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Geesthacht
Centre for Materials and Coastal Research

Assimilation of HF Radar Data into a 3D Primitive Equation Hydrodynamic Model for the German Bight

Emil Stanev, Johannes Schulz-Stellenfleth, Joanna Staneva, Friedwart Ziemer and Jörg Seemann

In cooperation with:
K-W. Gurgel, T. Schlick

COSYNA

NURC,
11-13 October 2011

Challenges and Motivation

Research Issues

Currents in the German Bight are dominated by tides

Observations measured at a high temporal resolution constitute a challenge for sequential data assimilation schemes. The analysis steps produces often unrealistic transient processes (e.g. Malanotte-Rizzoli et al, 1989) which are not dissipated when the length of the assimilation cycle is short. Too frequent assimilation of observations can thus degrade the model results (Talagrand, 1972). To avoid this problem, it is thus preferable to correct the source of the model error (if this is possible) rather than the model state.

In coastal models since signals are not generated within the domain, but are rather propagated inside the domain through the boundary conditions. For improving the modeled tidal variability it is therefore not sufficient to update the model state via data assimilation without updating the boundary conditions.

Applications

Contribution to the Marine Services

The Marine Service: From Generic Products to Intermediate and End Users

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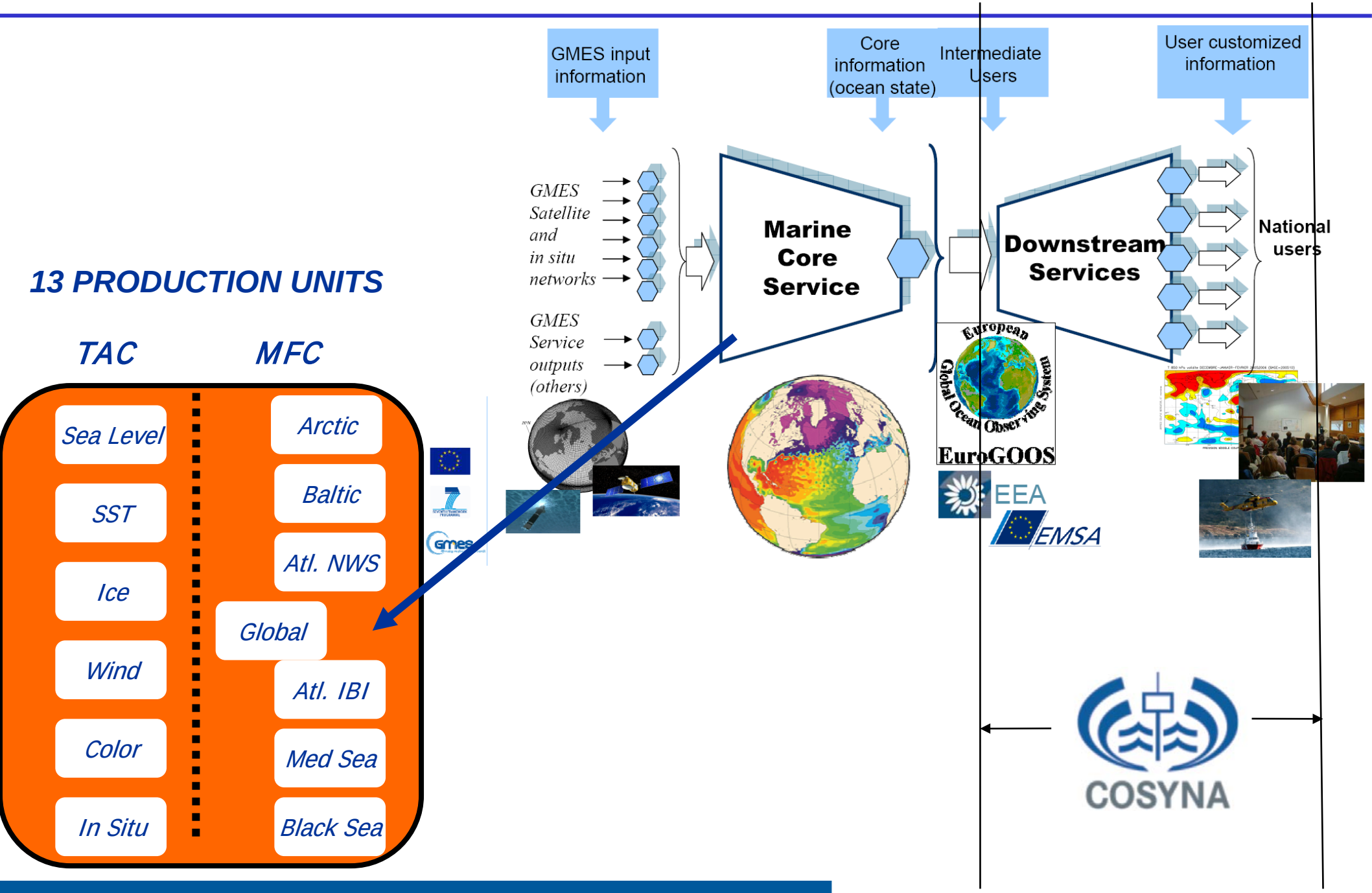

The Area and Data/COSYNA/ Past Experiences

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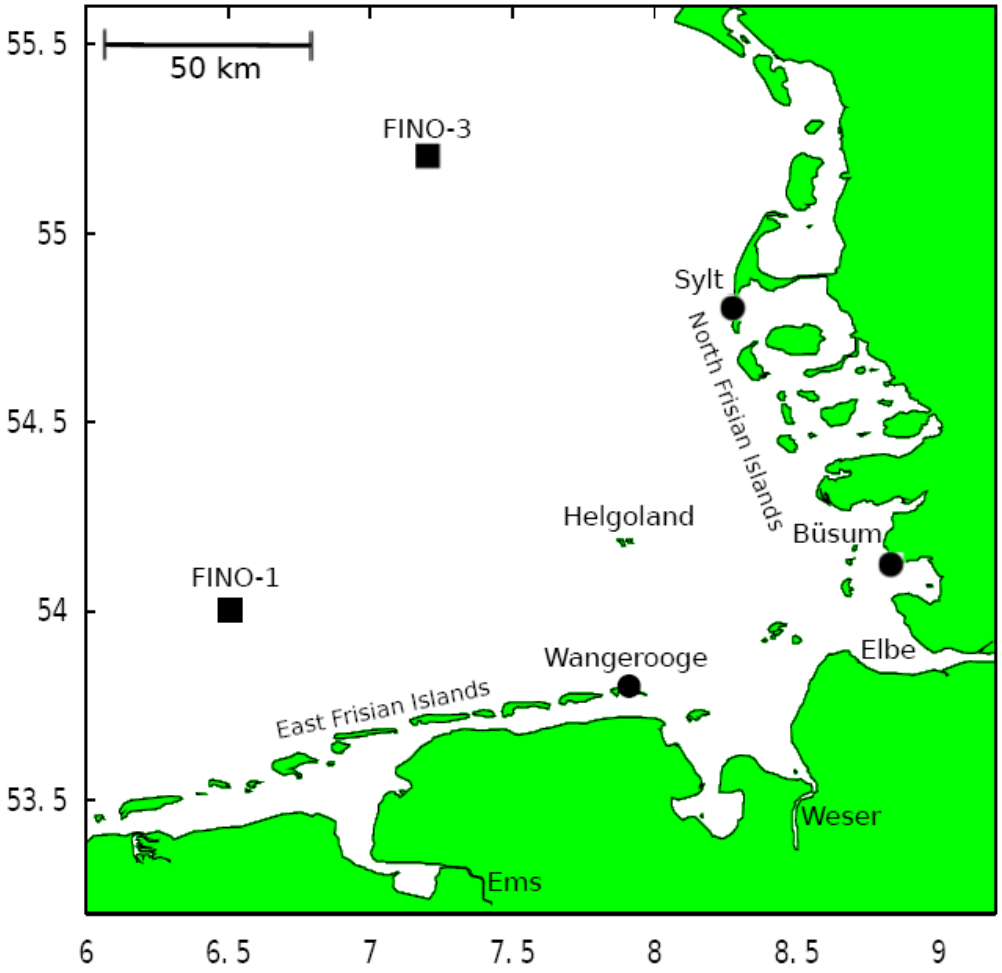

Data (COSYNA, PRISMA):
Port et al. (ODyn 2011)
Wahle and Stanev (GRL, 2011)

COSYNA:
Stanev et al. (OS, 2011)

Data Assimilation
Barth et al. (OS, 2010)
Ensemble perturbation smoother …
Barth et al. (ODyn, 2011)
Correcting surface winds by assimilating …

Optimal Design:
Schultz-Stellenfleth and Stanev (OMod, 2010)

The Data

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Radar wavelength: 22 m to 28 m

(λBragg 11 m and 14 m).

The sensed depth: 1/(4π)λBragg ≈ 1 m

HF Radar product:

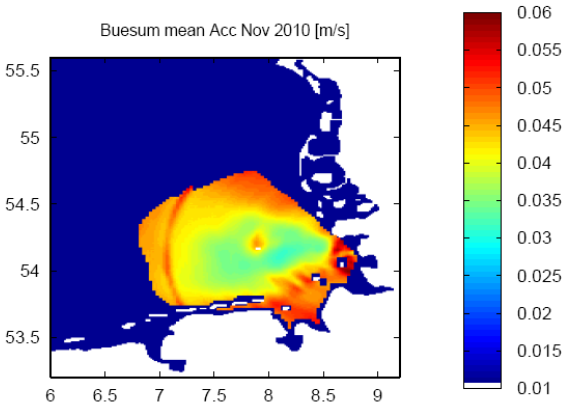
Integration time: 9 minutes.

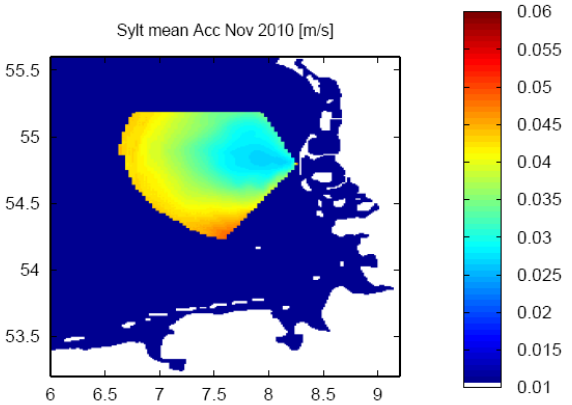
Integration windows: centred at 4 min 26 sec, 23 min 26 sec and 43 min 26 sec after each full hour.

