Joint European Research Infrastructure network for Coastal Observatories

D9.3 : WP9 first report on OSSE

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1. Document description

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2. Executive Summary

In WP9 OSSE experiments are applied in the Adriatic Sea, the North Sea, The Baltic Sea and the Bay of Biscay ad the Irish Sea. The methodologies range from estimating the impact in twin experiments to methods based on the evaluation of properties of the matrix of analysis errors. Most of the experiments are in their initial development phase, except the Bay of Biscay experiment in which some estimates are already produced concerning the impact of the future observations, as well as in North Sea experiments (HZG) which indicate that better results are obtained when two ferry lines are used instead of one. We expect that in the next phase of the project most of the OSSE experiments will produce the first results.

3. Introduction

OSSE experiments are very important for planning the deployment of future observational platforms. They can be performed either by estimating the impact of historical observational experiments that lasted for a limited time, or by producing synthetic observations that can later be assimilated. Some methods are based on the evaluation of the change in the properties of analysis error covariances. The methods applied in the WP9 use different methodologies in different experiments covering different coastal areas.

4. Main Report

4.1. Adriatic Sea

4.1.1 Experiment set-up

The first OSSE experiment will estimate the impact of the assimilation of data from surface drifters in the Adriatic Sea. A large set of surface drifters will be simulated in the Adriatic Sea by using the velocity forcing fields produced in an assimilation experiment. These assimilation estimates will represent the real state of the ocean. In the OSSE assimilation experiment simulated surface drifters will be assimilated with all other observations, but the initial condition and the atmospheric forcing will be pertutrbed. In the experiment we will estimate how surface drifters may improve the estimate of the surface circulation and also other physical state parameters like the temperature and salinity distribution.

The second OSSE experiment will assimilate in-situ observations provided by instruments installed on fishing nets. During 2003-2008 in the EU project MFSTEP there was an extensive observational program based on the instruments installed on fishing nets in the Adriatic. In an experiment we will assimilate these observations and estimate their impact on the accuracy of the analysis. In another experiment we will produce synthetic observations of temperature and salinity from an assimilation system. These observations will have the distribution of the historical observations of temperature by fishing vessels, but they will be assumed to be more accurate and contain both temperature and salinity information. They will simulate the future more accurate instruments for measuring both temperature and salinity that will be deployed on the fishing vessels in the Adriatic Sea.

4.1.2. Ongoing development

a) Assimilation of surface drifters

The assimilation experiment that produces data from surface drifters is under development. It will produce 3-4 years of surface data in the Adriatic. After performing this experiment we will choose the period and areas in which these data will be assimilated.

b) Assimilation of observations produced by fishing vessels

The observations by fishing vessels are currently processed in order to estimate the quality of data and estimate some typical errors. In the next stage these observations will be assimilated in an experiment. The period of the assimilation will be decided after the quality check procedure. The experiment that produces the synthetic profiles of temperature and salinity is under development. After the completion of the experiment we will define the most suitable periods and areas for performing OSSE experiments.

4.1.3. Expected problems

The major problem might be that by defining the period and area that are not representative for the complexity of coastal process we may overestimate the impact of observations. This problem can be especially important in OSSE experiments where synthetic observations are generated by a model and therefore do not necessarily reproduce the full signal the real observations can contain. Therefore for producing synthetic observations we will carefully choose those areas in the Adriatic Sea that have the highest dynamical complexity.

4.2. North Sea – MUMM

4.2.1. Experiment setup

In the OSSE experiments, the impact of data from moving platforms (e.g. wave glider, ferrybox) on model forecasts will be simulated by assimilation of temperature data on the North Sea domain located between 4°W to 10°E in longitude and 48.5°N to 60°N in latitude. Simulations will be performed for September 2001.

One critical issue for assimilating data in a coastal zone where temperature and salinity fronts are present is to determine the size of the influence radius of the assimilated data (referred to as assimilation radius). In order to get the largest impact from the assimilation of one observation, the assimilation radius should be as large as possible. However, as thermal fronts might be present, a data at a given location might not be correlated with points in a close neighbourhood.

When observations from fixed locations are available, their influence radius can be determined before performing the simulations. However, in the case of a moving platform such as a wave glider or a ferrybox, the data locations differ from one simulation to another. As a result, the influence radius of the data is to be computed during the model run.

To this aim, the spatial homogeneity of the temperature field close to the location of the available data has to be determined at the assimilation step of the model run. Given the coordinates of a data location, the model grid points located within a radius of 70km will be identified and the difference between the modelled temperature at the data location and the selected neighbouring points will be computed. If it is smaller than 1°C, then the selected grid point will be considered as spatially correlated to the data location, and the assimilation process will be applied to correct the temperature at that point. Otherwise, the influence radius of the assimilated data will be assigned to 10km (order of magnitude of the horizontal model grid spacing).

