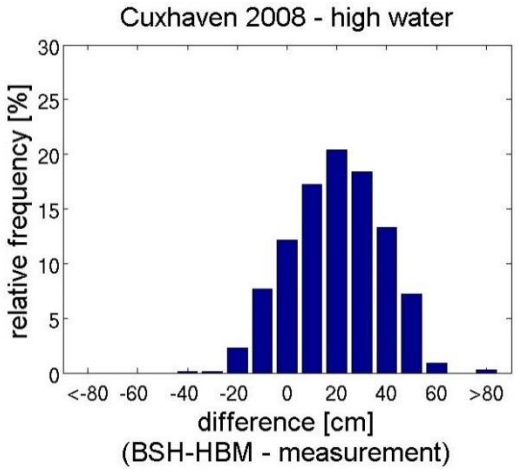
Introduction
Model system

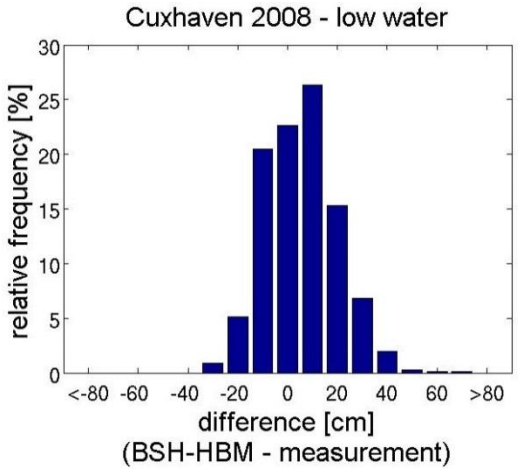
Station	M2 amp [cm]	M2 amp err [cm]	M2 pha [deg]	M2 pha err [deg]	S2 amp [cm]	S2 amp err [cm]	S2 pha [deg]	S2 pha err [deg]
Borkum	107.6	2.8	278	8	28.1	1.0	338	5
Helgoland	113.2	4.6	312	0	30.8	1.9	13	-5
Cuhaven	147.9	13.5	340	-4	37.1	2.7	46	-7
Buesum	154.7	-1.5	341	4	41.0	-1.1	47	0

Validation – total water level in the North Sea

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Station	Total water level			
	High water		Low water	
	Bias [cm]	RMSD [cm]	Bias [cm]	RMSD [cm]
Borkum	-3	11	10	14
Helgoland	3	14	10	11
Cuxhaven	19	18	5	14
Buesum	15	18	6	17





After bias correction:

With an error of ± 10 cm BSH-HBM reproduced 39% of the high and 49% for low waters.

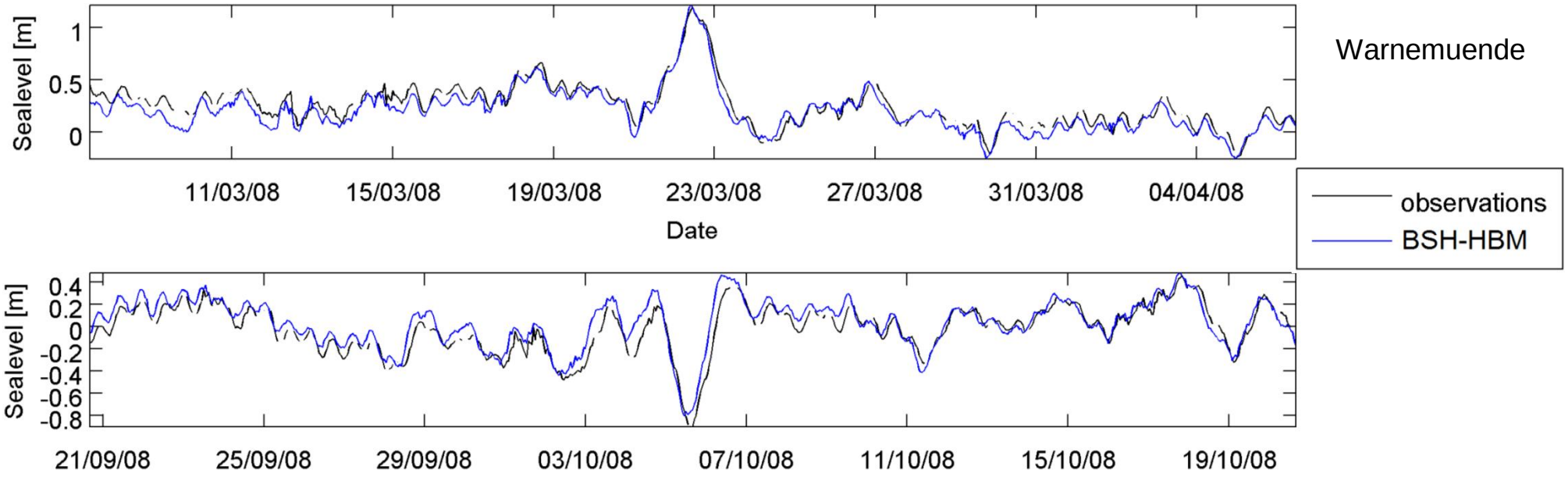
With an error of ± 20 cm BSH-HBM reproduced 69% of the high and 85% for low waters.

With an error of ± 30 cm BSH-HBM reproduced more than 90% of both high and low waters.

Validation – water level in the Baltic Sea

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Station	Water level elevation						
	Observations			BSH-HBM			
	N	σ [m]	mean [m]	Bias [m]	σ [m]	RMSD [m]	r
Kiel-Holtenau	8158	0.25	0.05	0.07	0.28	0.12	0.90
Koserow	8301	0.21	0.10	0.18	0.23	0.10	0.90
Sassnitz	5792	0.21	0.13	0.15	0.22	0.10	0.89
Travemuende	8472	0.24	0.07	0.08	0.28	0.12	0.90
Warnemuende	7477	0.22	0.08	0.11	0.25	0.11	0.89



Validation – currents

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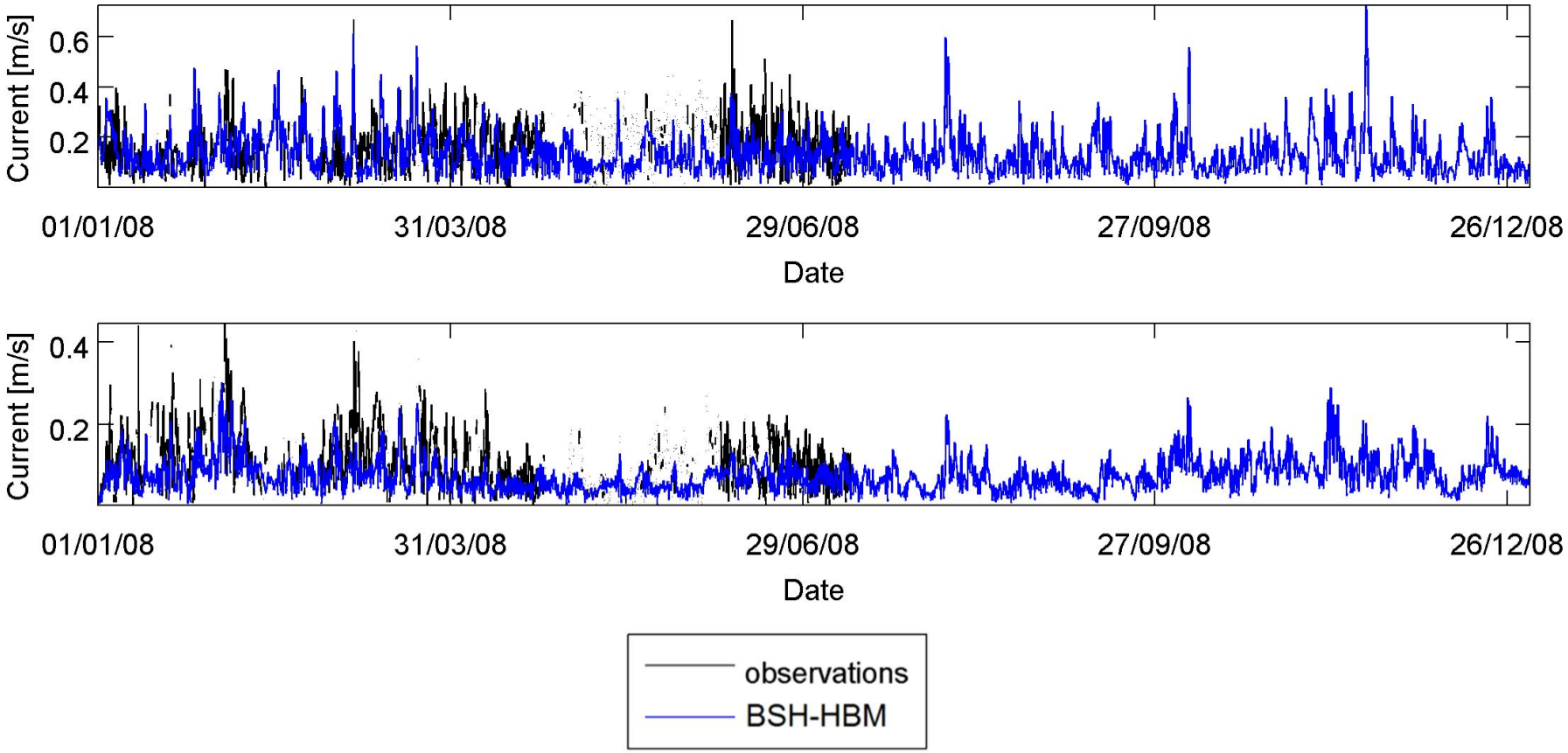
- Very difficult to validate
  - Only few measurements
  - High variability due to local topographic effects -> resolution not sufficient / difficult to find the corresponding grid point