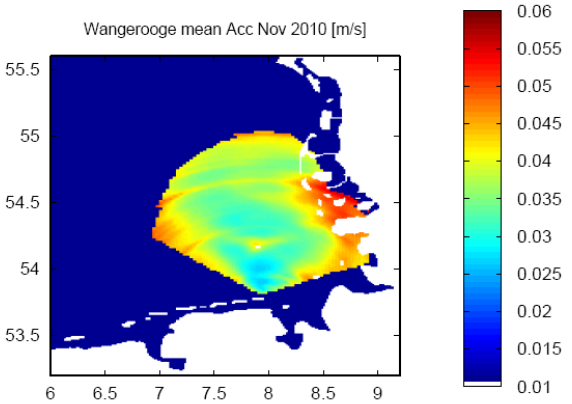
spatial grid with 2 km binsize

Accuracy is estimated using a signal processing approach (Gurgel, 2011)

Availability: about 30 min after acquisition (under favourable data transmission conditions- 10 min after the measurement).







Data Validation

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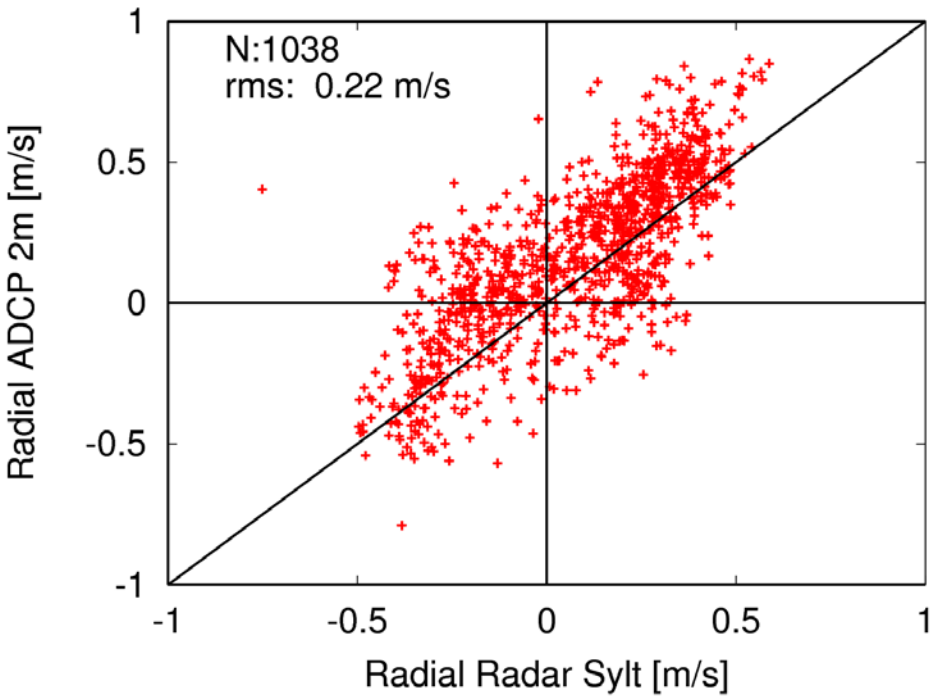
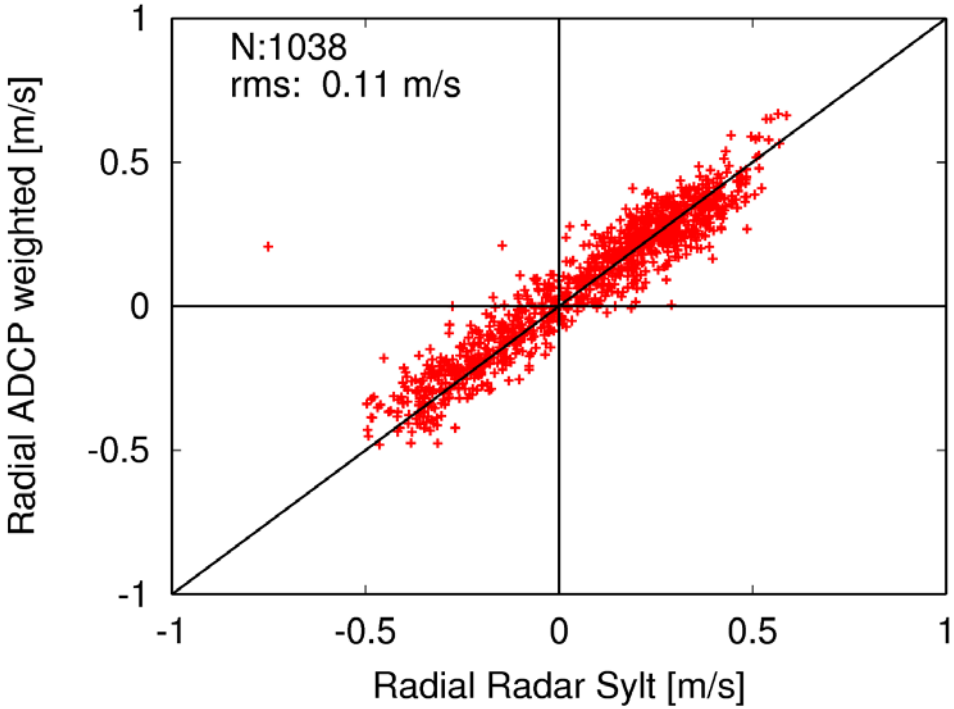
Bottom Mounted ADCP Measurements Every 10 min.

Radar versus ADCP 2 m depth



Radar versus ADCP optimal (a least squares fit) weighted average of 2 m,4 m, 6m depth obs



The Model

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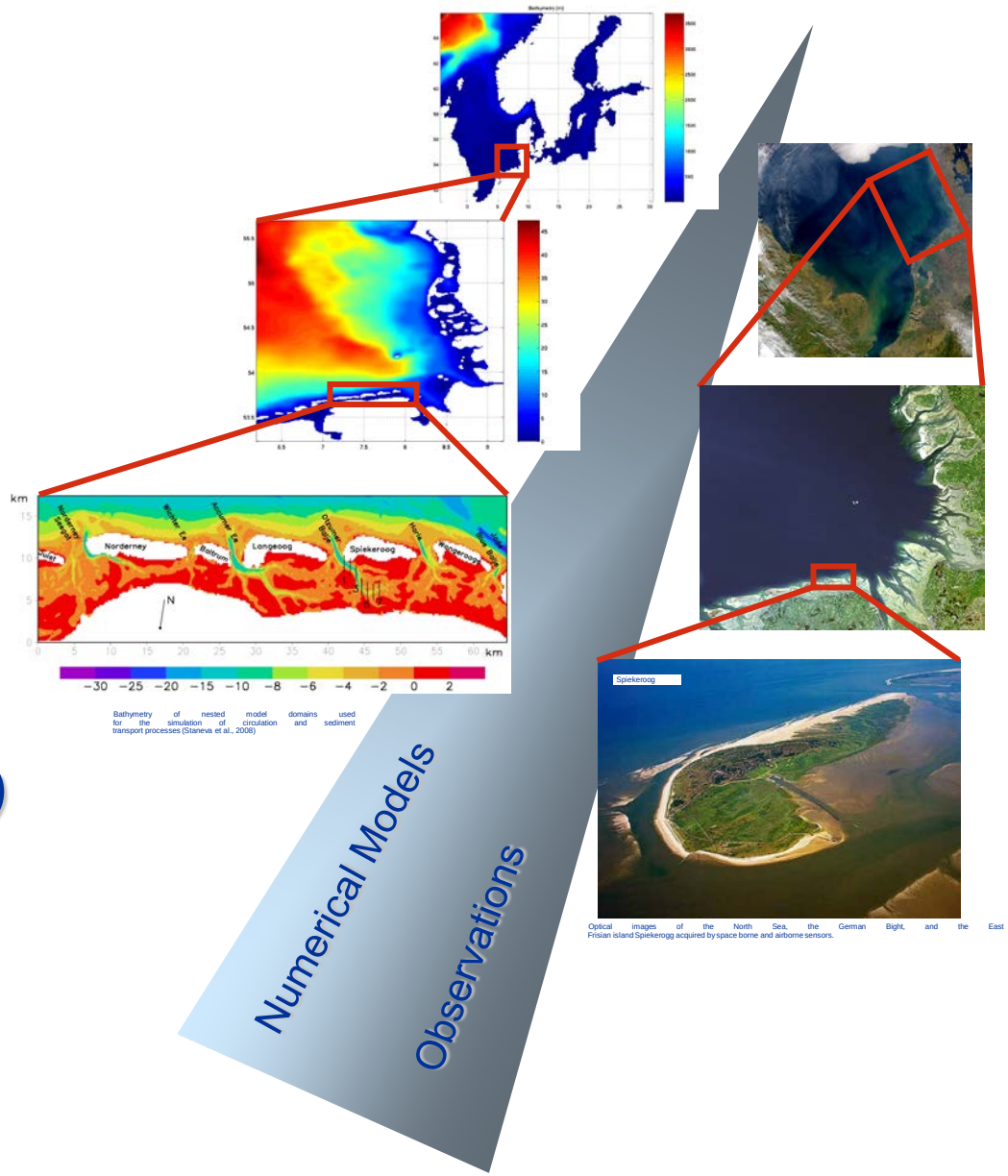
Nested Modeling System