Model

The simulations will be performed with the regional model COHERENS (Coupled Hydrodynamical-Ecological Model for Regional and Shelf Seas), a finite difference model developed by Luyten, [2011]. The model will be run with a horizontal resolution of 4 nautical miles, 20 σ-levels in the vertical and a time step of 20 seconds.

Meteorological data are supplied by the Danish Meteorological Institute (DMI) from the HIRLAM model with a temporal resolution of one hour. Tidal harmonics and daily profiles of currents, temperature, salinity and inflow/outflow conditions at the boundaries of the domain are derived from simulations with the POLCOMS (Proudman Oceanographic Laboratory) model covering a larger area. River runoffs from the Elbe, Scheldt, Rhine/Meuse, Thames, Humber, Tyne/Tees are taken into account. Baroclinic inflow/outflow conditions are imposed at the eastern boundary to include the exchange of water masses with the Baltic Sea.

Observations and data assimilation scheme

Synthetic temperature profiles generated from model simulations with a higher spatial resolution (one nautical mile) will be assimilated at 20 locations (the same data as used for OSE experiments). Using the low rank square root algorithm of the ensemble Kalman filter proposed by Evensen, [2004] which allows an ensemble representation of the assimilated data errors, they will be assimilated at one different station each day to represent the possible trajectory of a moving platform. This will allow to validate the method described above to determine the size of the influence radius of an assimilated data.

4.4.2. Ongoing developments

The implementation of the method for computing the assimilation radius is ongoing. Once the simulations will be performed, the impact of the assimilation of data from moving platforms will be assessed using the following criteria:

- the reduction of the ensemble spread on the whole North Sea domain [Mourre et al., 2006],
- the root mean square error between the model results obtained with data assimilation and the assimilated data [Wei and Malanotte-Rizzoli, 2010].

4.3. Baltic Sea

4.5.1. Experiment set-up

a) Physical model

In the Baltic Sea, DMI is running a two-way nested, free surface, hydrostatic three-dimensional (3D) circulation model called HIROBM-BOOS (HBM). The model code forms the basis of a common Baltic Sea model for providing GMES Marine Core Service since 2009. The finite difference method is adopted for its spatial discretization in which a staggered Arakawa C grid is applied on a horizontally spherical and vertically z-coordinate. The model has a horizontal resolution of about 6 nautical miles (nm) and 50 vertical layers. The top layer thickness is selected at 8 m in order to avoid tidal drying of the first layer in the English Strait. The rest of the layers in the upper 80 m have 2 m vertical resolution. In the Danish Strait, the horizontal resolution is increased to 1 nm to better resolve the complex bathymetry. A detailed description of the model can be found in Berg and Poulsen (2011).

The meteorological forcing is based on a reanalysis using the regional climate model HIRHAM through a dynamic downscaling (including a daily re-initialization) from ERA-Interim Global reanalysis. HIRHAM is a regional atmospheric climate model (RCM) based on a subset of the HIRLAM and ECHAM models, combining the dynamics of the former model with the physical parameterization schemes of the latter. The original HIRHAM model was a collaboration between DMI, the Royal Netherlands Meteorological Institute (KNMI) and MPI. A detailed description of HIRHAM Version 5 can be found in Christensen et al. (2006).

b) Observations

In the OSSE experiments, we are planning to examine the impact on the simulation systems of repeated XBT lines and moored buoys in the Baltic Sea. The repeated XBT lines are designed to follow the major saline water inflows from the Danish water to the central Baltic. The moored array is set up in 40x40 km grids in the Baltic Sea. The observing system is presented in Fig. 4.3.1.

c) Experiments

OSSE with twin experiment approach is widely used as proof-of-concept for data assimilation methods. It relies on the assumption that there exists one model configuration which provides a complete knowledge of the true state of the ocean..The OSSE experiments in the Baltic Sea are described as follows. The ‘true’ ocean state is generated by an unconstrained model run starting on January 1, 2009. We consider the model boundary and flux conditions as error-free. In addition to the ‘true’ ocean state, a false experiment is conducted by starting the model from a false initial condition (taken from another year). The temperature and salinity profiles will be assimilated in the false experiment with the 3DVAR to reconstruct the ‘true’ state. The experiments assimilating the T/S profiles from XBT and moored buoy use the same initial conditions.

Figure 4.3.1. The observing system comprising repeated XBT lines (blue lines) and moored buoy array (red square).

4.3.2. Ongoing development

The ‘true’ ocean state can be generated from the current HBM with a horizontal resolution of 10 km. It can also be taken from a new high resolution version of HBM. The choice of the true ocean state is being tested at present. In addition, the design of the frequently repeated XBT lines and moored array can be improved.

4.3.3. Problems and plans to solve them

The central Baltic Sea is strongly stratified with a mean thermocline at the depth of about 40-60 m. In the bottom layer, the residence time of deep waters is of the order of years until the major saline water inflows occur irregularly. The current model is inadequate to resolve the major saline water inflow from the Danish Strait to the central Baltic. It is of particular interest to investigate if the designed observing network can much improve the simulation.