- Data from a few Baltic stations were analysed
  - BSH-HBM reproduces variability of currents rather good (STD of BSH-HBM is nearly the same than STD of measurements)
  - Bias at bottom lower than 10 cm/s at all places
  - Bias at surface lower than 10 cm/s at most stations

Validation – current speed

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

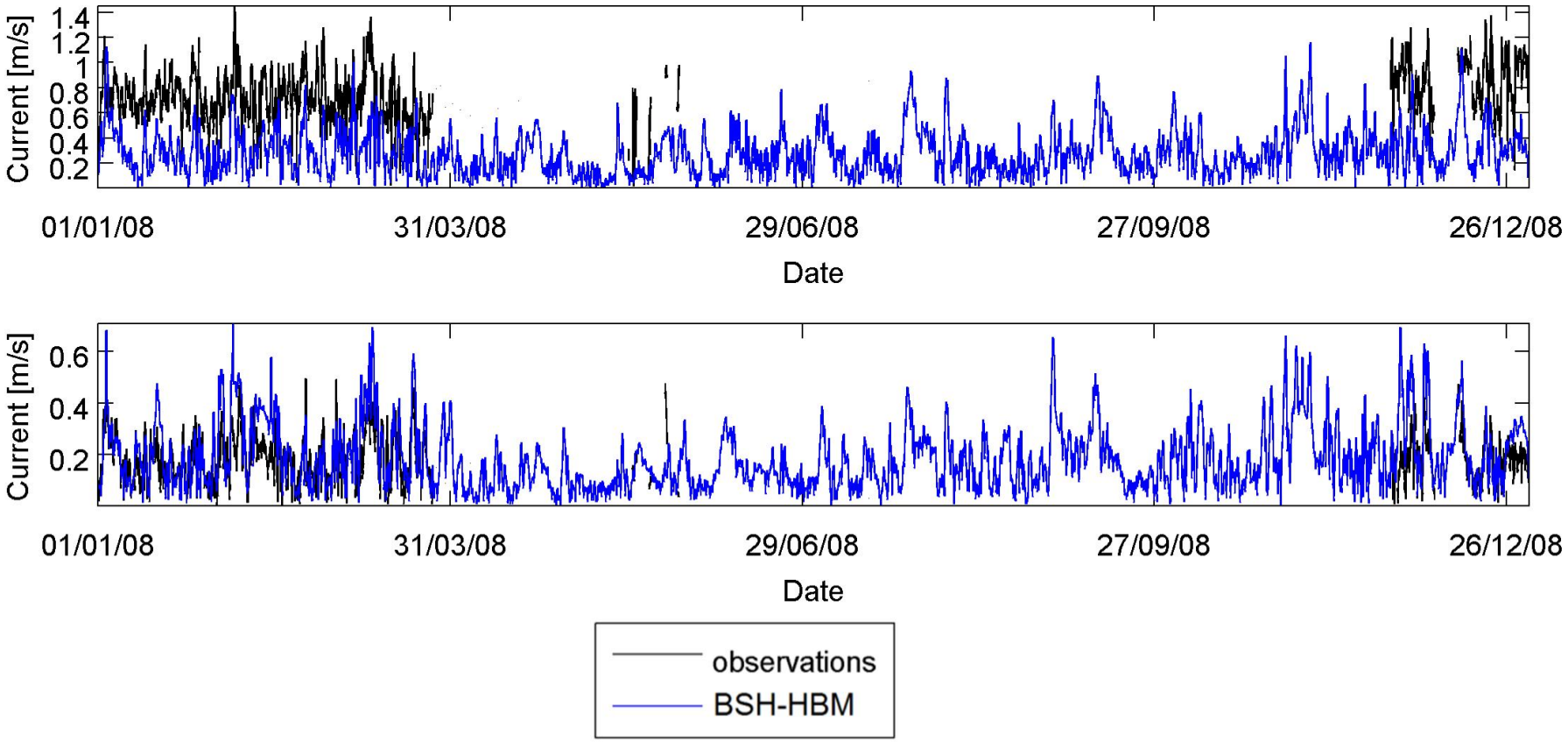
Arkona 54 ° 53,11‘ N, 13 ° 51,64‘ E, depth: 46m



Validation – current speed

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

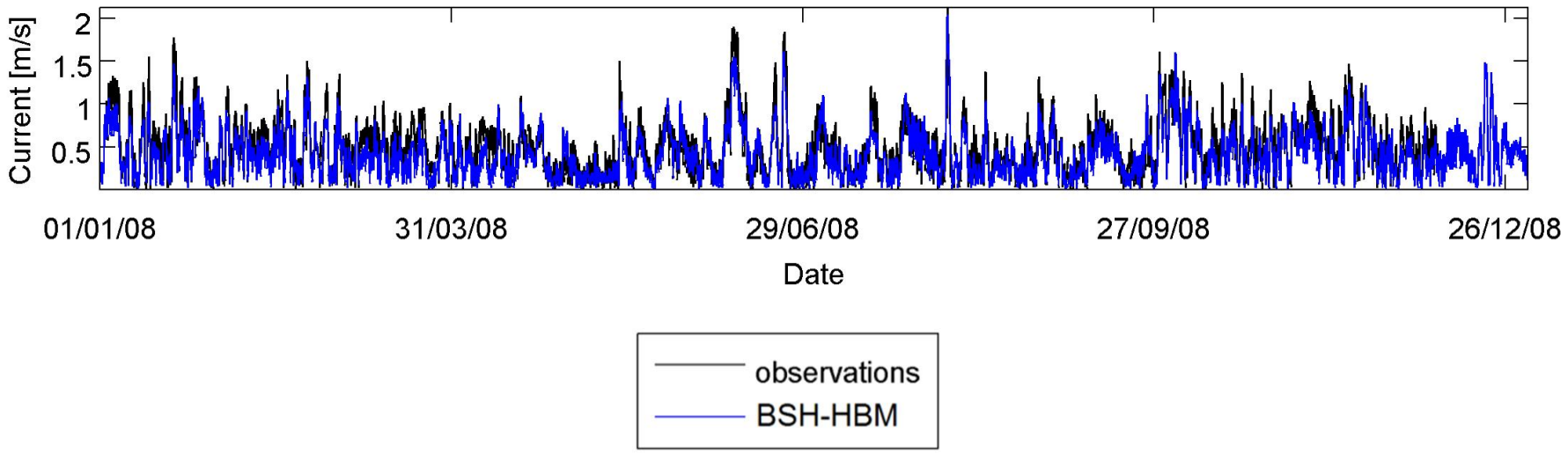
Darsser Sill 54 ° 41,9‘ N, 12 ° 42‘ E, depth: 21m



Validation – current speed

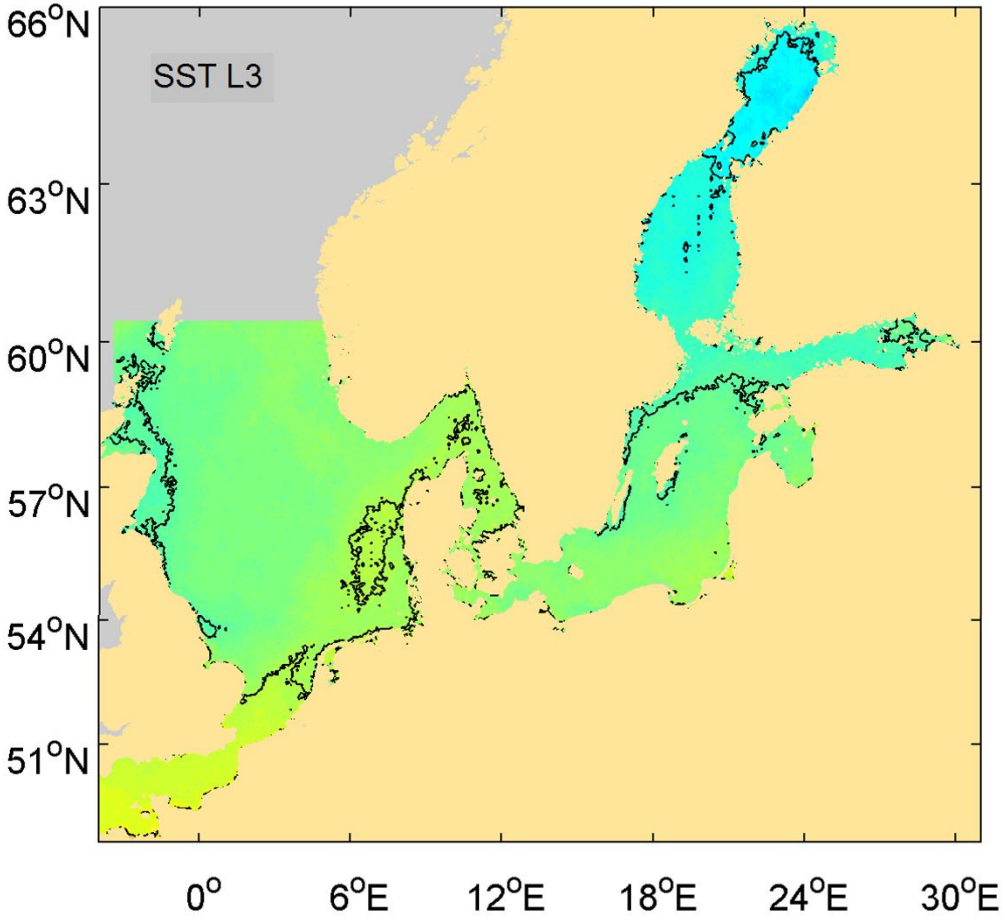
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