Platforms: BSH, GETM

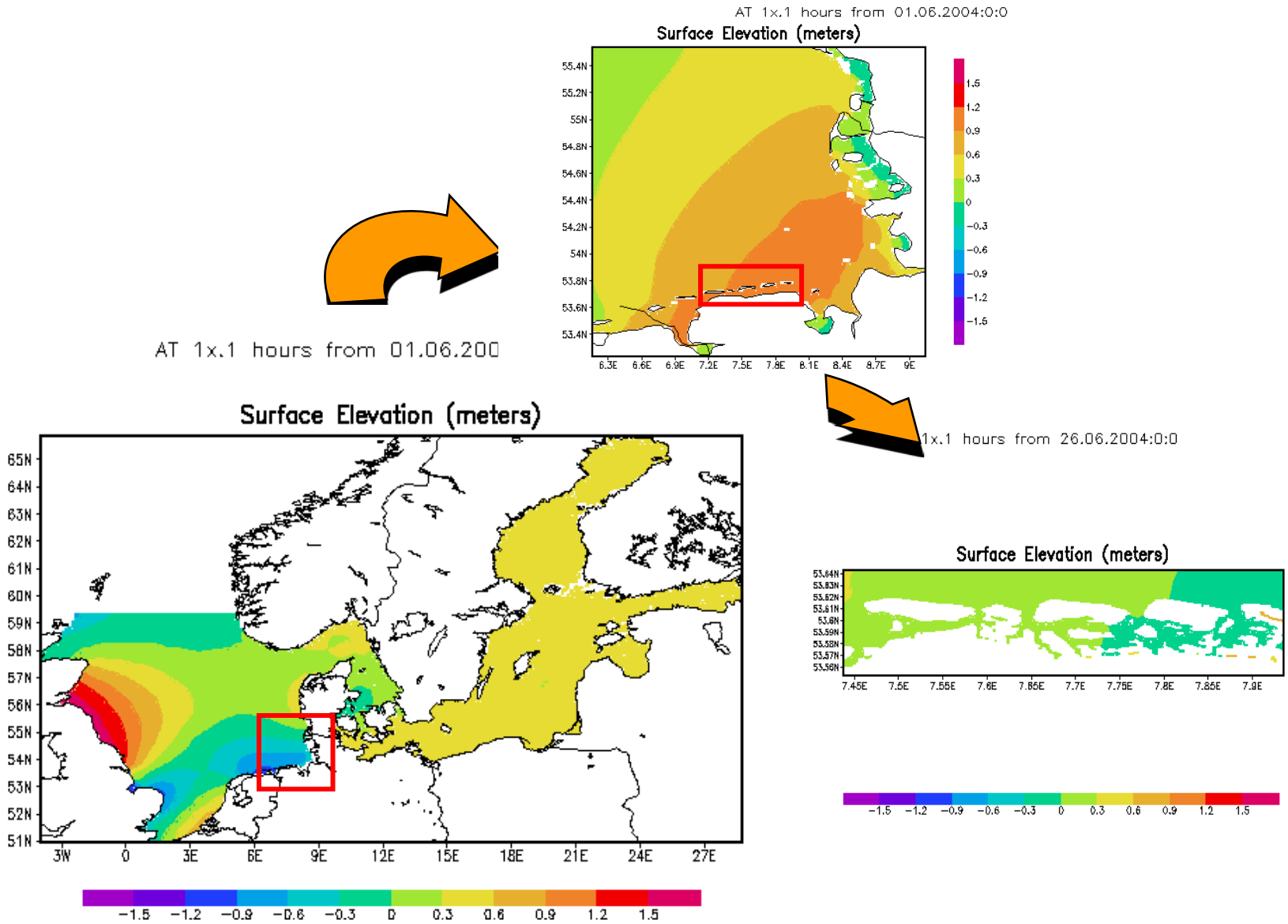
The modeling system consists of three nested models:

- **North Sea-Baltic Sea model (5 km)**
- **German Bight model (0.8 km)**
- **Wadden Sea model (200 m)**
- **Forcing**
  - Atmospheric forcing (DWD 1-hr atmospheric forecasts),
  - River run-off – hourly data,
  - Open BC – tides, T and S



Bathymetry of nested model domains used for the simulation of circulation and sediment transport processes (Staneva et al., 2008)

Optical images of the North Sea, the German Bight, and the East Frisian island Spiekerogg acquired by space borne and airborne sensors.


AT 1x.1 hours from 01.06.2004:0:0
Surface Elevation (meters)
AT 1x.1 hours from 01.06.200
1x.1 hours from 26.06.2004:0:0
Surface Elevation (meters)
Surface Elevation (meters)

Model vs. WERA (Radial Component Wangerooge)

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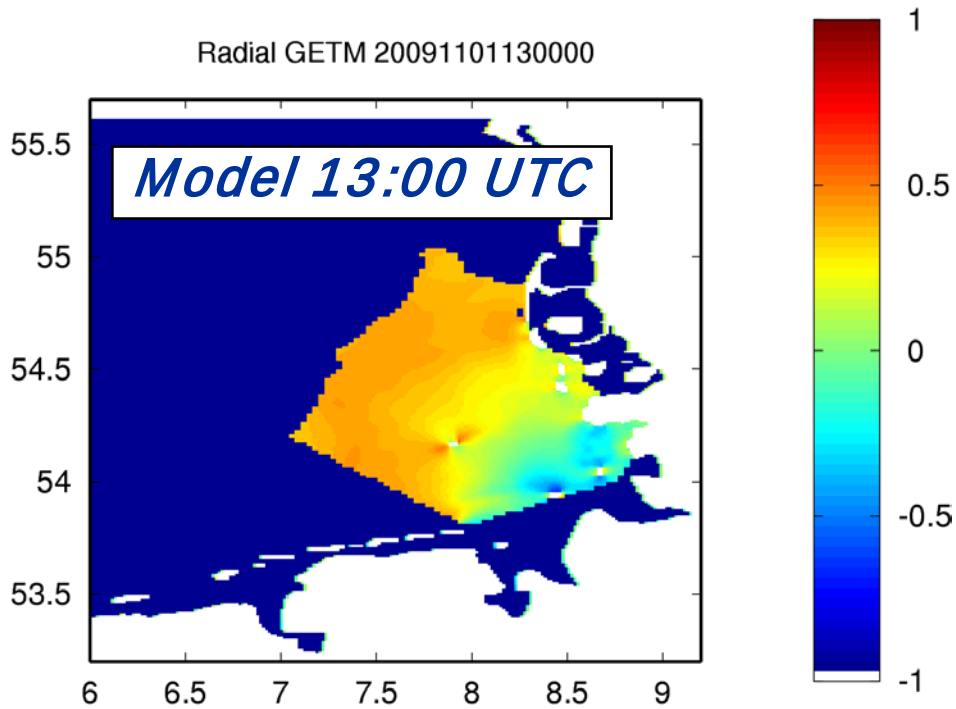

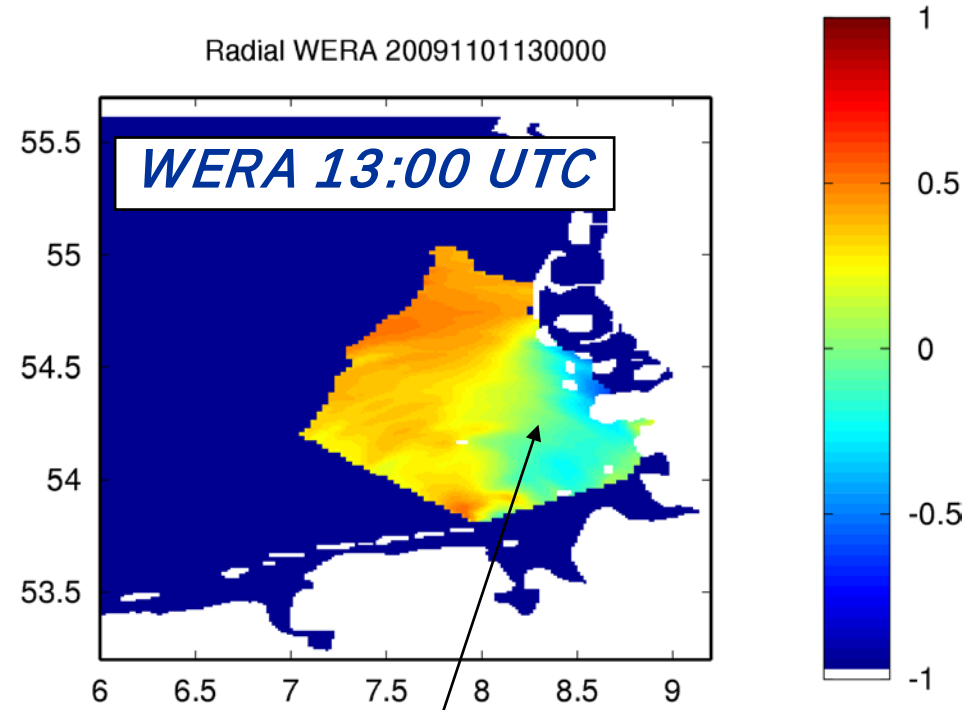

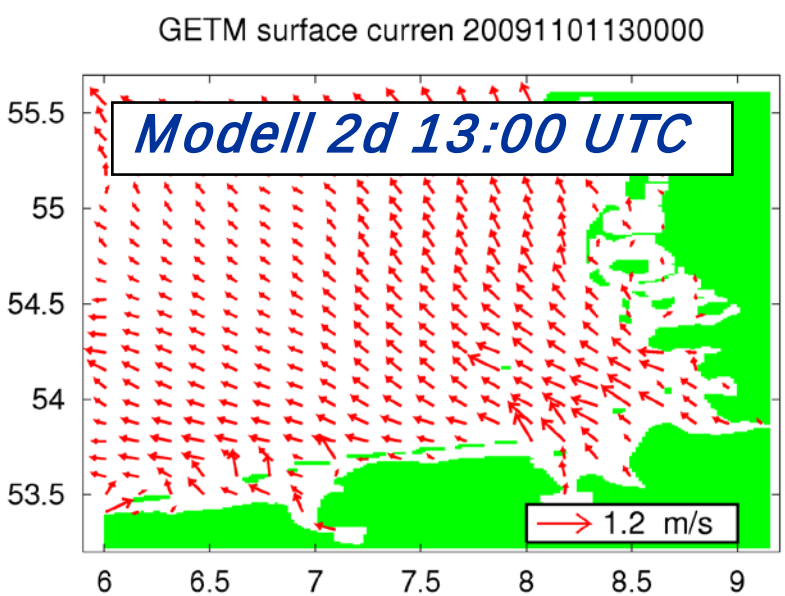

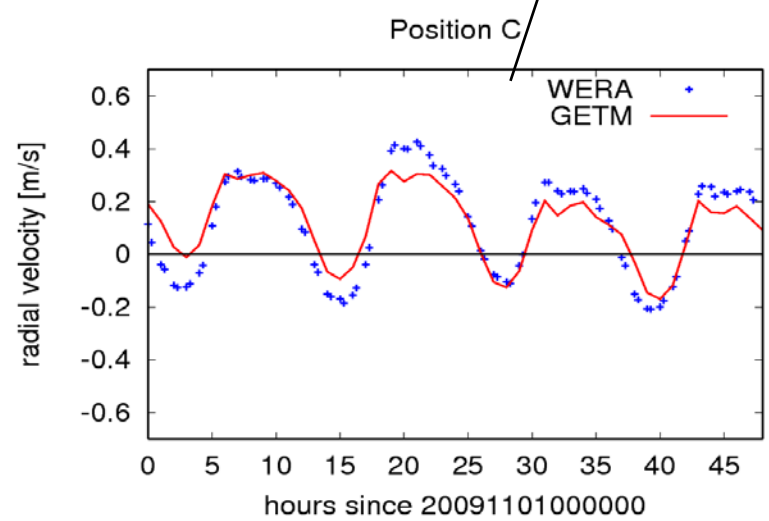

Analysis of previous 12 Hours

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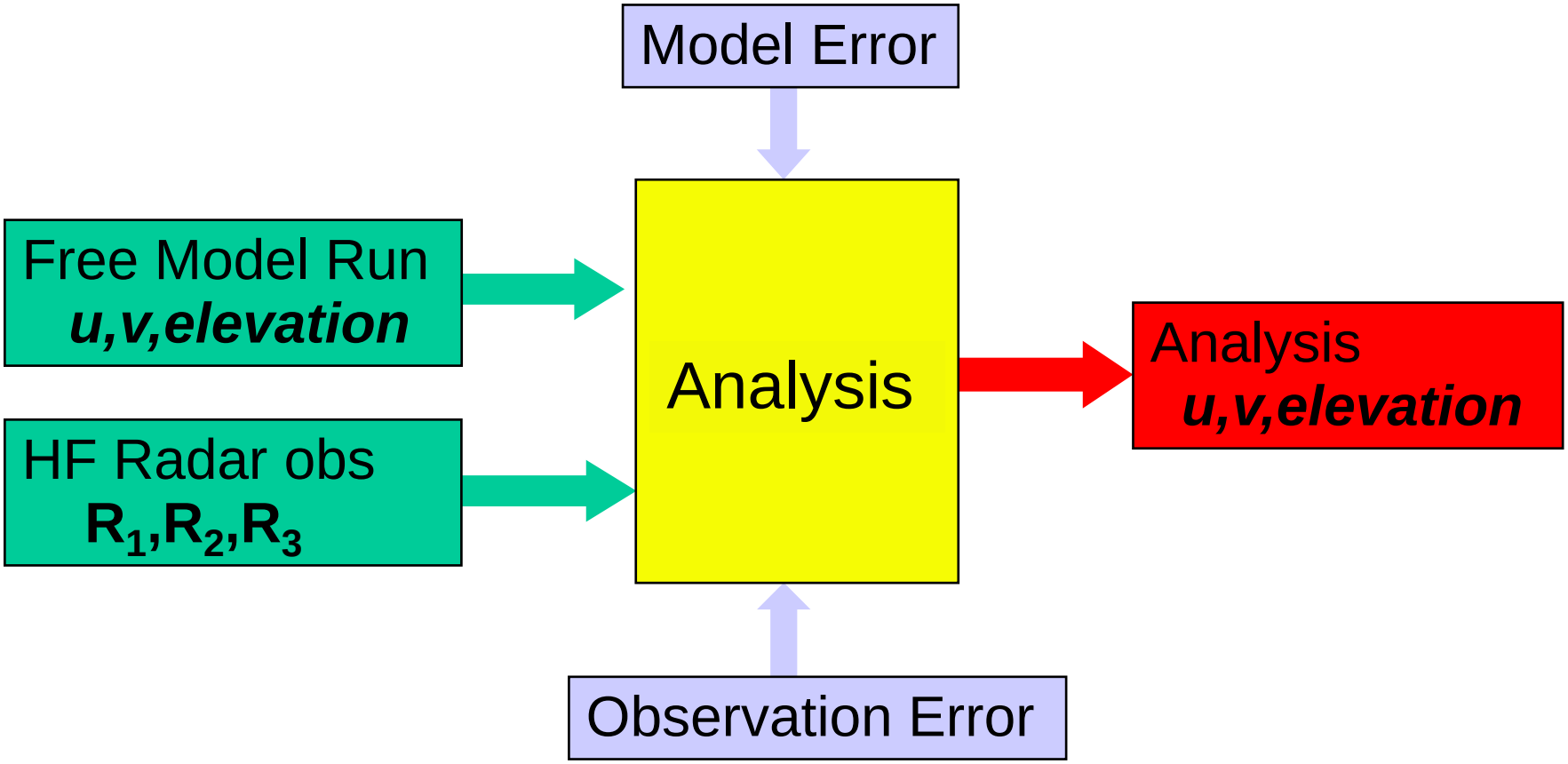

- *Use HF radar observations and free model run of the previous 12 hrs to compute a analysed model trajectory for the same period.*
- *Considered state variables: surface current components u, v*
- *Requires EOF analysis with state dimension of about 800.000*

Assimilation Approach

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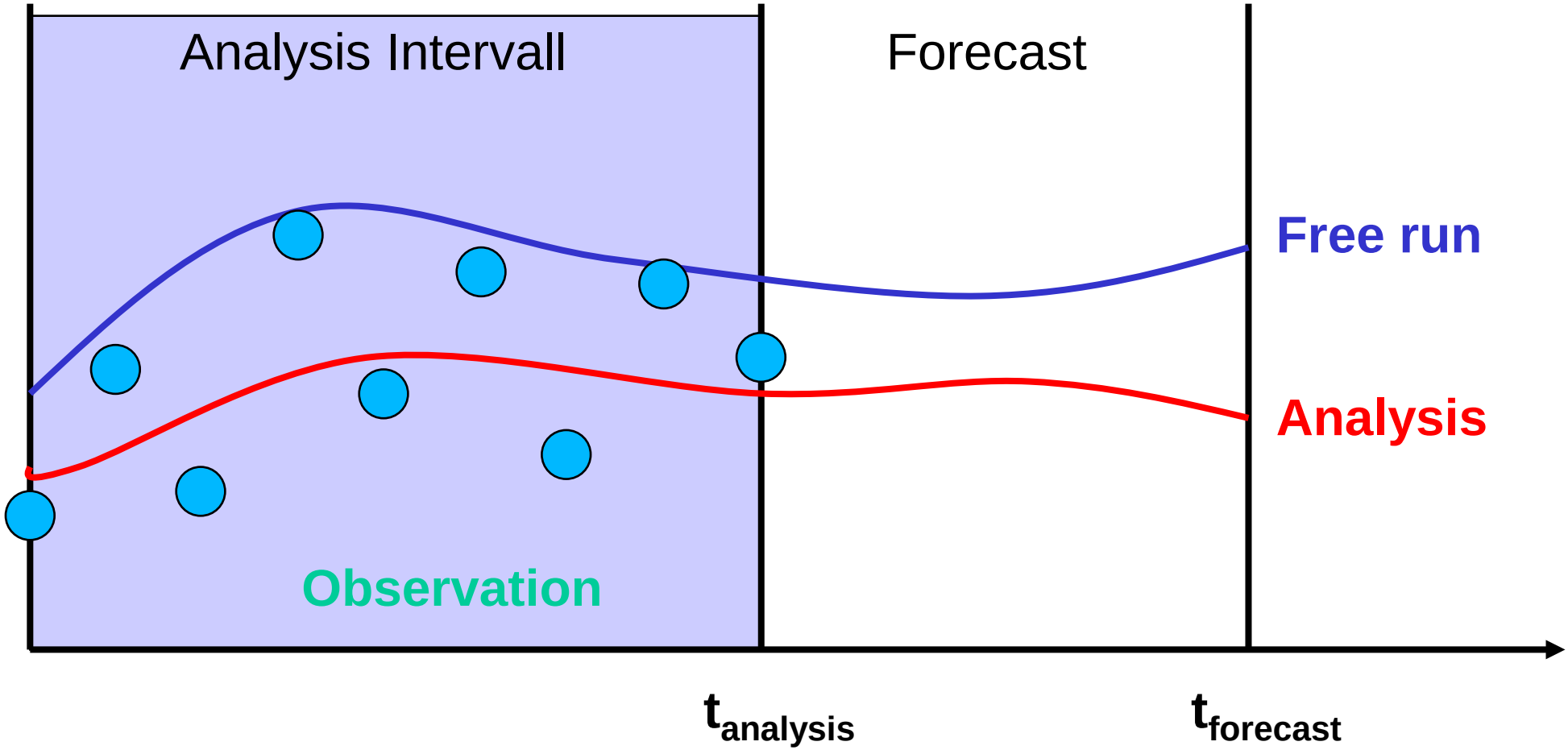
Use analysis intervall in oder to

- avoid frequent shocks in the model

- better use information on phase of tidal constituents



Assimilation Approach (continued)

Problems:

We deal with irregular data gaps and inhomogeneous observation errors.

The treatment of the boundary forcing and the information transfer into the subsurface layers are demanding tasks.

Solution:

A spatio temporal optimal interpolation procedure, which processes a period of 12 hours in a single analysis step.

The required background statistics is derived by EOF analysis of a free model run.

Unlike to the classical Kalman filter, where an analysis is performed whenever observations are available, we correct the phase and magnitude of the M2 tidal component (12.4 hour period). The statistical analysis is based on hourly model output for 2010.

Analysis of Previous 12 Hours

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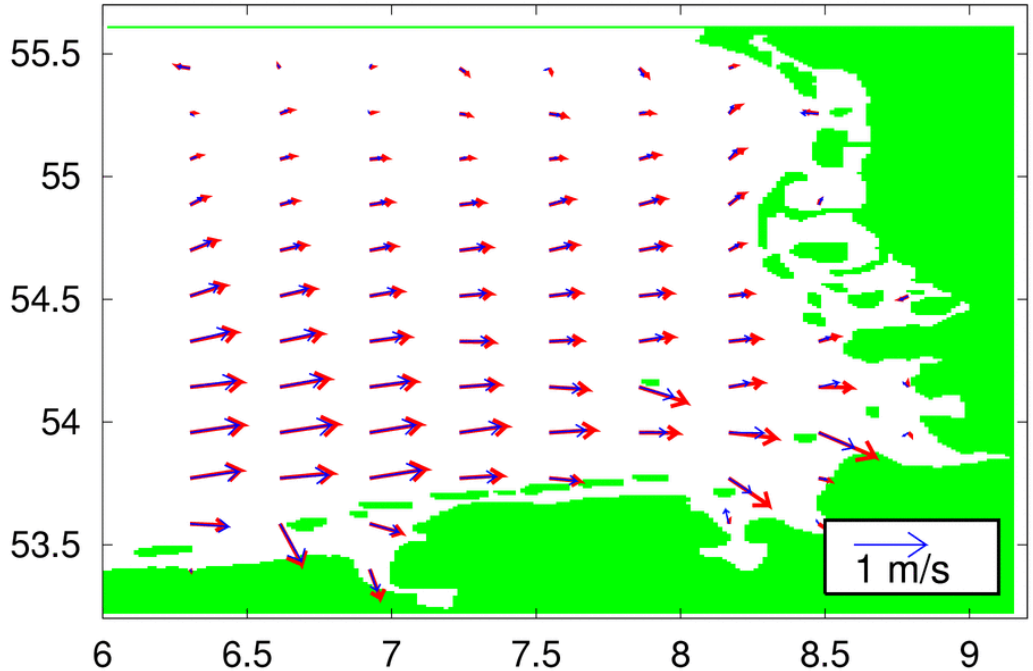
$$X_i = \left(x(t_1), \ldots, x(t_{i+12})\right)$$

Hrs since Dec 5, 2009, 00 UTC: 01



Free run

Analysis

Forecast current fields and HF radar observations over period of 12 hrs

Information on background statistics and observation errors

Kalman filter analysis

Modified current fields over period of 12 hrs

Schulz-Stellenfleth,K. Wahle, J. Staneva, J. Seemann, M. Cyseswky, K.W. Gurgel, T. Schlick, F. Ziemer, E.V. Stanev, Nutzung eines HF-Radarsystems zur Beobachtung und Vorhersage von Strömungen in der Deutschen Bucht im Rahmen von COSYNA, DGM Nachrichten, 3/10, pp 3-8, 2010

Consistency with HF Radar (Nov 23 to Dec 15, 2010.)