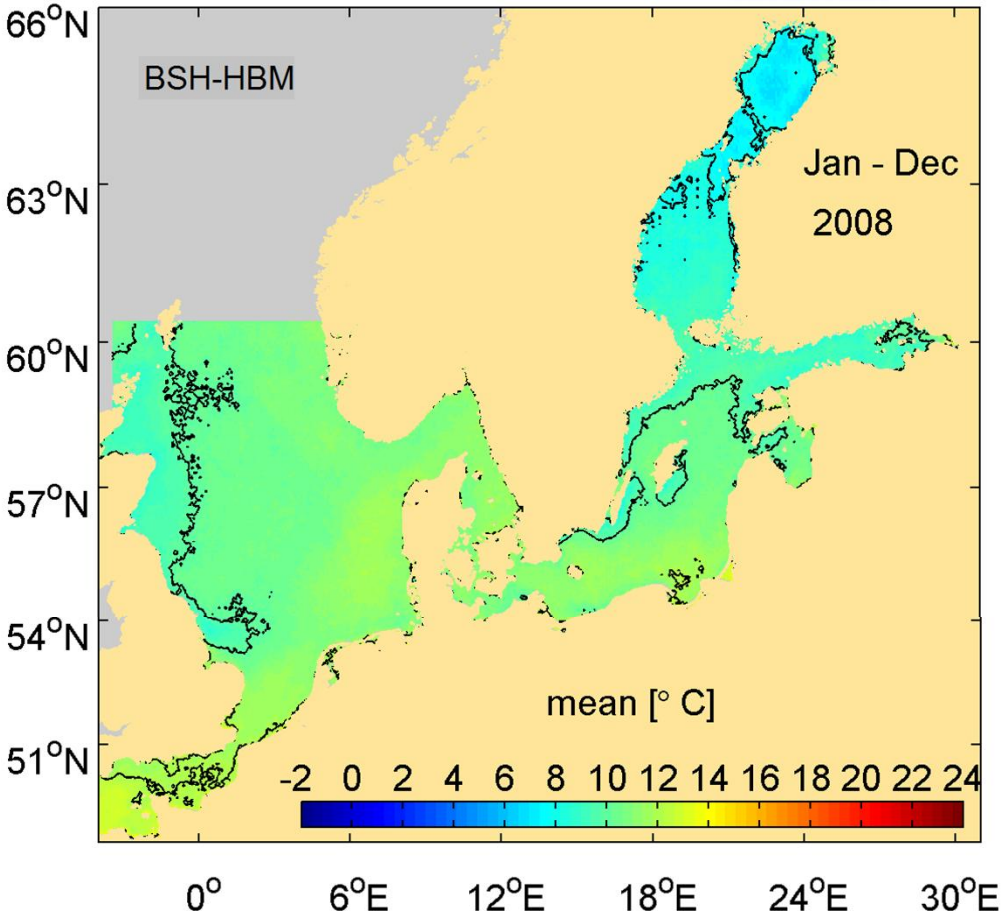
Vengeance Grund in the Great Belt



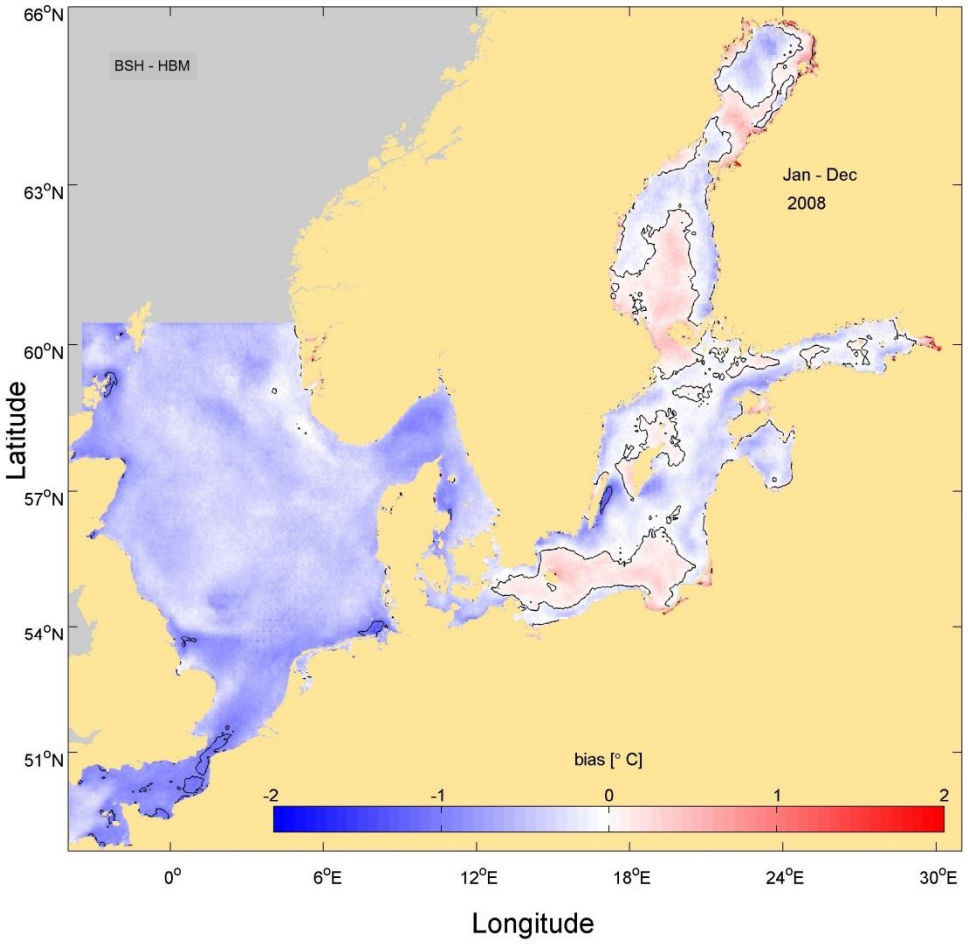
Validation – sea surface temperature

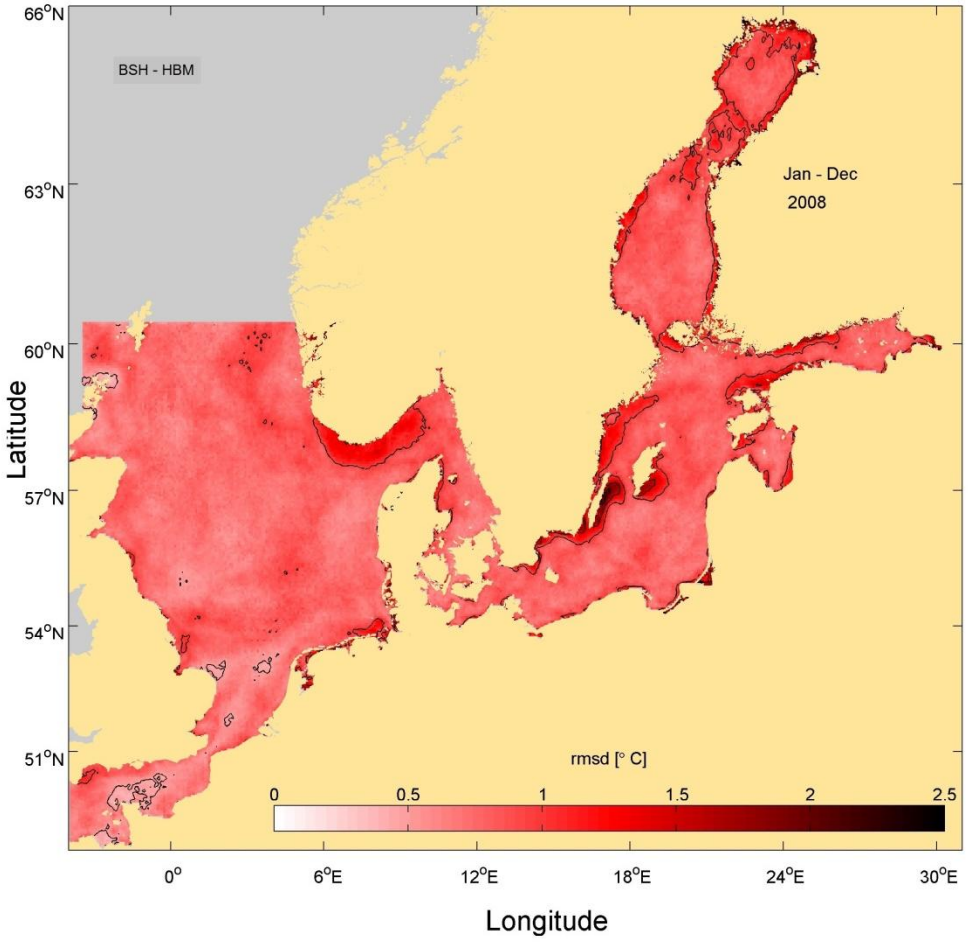
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE