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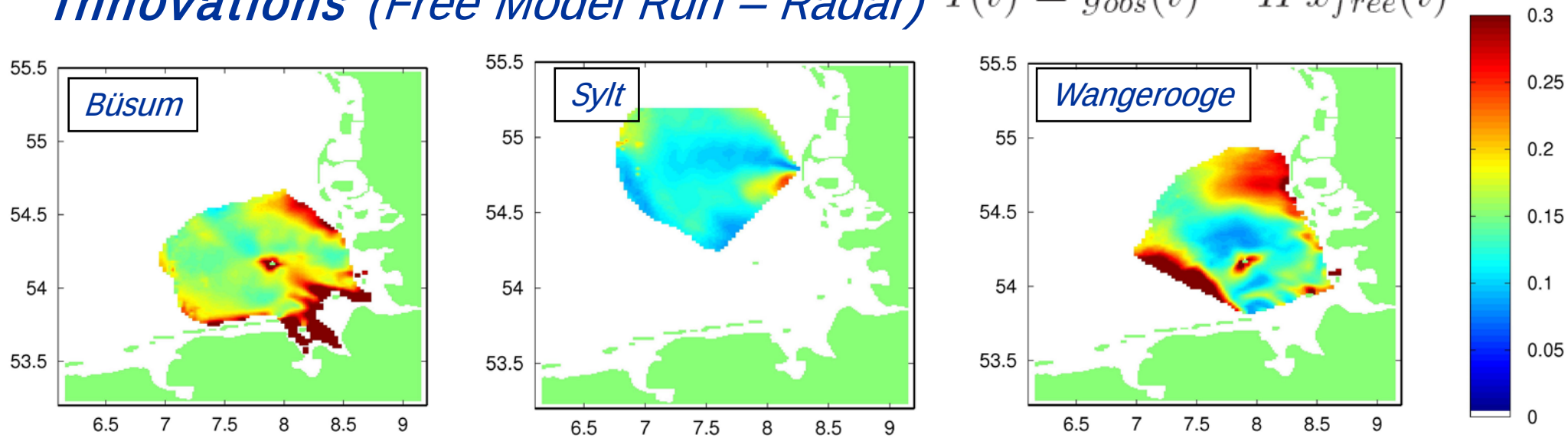
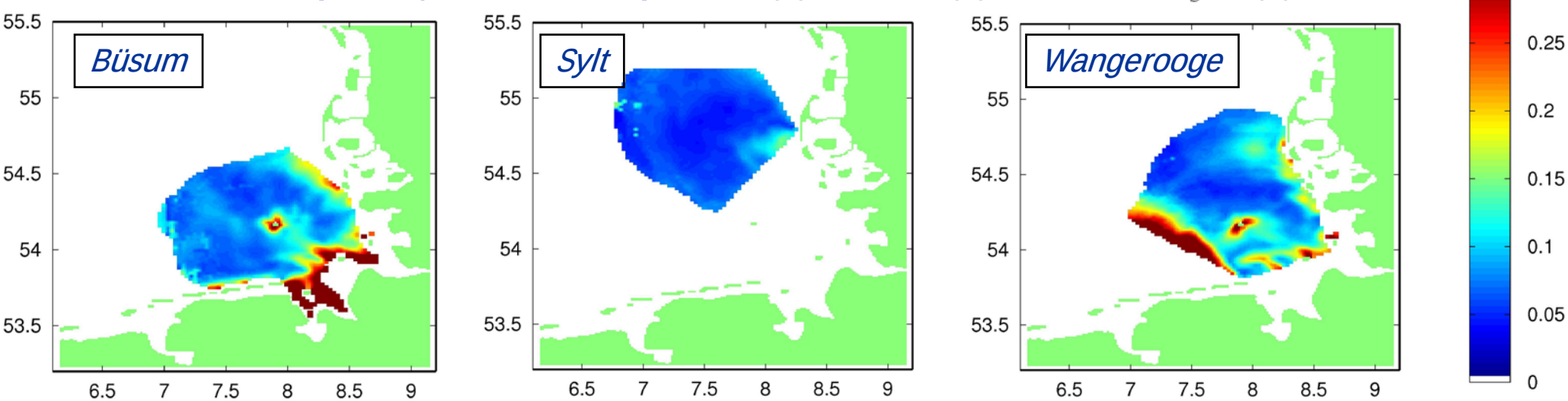
Innovations (Free Model Run – Radar) $I(t) = y_{obs}(t) - H\, x_{free}(t)$ [m/s]



Residual (Analysis-Radar) $R(t) = y_{obs}(t) - H\, x_{analysis}(t)$



Comparison of u/v components

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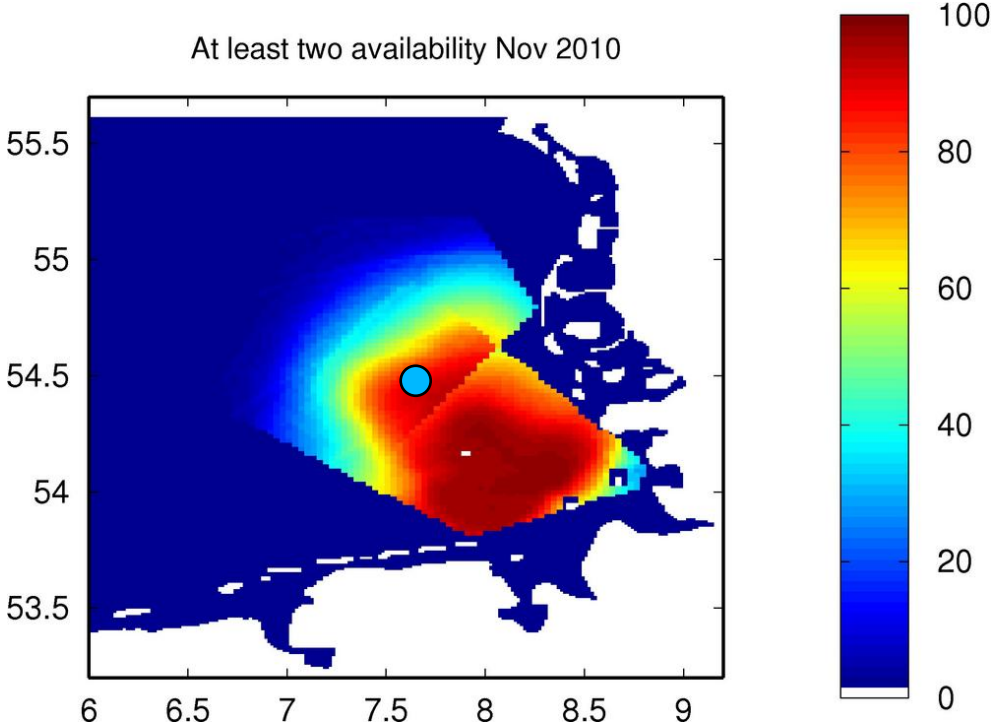