Validation – sea surface temperature





Validation – temperature at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

- Surface:

  In all places: Bias and RMSD < 0.7 ° C, Correlation > 97 %

- Depths between surface and 80 m

  At most and especially all German stations:

  Bias: 0.2 - 2 ° C, RMSD: 0.5 - 1 ° C, Correlation: > 90 %

- Water depth > 80 m in the Baltic

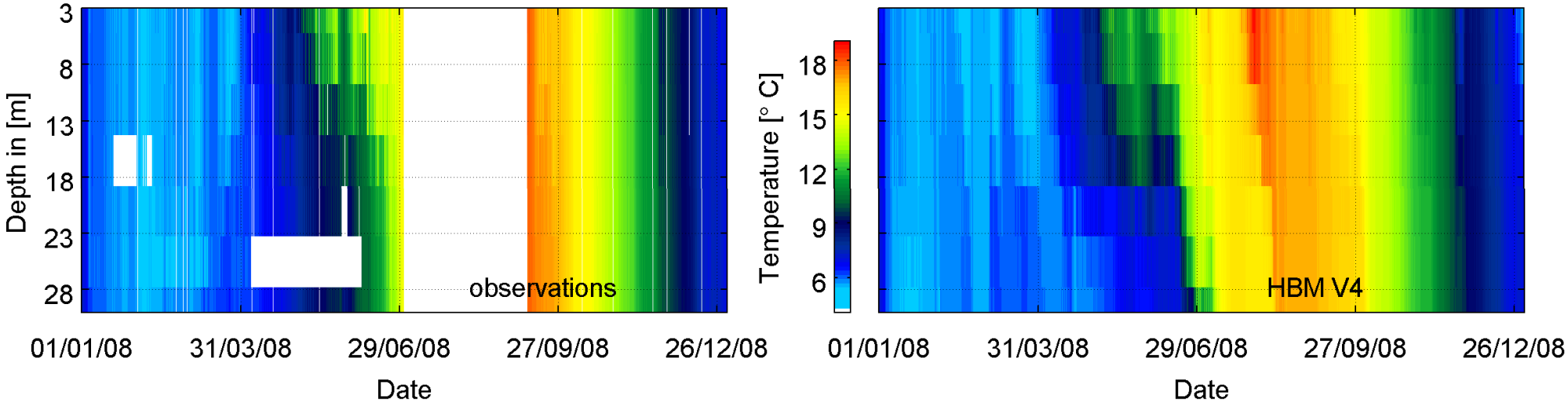
  Bottom temperature at Huvudskar Ost in the central Baltic

  Bias: -0.77 ° C, RMSD: 0.36 ° C, Correlation: 33 %

Validation – temperature at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

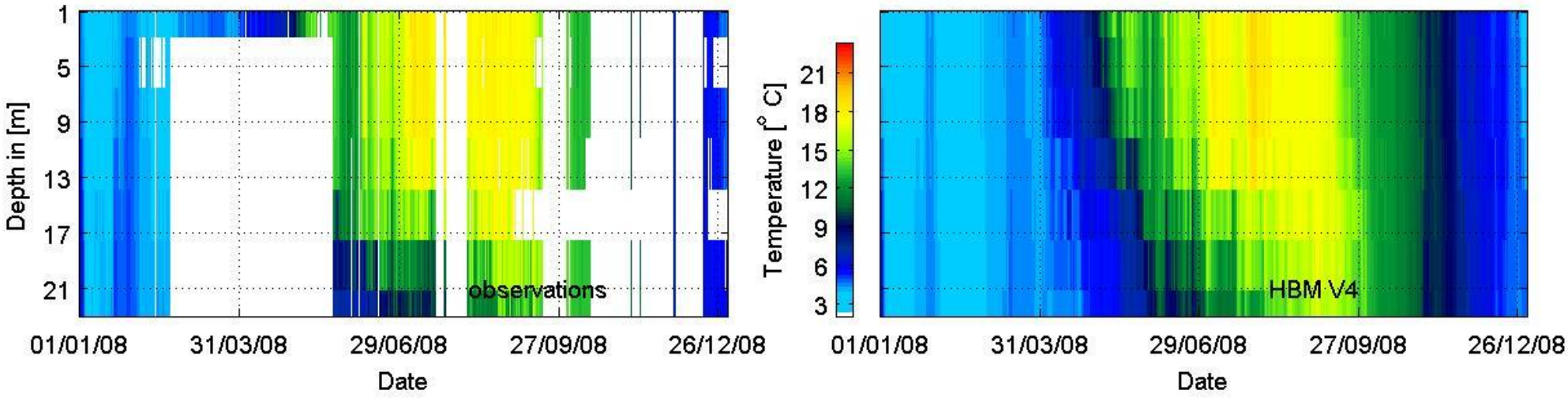
Station UFS Deutsche Bucht in the German Bight / North Sea



Validation – temperature at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

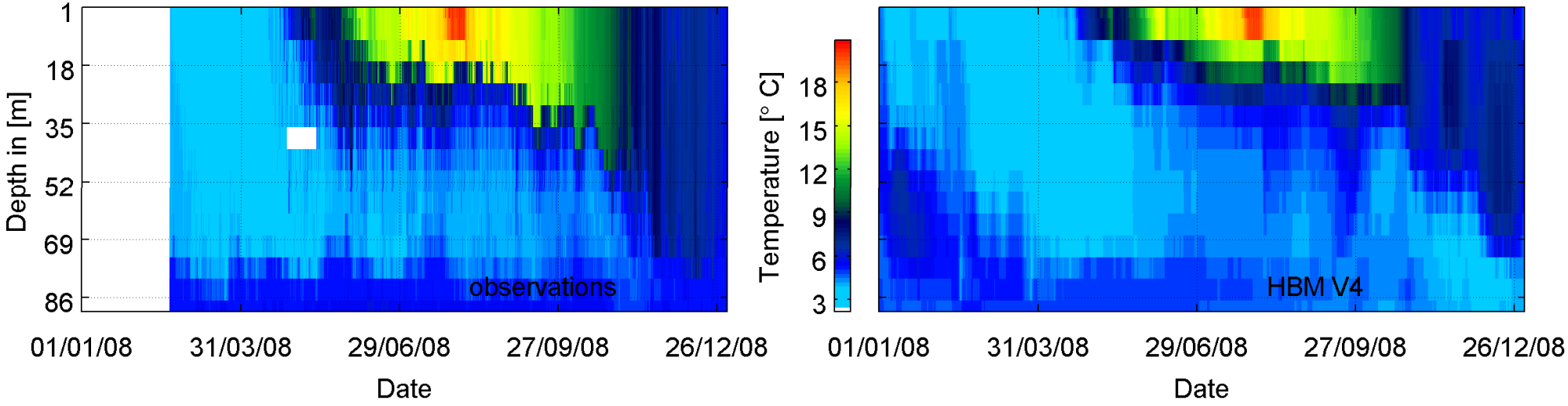
Station Fehmarn Belt in the Western Baltic



Validation – temperature at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Station Huvudskar Ost in the central Baltic



Validation – salinity at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

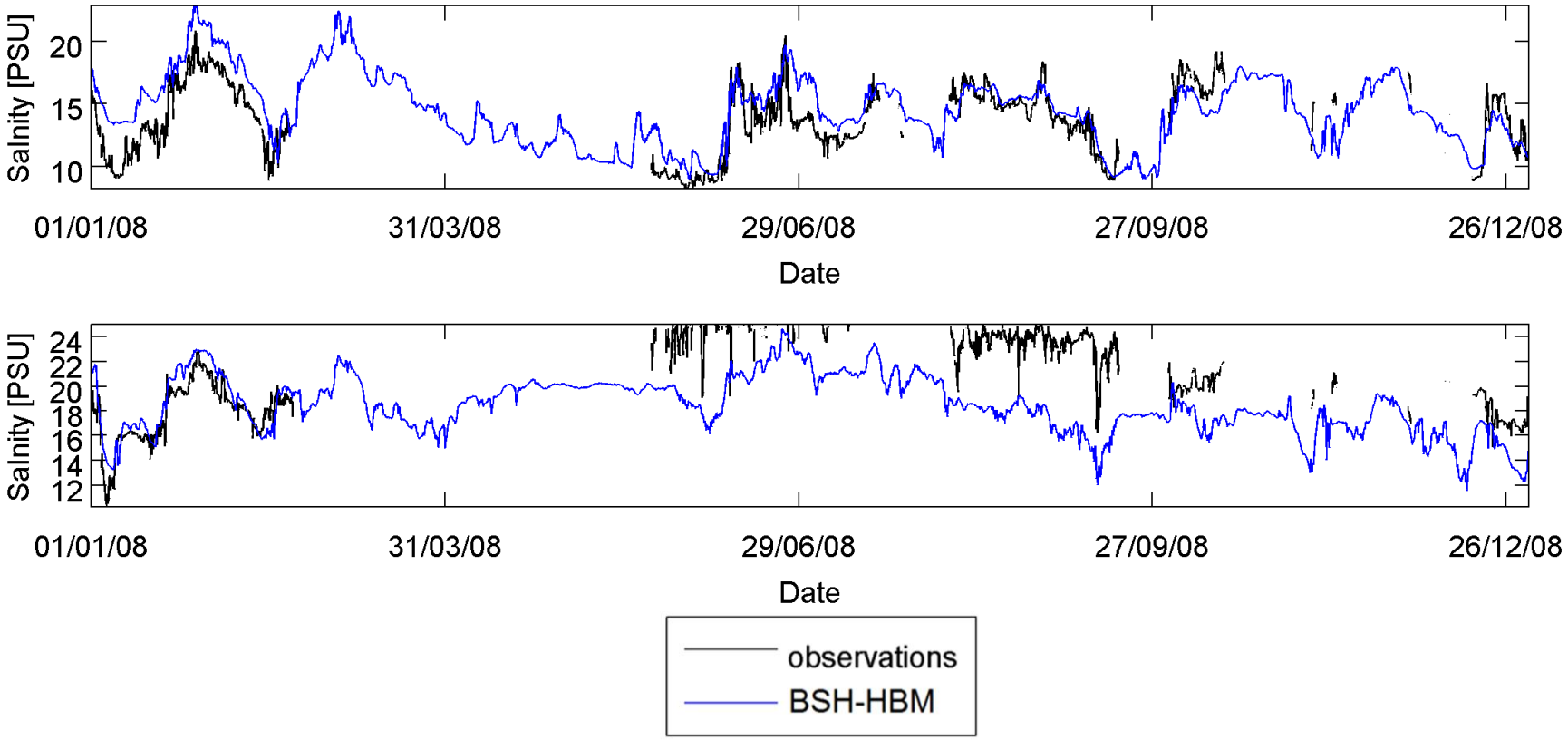
- Only few observations available
- Good agreement in deeper water depths (> 60 m)
- Sufficient correlation at surface, but potential for improvements
- At depths above the permanent halocline and below the surface measurements show generally stronger fluctuations than BSH-HBM

  This is most probably owed to a combination of the complicated bathymetry of the Baltic Sea and the (probably too) coarse vertical resolution of the applied model setups

Validation – salinity at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

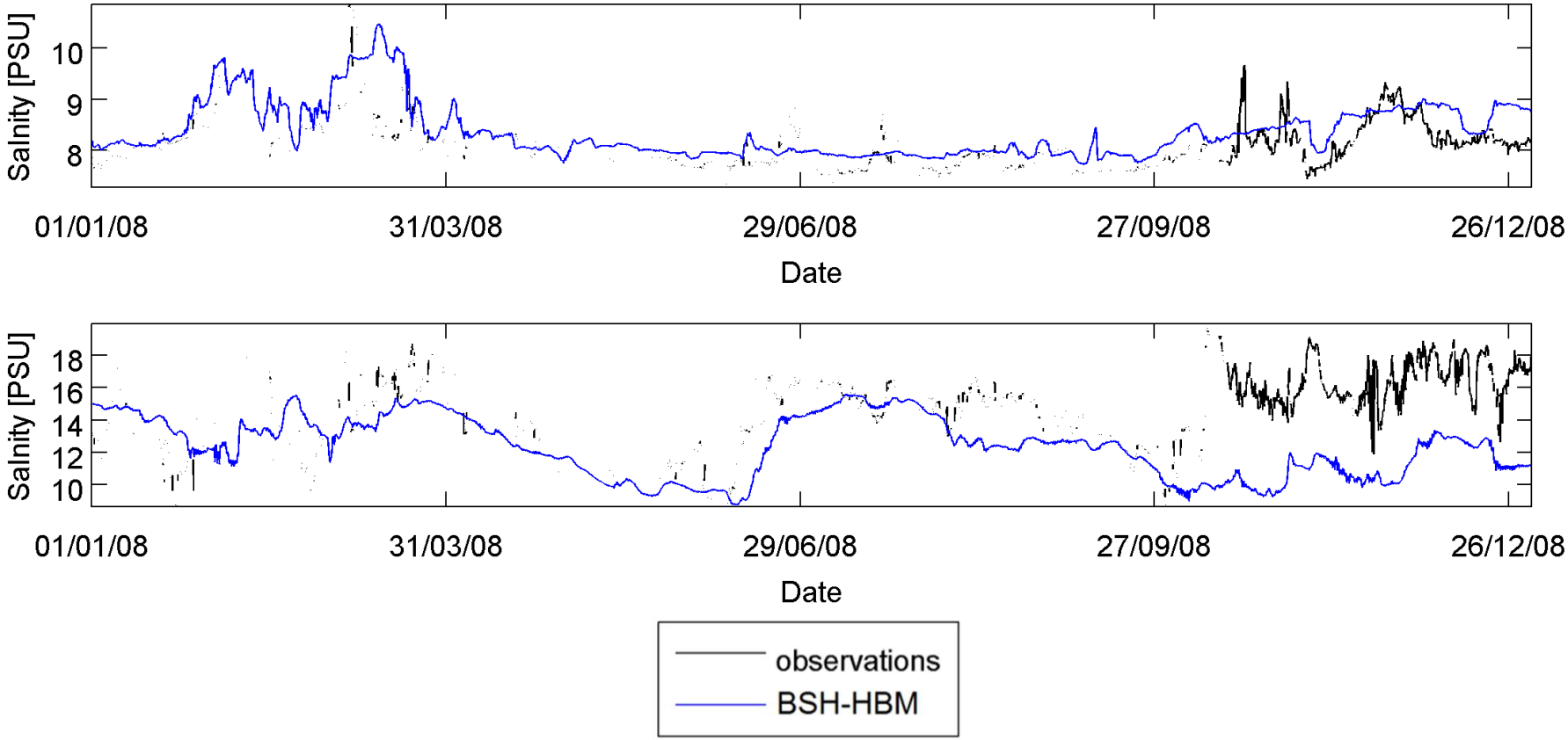
Station Fehmarn Belt in the Western Baltic