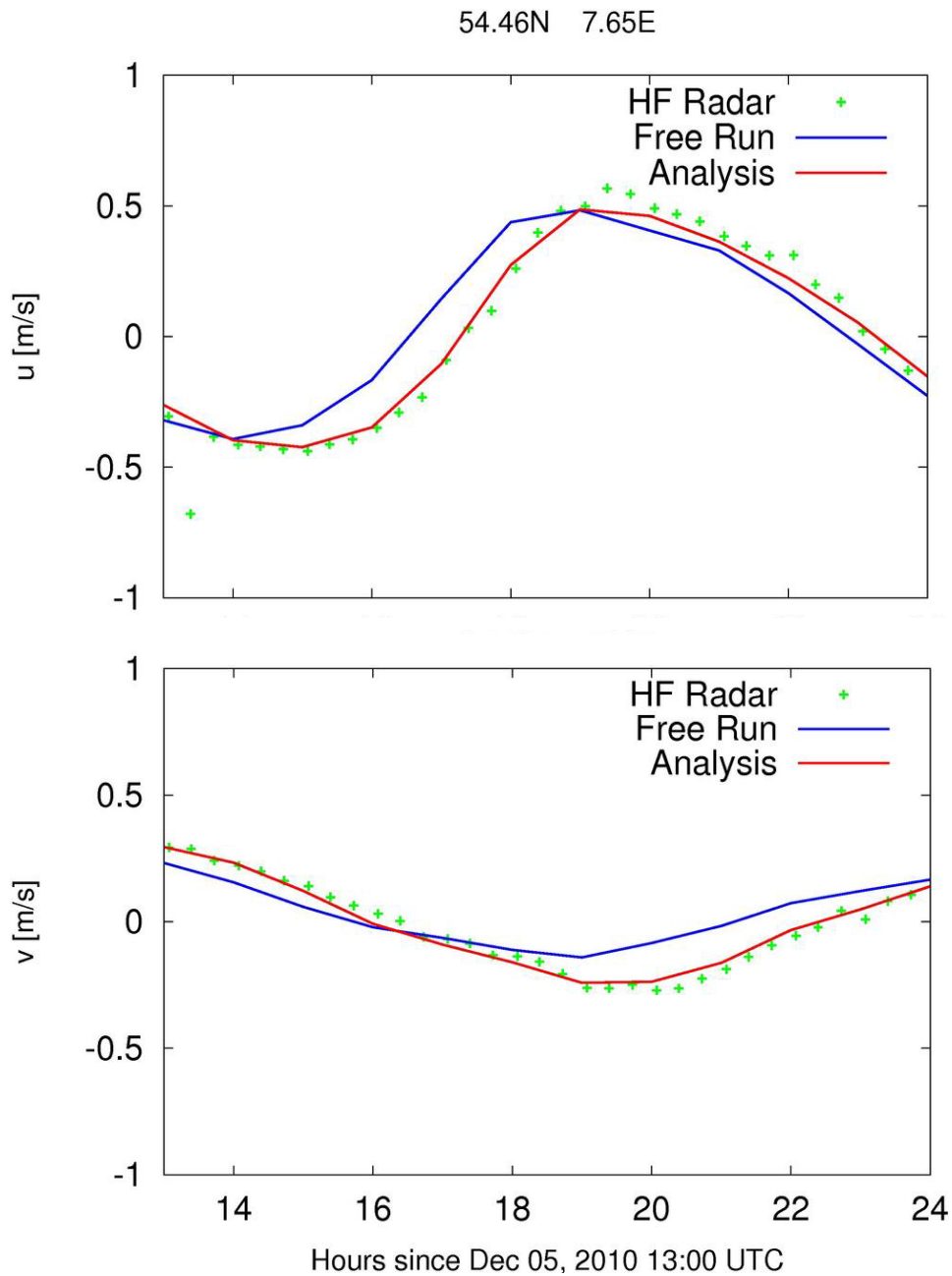

Tidal Ellipses

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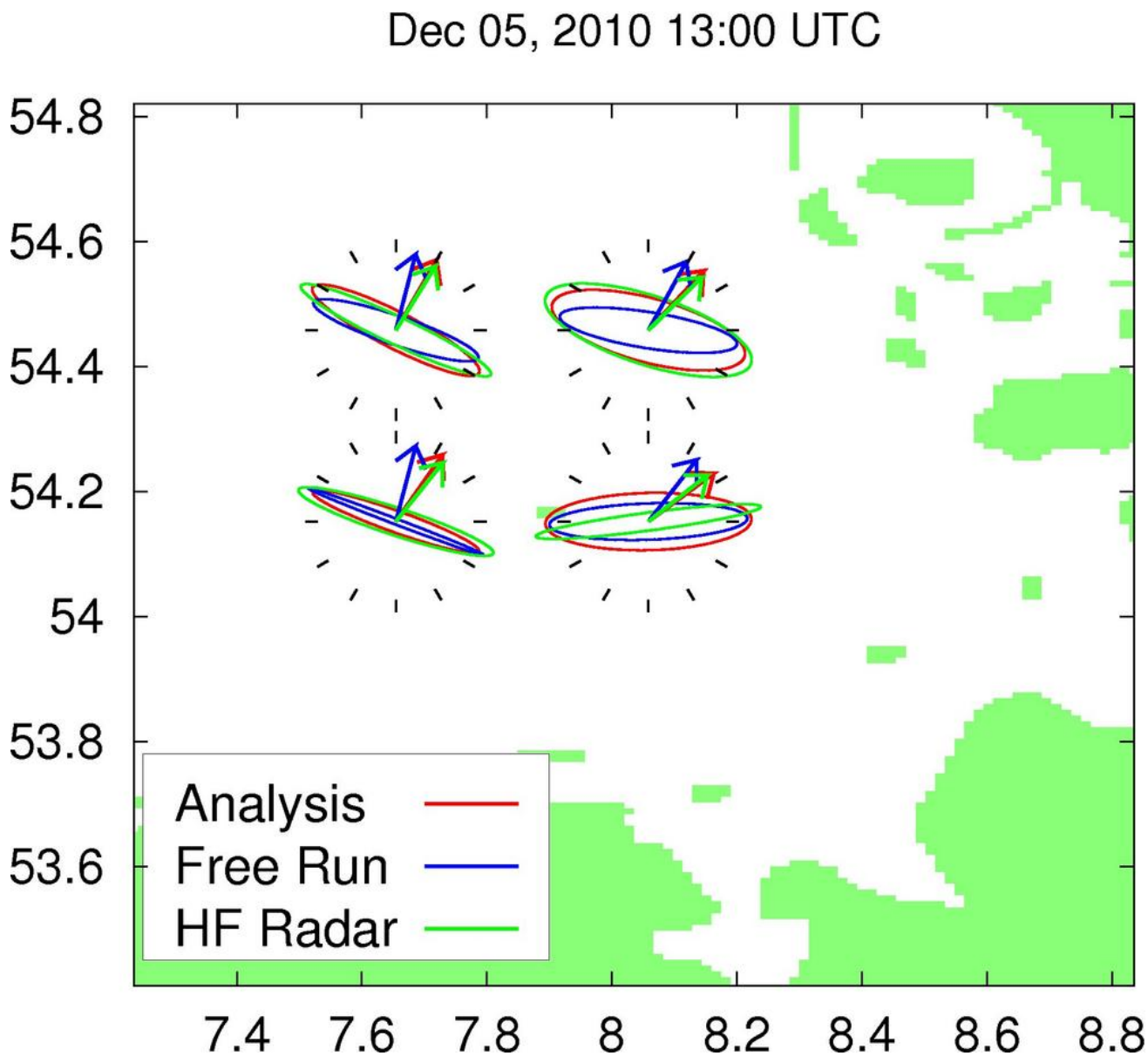

Integrated COSYNA Surface Current Product

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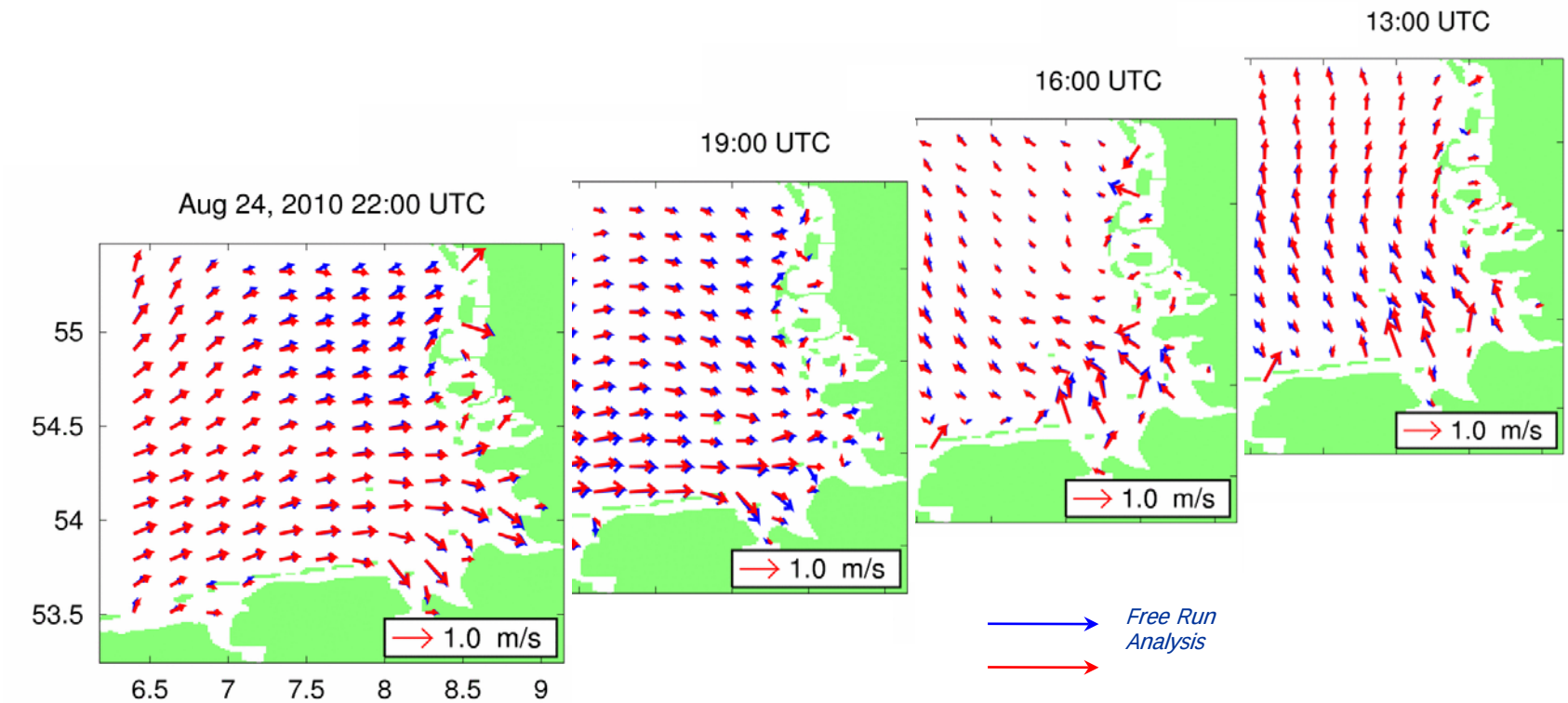

- *Analysis of surface currents for previous 12 hrs*
- *Update every hour*
- *Provided on a 1 km grid with hourly sampling*

Statistical Forecast

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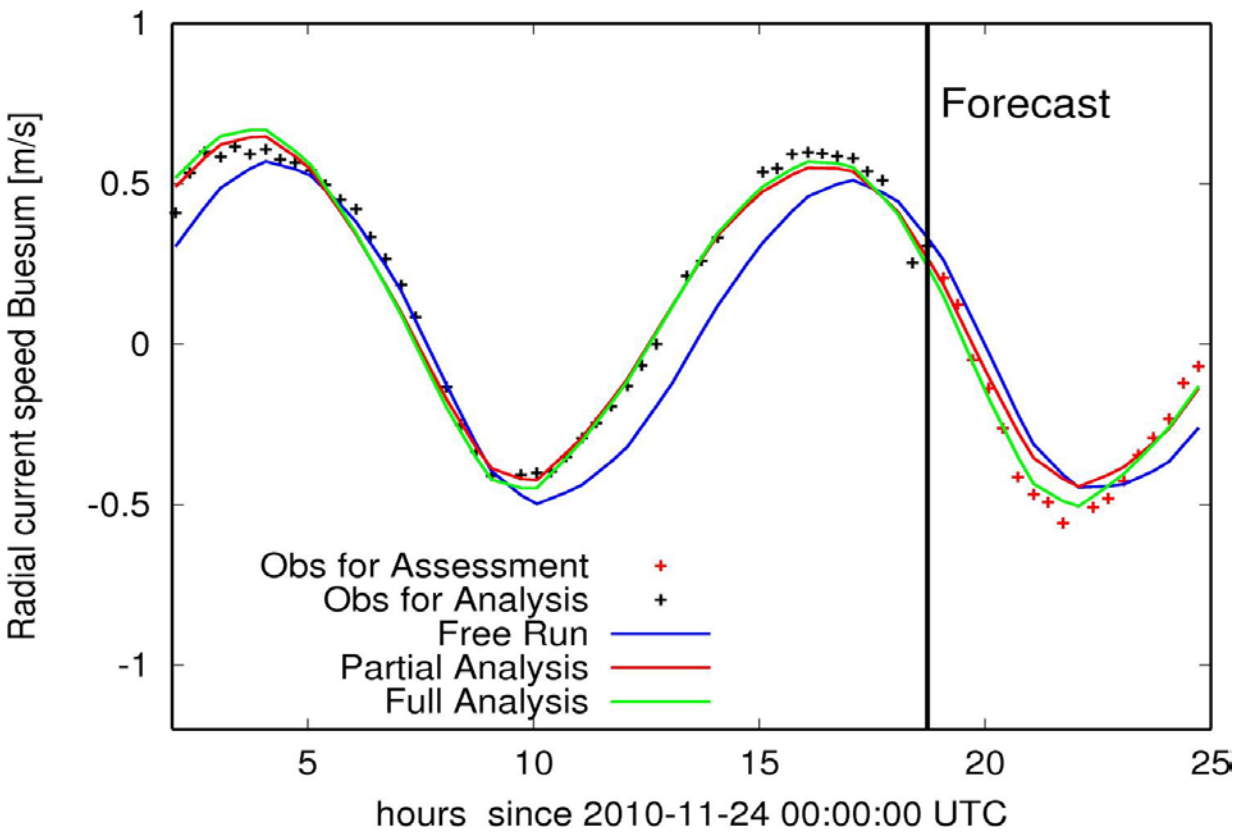