Validation – salinity at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

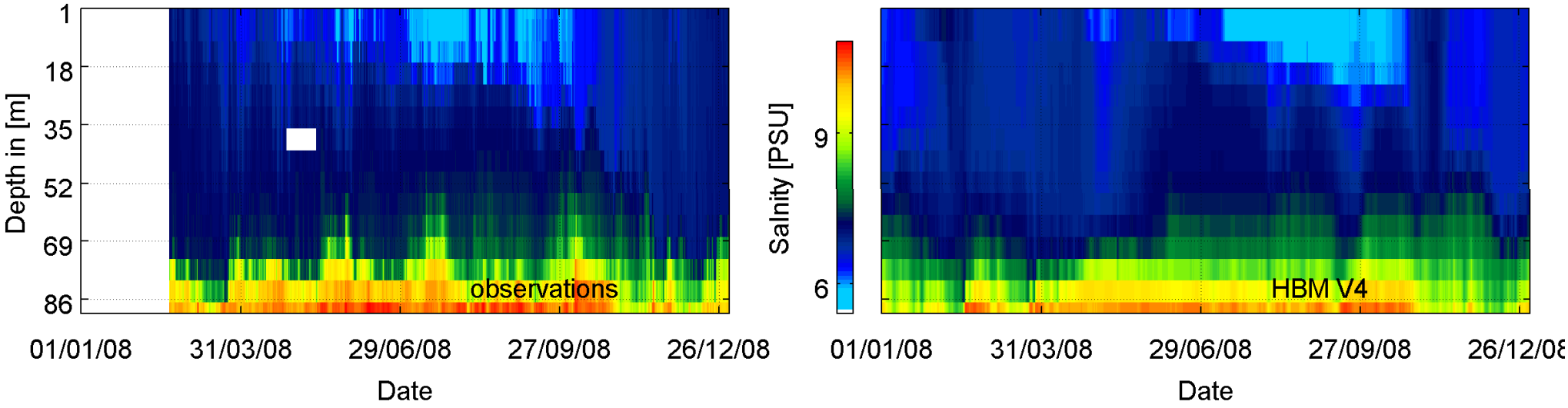
Station Arkona in the Western Baltic



Validation – salinity at stations

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

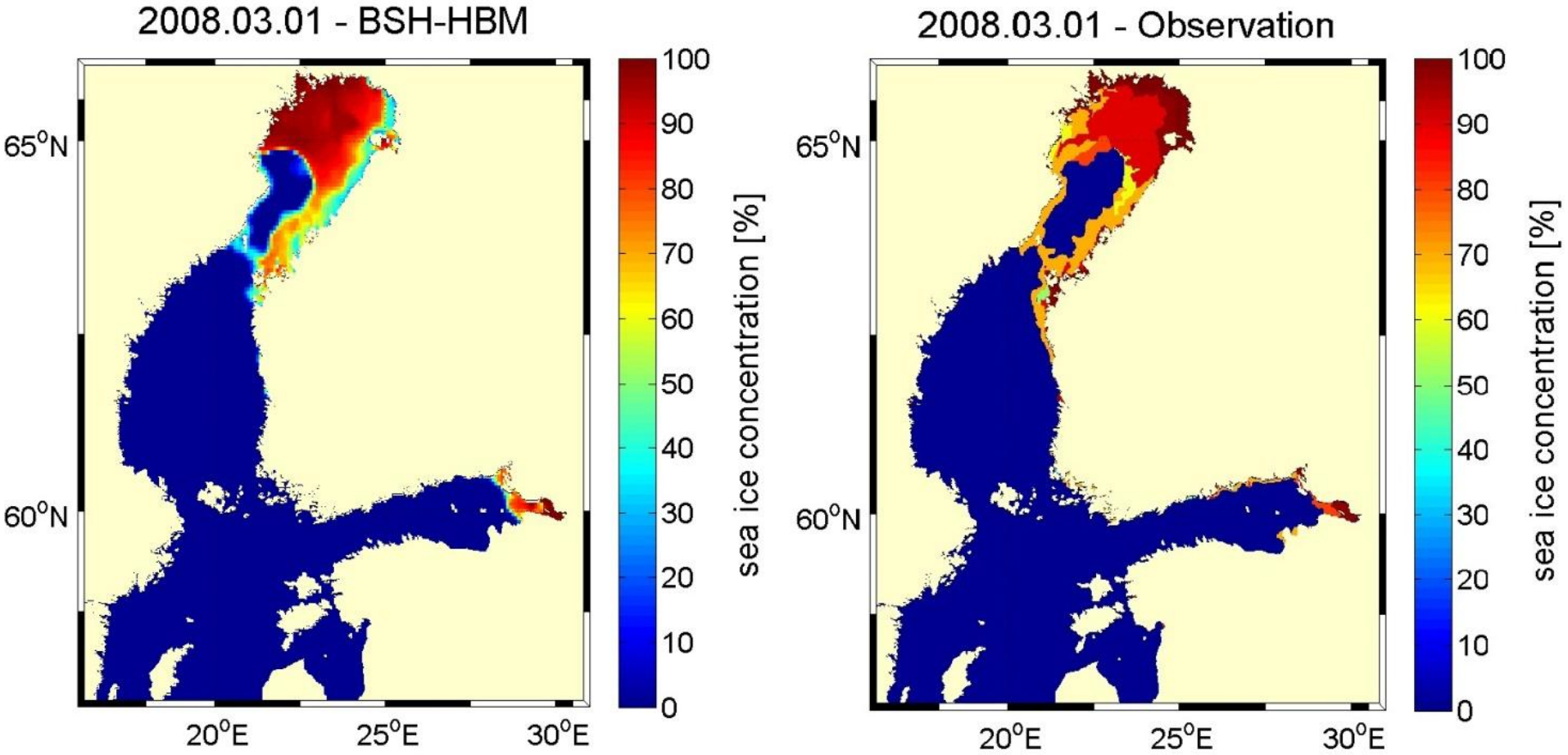
Station Huvudskar Ost in the central Baltic



Validation – Sea Ice

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Validation – Sea Ice



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Elbe flood

(May / June 2013)

Elbe flood

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

- Heavy rainfall in south-east Middle Europe in May and June 2013 caused a flood at various rivers in that region.
- Along the river Elbe water levels which never occurred before were measured.
- Very high water levels in the tidal influenced part of the Elbe estuary between St.Pauli and the weir in Geesthacht.

Elbe flood

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

- The forecast of the river discharge was characterized by high uncertainties and therefore a high variability from forecast to forecast.
- Best estimate forecast of BSH-HBM works with discharge calculations from water levels in Neu Darchau (outside the EL-model region).
- Calculated river discharges of more than 4000 m^3/s (nearly five times as high as the medium discharge) were also fraught with uncertainty.

Elbe flood

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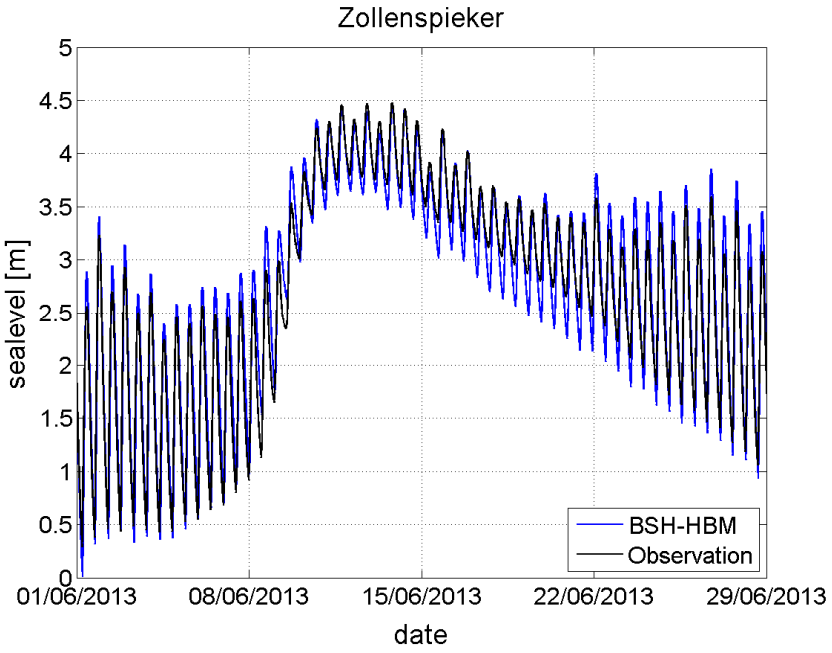
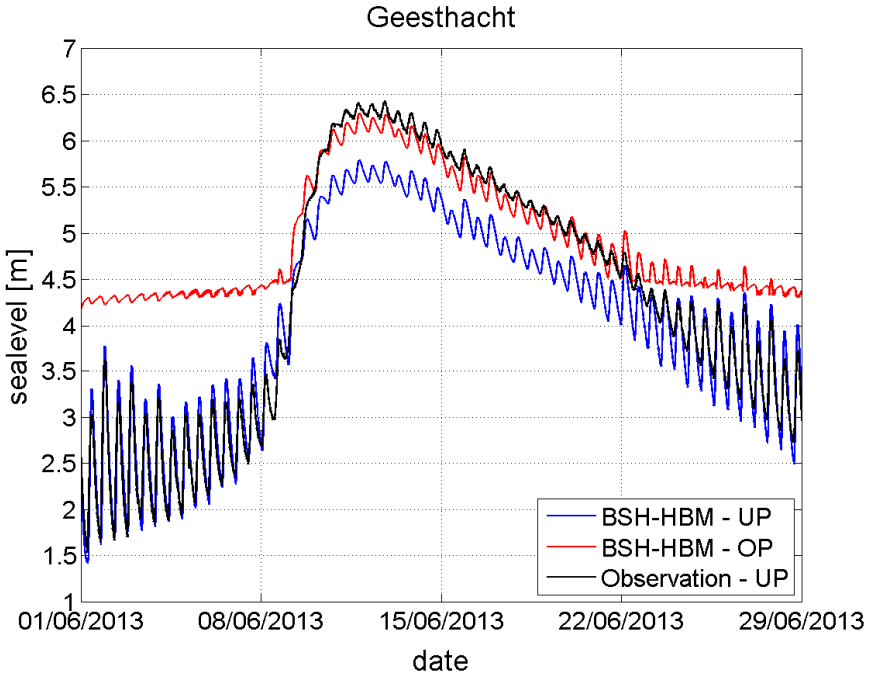




BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

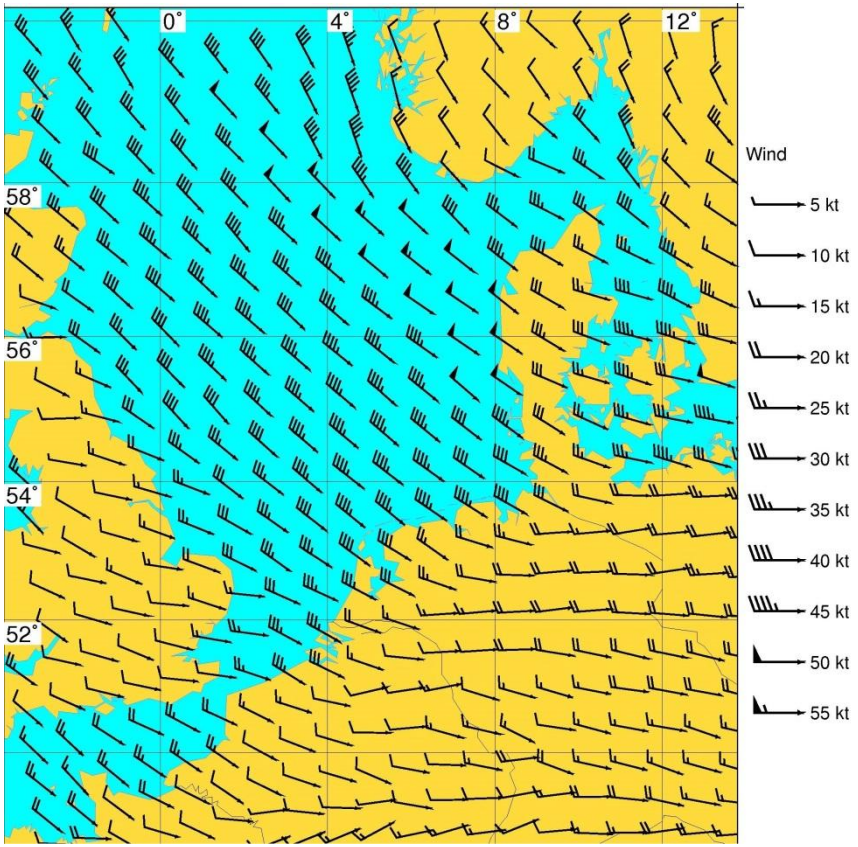
Xaver

(5th to 7th December 2013)

Xaver

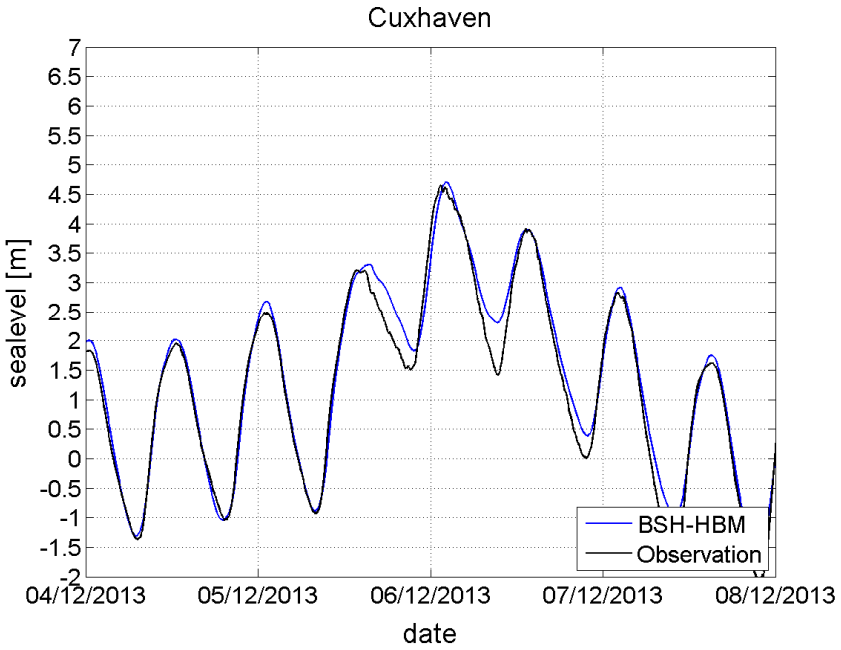
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

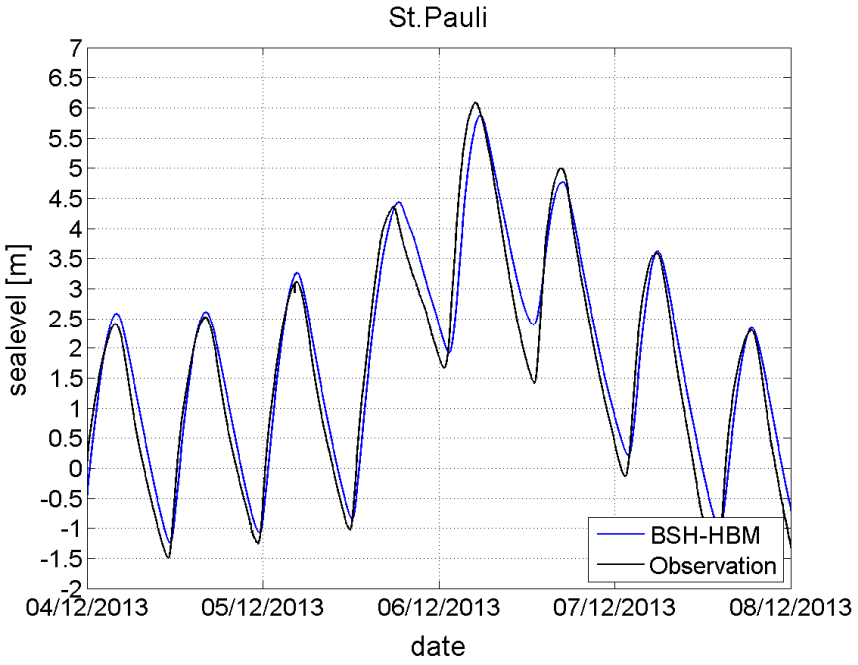
- Very high middle wind speeds between 45 and 55 knots (9-10 Beaufort) from north-westerly directions in the German Bight.
- Up to four storm surges and up to two strong storm surges in a row at almost all German North Sea stations.
- Highest water level elevation at station St.Pauli with 3.98 m above the mean high water, i.e. 6.09 m above mean sea level – a very strong storm surge and the second highest value ever.



Xaver

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

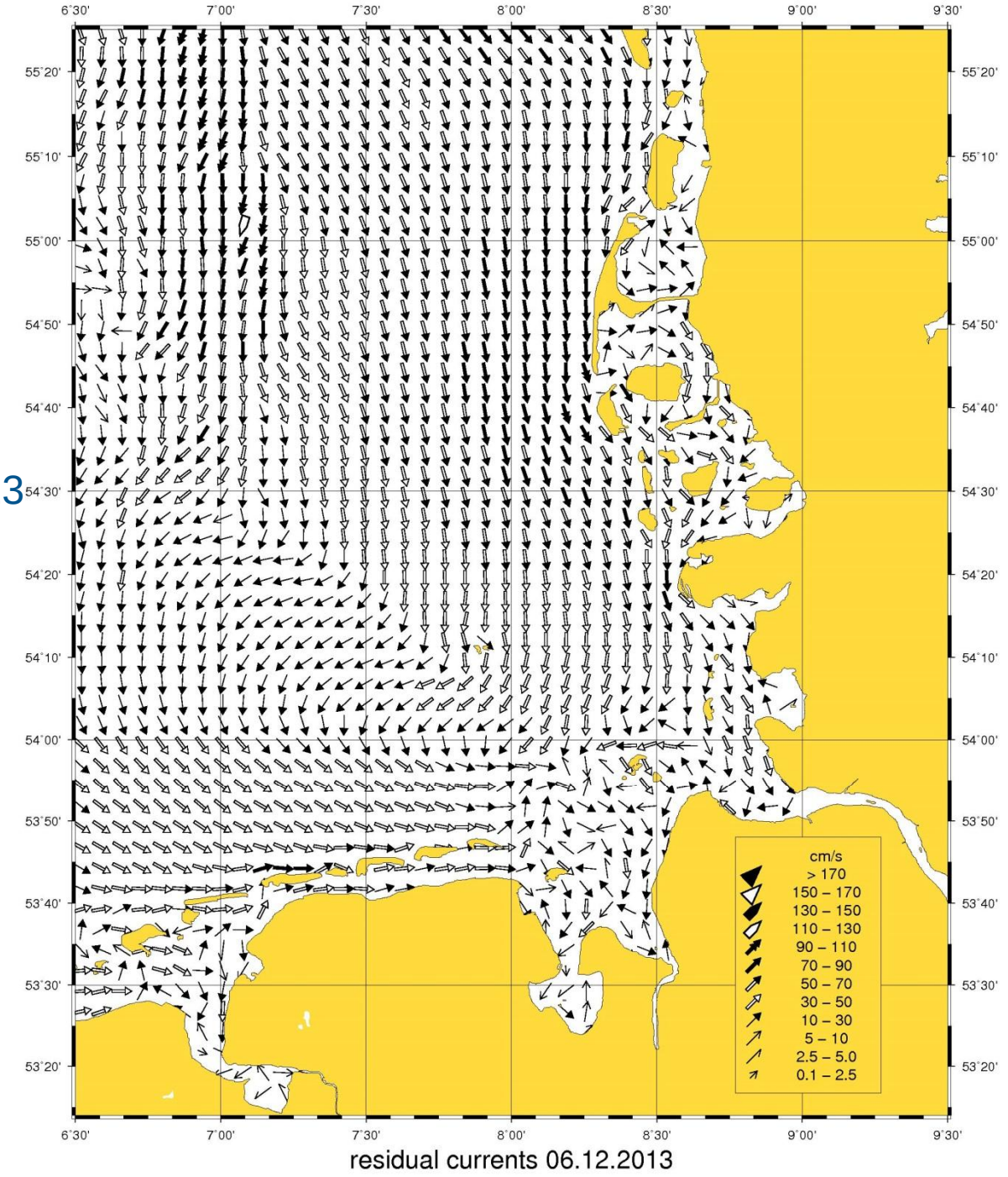




Xaver

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Residual Currents on 6th December 2013



residual currents 06.12.2013

Three times as high as compared to a situation with stable wind conditions of 4-5 Beaufort from one direction over a whole day.

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Outlook

Biogeochemical module
(under development)

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- Internal coupling interface (F90 modules)
- Development in co-operation with DMI
- Combined „**North Sea/Baltic Sea model**“
  → Online coupling of HBM + **ERGOM (DMU)**

- **Goal:** Operational model with data assimilation

Will go pre-operational this summer!!