-***Basically the same analysis technique as used for hindcast***

- ***24 Hrs window used for analysis***

-***Observations only available during first 18 hours***

12 Hour Forecast with Restart

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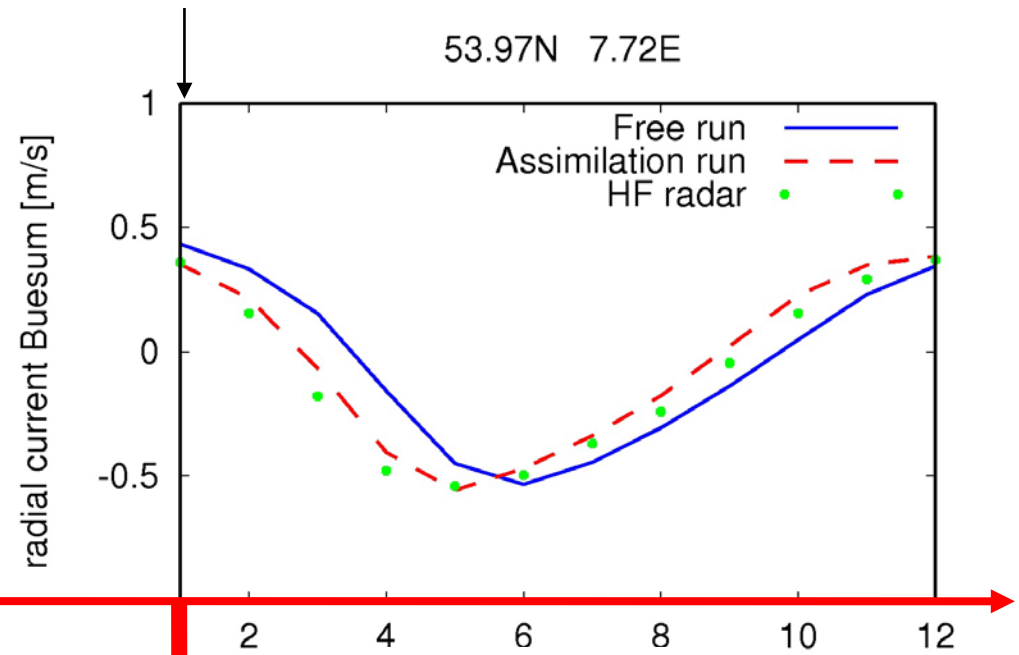
-*Analysis of the previous 24 hrs*

-*Analysis of boundary forcing for next 12 hrs*

-*Analysis of meteo forcing for next 12 hrs*

Restart of Model



Past

24 hrs analysis period

t_a

Future

12 hrs forecast period

Summary/Outlook

- *Spatio temporal OI method for combination of HF radar data and numerical model results developed*
- *12 hours hindcast pre-operational*
- *Improved consistency with both radar data and independent insitu observations*
- *Statistical forecast method developed*
- *Forecast method with model restart developed*
- *Ongoing activities to validate and optimise analysis techniques*
- *Ongoing activities to optimise observation error models*

FerryBox-Daten Assimilation

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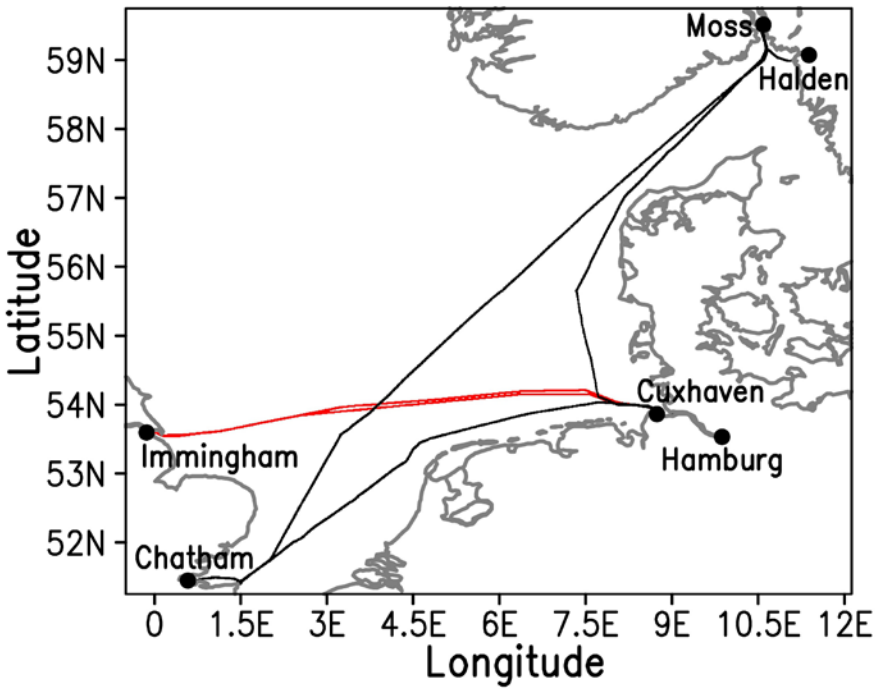
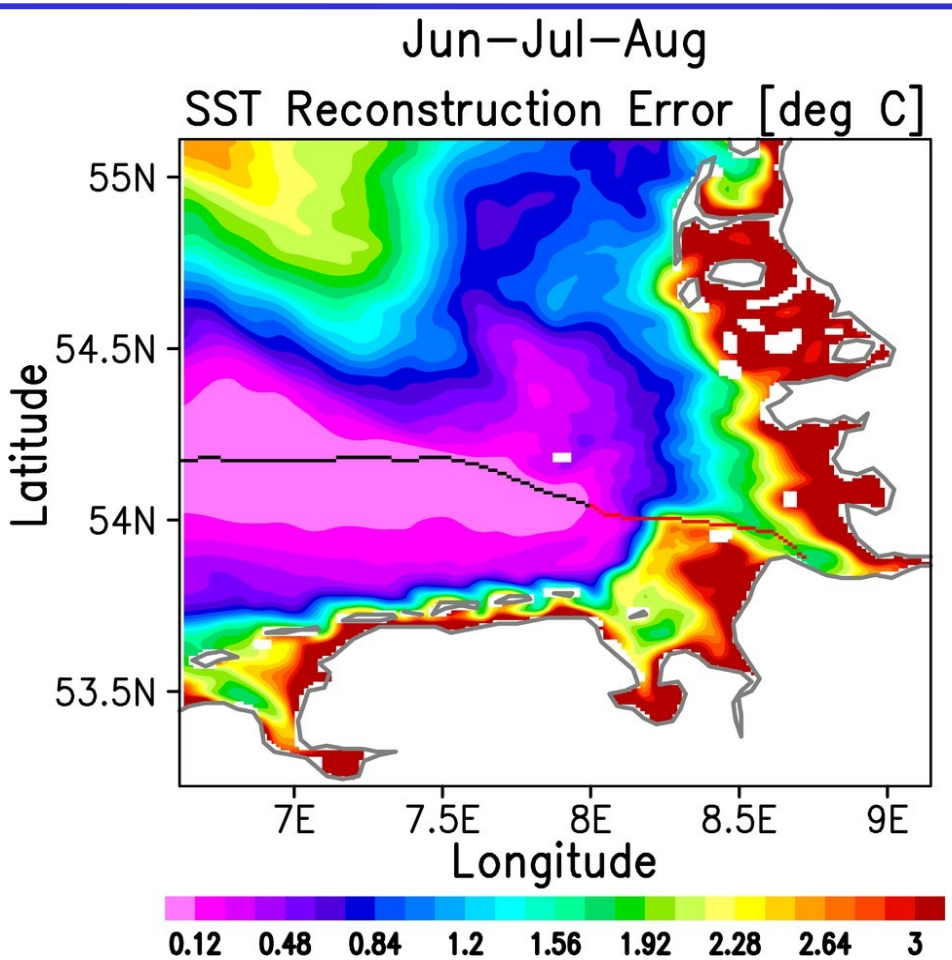




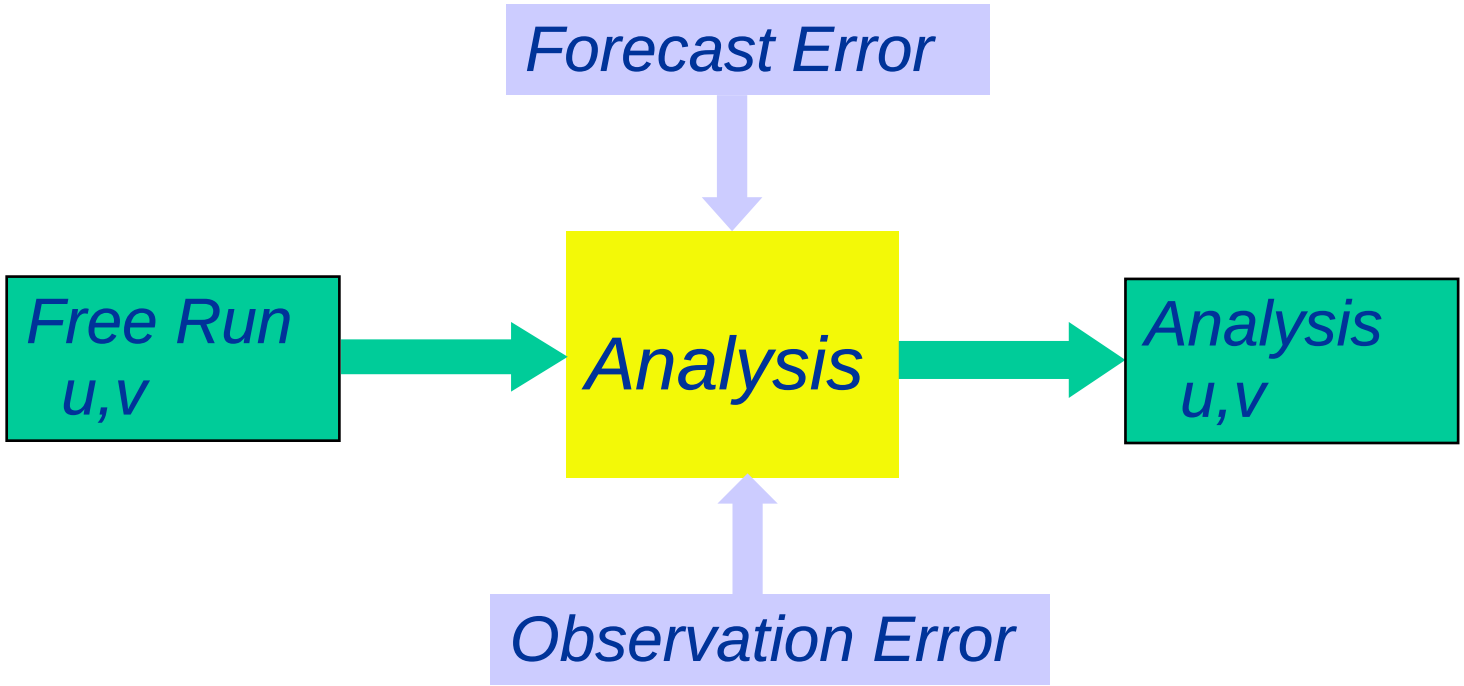
Cuxhaven–Immingham Route:

Cruising Speed:	15 Kn
Sampling Rate:	0.1 Hz
Revisit time:	≈36 hrs
Sampling depth:	4-6 m

For details:

S. Grayek, J. Staneva, J. Schulz-Stellenfleth, W. Petersen, E. Stanev, *Use of FerryBox surface temperature and salinity measurements to improve model based estimates for the German Bight*, accepted, J. of Marine Systems, 2010

Analysis of Previous 12 hours



- *Use HF radar observations and free model run of the previous 12 hrs to compute analysed model trajectory for the same period.*
- *Considered state variables: surface current components u, v*
- *Requires EOF analysis with state dimension of about 800.000*

Validation

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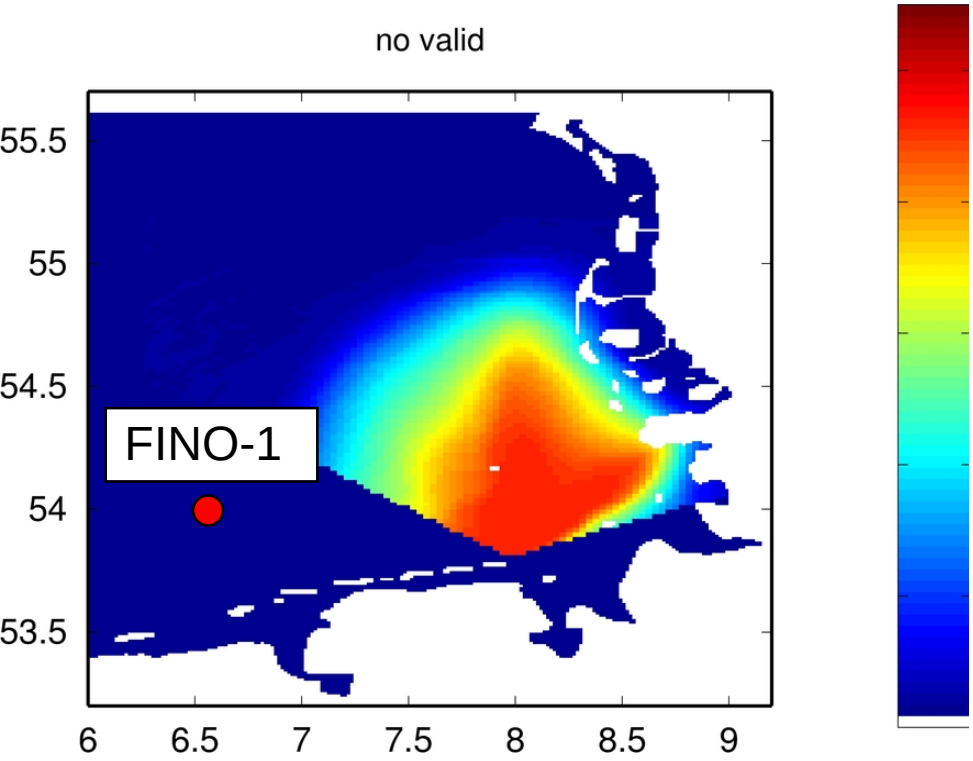

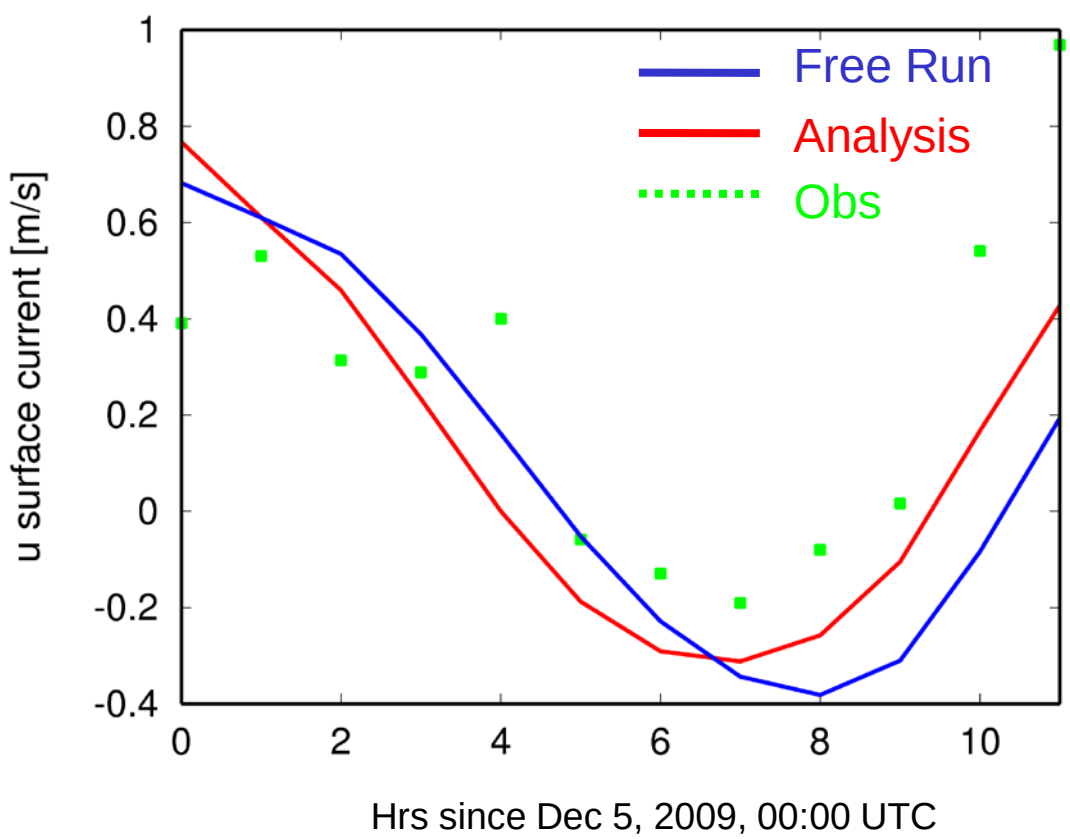

Integrated COSYNA Surface Current Product

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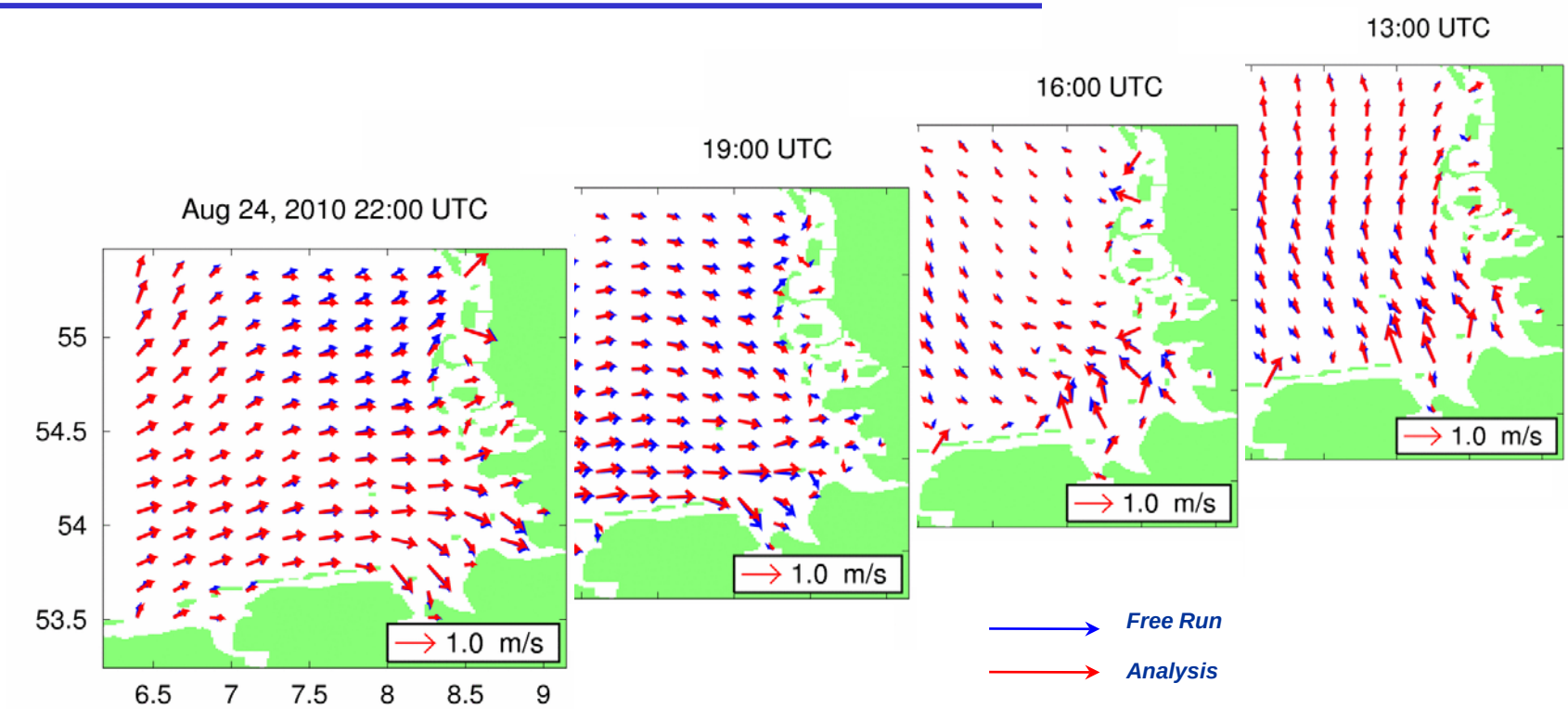

- *Analysis of surface currents for previous 12 hrs*
- *Update every hour*
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http://kofserver2.hzg.de/codm/