DeMarine

Development of pre-operational coupled current/wave model system by BSH & DWD

Coupling of

HBM circulation model and

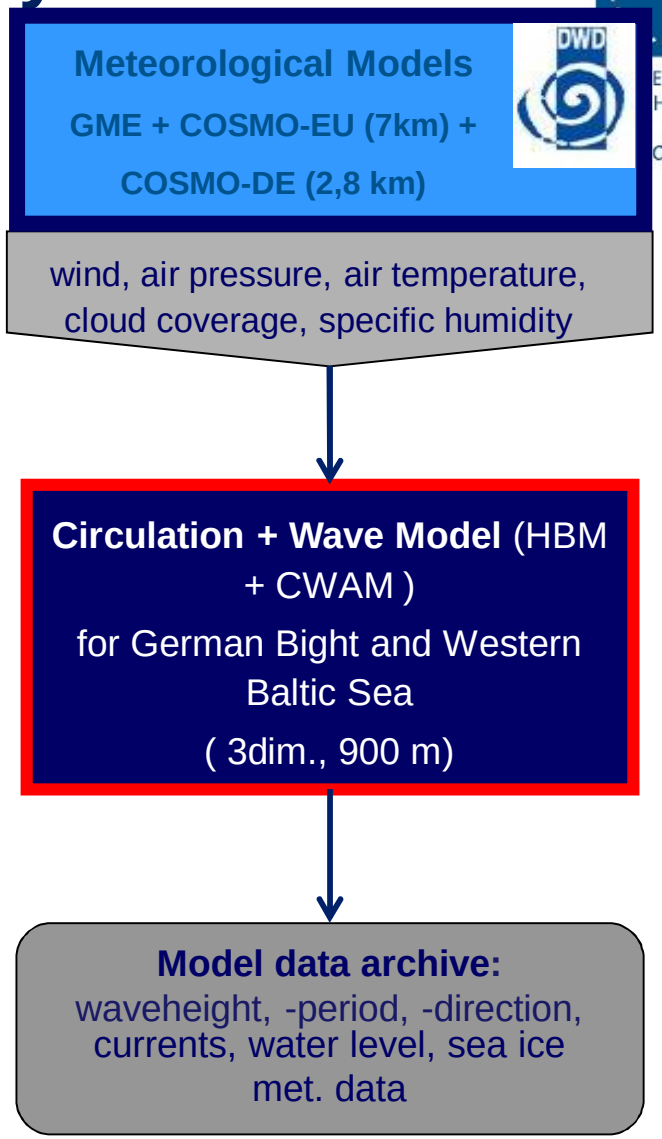
WAM wave model

based on OASIS3 coupler

with 900m resolution

products for

- weather
- waves
- Currents+sea level+ice

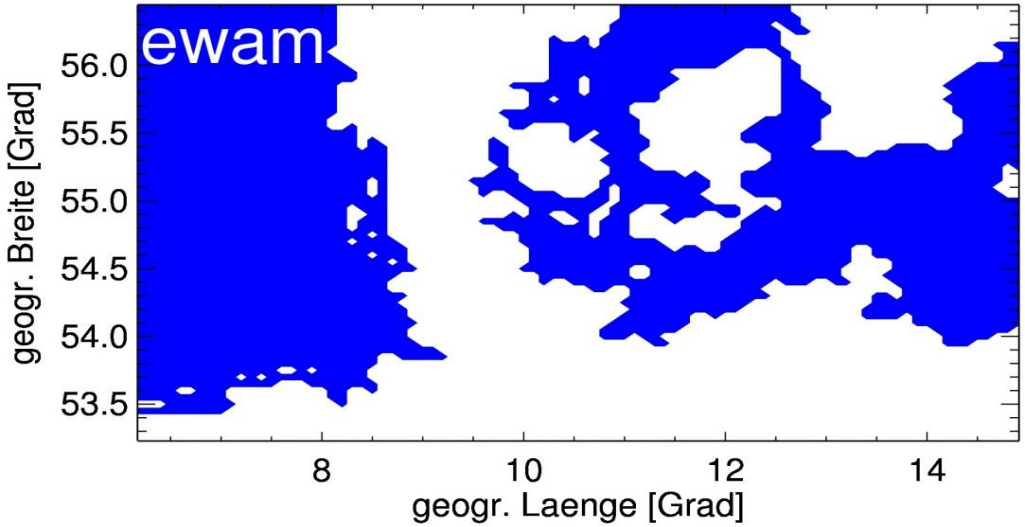


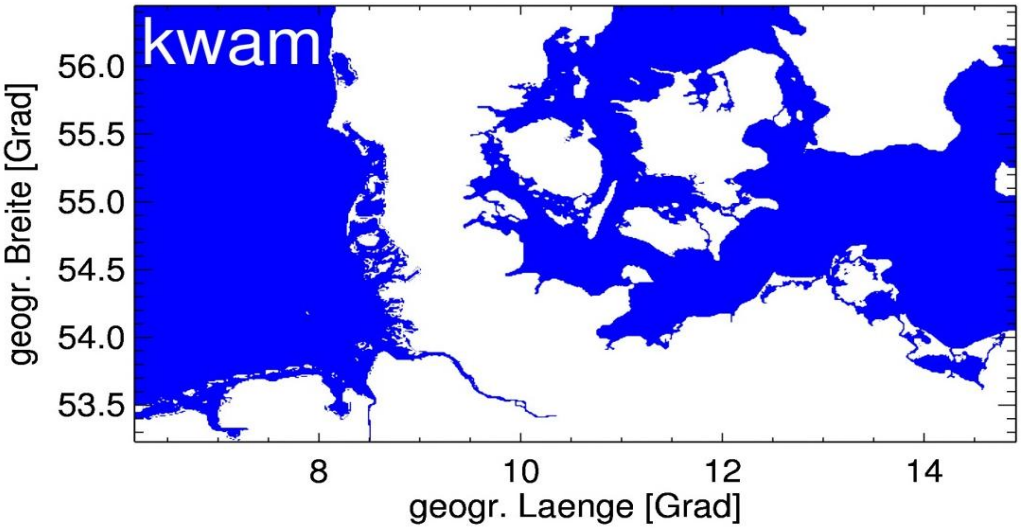
DeMarine

Deutscher Wetterdienst

Model domain and resolution

Model domain cWAM: 53.2292 ° N – 56.4458 ° N
6.1736 ° O – 14.9097 ° O





Coarse resolution EWAM
(„Europäisches wave model“)
Grid spacing:
Lon.: 0.1 ° , Lat.: 0.05 °

fine resolution c(K)WAM
(„coastal wave model“)
Grid spacing:
Lon.: 0.01388 ° , Lat.: 0.00833 ° (ca. 900 m)

Prospects

Coupling of COSMO-CLM and HBM via OASIS within the KLIWAS-project to

- → Generate a regional coupled atmosphere-ocean-model
- → Extend the multi-model ensemble of coupled atmosphere-ocean-models
- → Effective and sustainable use of professional expertise at DWD and BSH

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BSH model system: (potential) coupling

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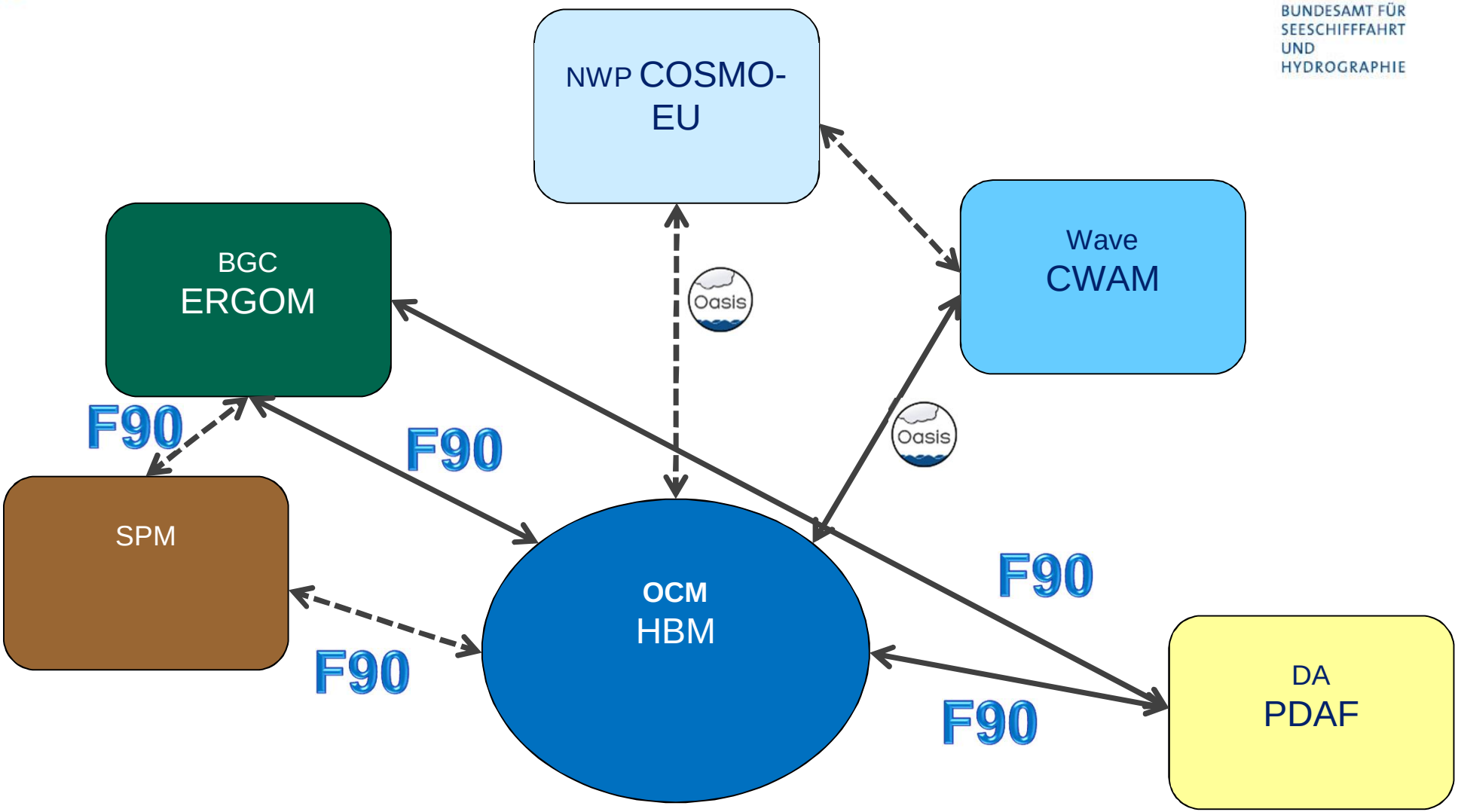

Thank you!

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