4.4. North Sea - HGZ

4.4.1 Experimental set-up

a) Numerical Model data

For the OSSE experiments in JERICO the 3-D numerical model GETM (Burchard and Bolding, 2002) is used to simulate the hydrodynamic processes in the German Bight. GETM is a primitive equation model, in which the equations for the three velocity components, sea surface height, temperature, salinity, as well as the equations for turbulent kinetic energy and the eddy dissipation rate are solved. The model is run on a spherical grid with 1 km resolution. Terrain following equidistant coordinates (σ-coordinates) are used in the vertical. OSSE studies for the North Sea were conducted using a setup with 5 km horizontal resolution. The water column is discretised into 21 nonintersecting layers. The model is forced by 1) atmospheric fluxes estimated by the bulk aerodynamic formula using 6-hourly ECMWF re-analysis data (wind, atmospheric temperature, relative humidity and cloud cover) and by simulated model SST, 2) hourly river run-off data provided by the Bundesamt für Seeschifffahrt und Hydrographie (BSH), and time varying lateral boundary conditions of sea surface elevations and salinity.
In parallel data from the MYOCEAN North West Shelf model, as well as from the operational BSH model were used for the OSSE studies.

b) FerryBox Data

A FerryBox is an autonomous measurement, data logging and transmission system, which operates continuously while the carrying ship is on its way (Petersen et al., 2007). Measurements are made using devices, which are either in direct contact with or sample from a continuous flow of seawater taken from a water depth of 4-6 m. The vessel position is tracked by Global Positioning System (GPS). It is connected to a station on shore via Global System for Mobile Communications (GSM) or satellite for remote control and data transfer. The basic sensors used in this study measure turbidity, temperature, salinity, and chlorophyll a fluorescence.
The North Sea routes so far equipped with FerryBox systems are the ones between Buesum and Helgoland, Cuxhaven and Harwich, Cuxhaven and Immingham (see Figure 4.4.1) and recently between Hamburg, Cuxhaven, Chatham, Moss and Halden. The typical cruising speed is 15 knts. The sampling rate is 10 seconds. Depending on the travel distance, the routes provide the following revisit times: Buesum-Helgoland, daily, Cuxhaven-Immingham, less than 36h, Hamburg-Cuxhaven-Chatham-Moss-Halden about 8 days. The Ferry routes do not change substantially. However, individual tracks show small deviations one from another. Therefore, to simplify the analysis we relate the data to an averaged track. The maximum deviations from the averaged track can reach 10km.

c) Analysis procedure

OSSE experiments were performed using the approaches described in Grayek et al. (2011) and Schulz-Stellenfleth and Stanev (2010). The first approach is a modified optimal interpolation technique with daily model restarts. The second technique uses a statistical method to estimate error bars for state estimates based on model and observation errors.

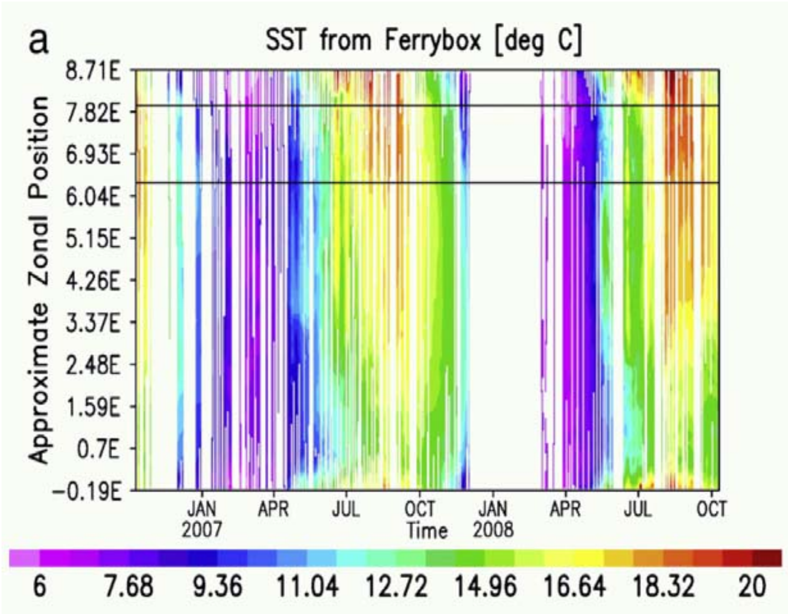

Figure 4.4.1: Example of SST data acquired by the FerryBox system operating between Cuxhaven and Immingham.

4.4.2. Discussion of some results

As an example Fig. 4.4.2 shows the relative errors to be expected from combined use of FerryBox and numerical model SST data. The errors are normalised, i.e. given in percent with respect to the background variance. The situation with one FerryBox line (left) is compared to a configuration with one additional line further North. One can see that the additional line has a significant impact on the SST errors.

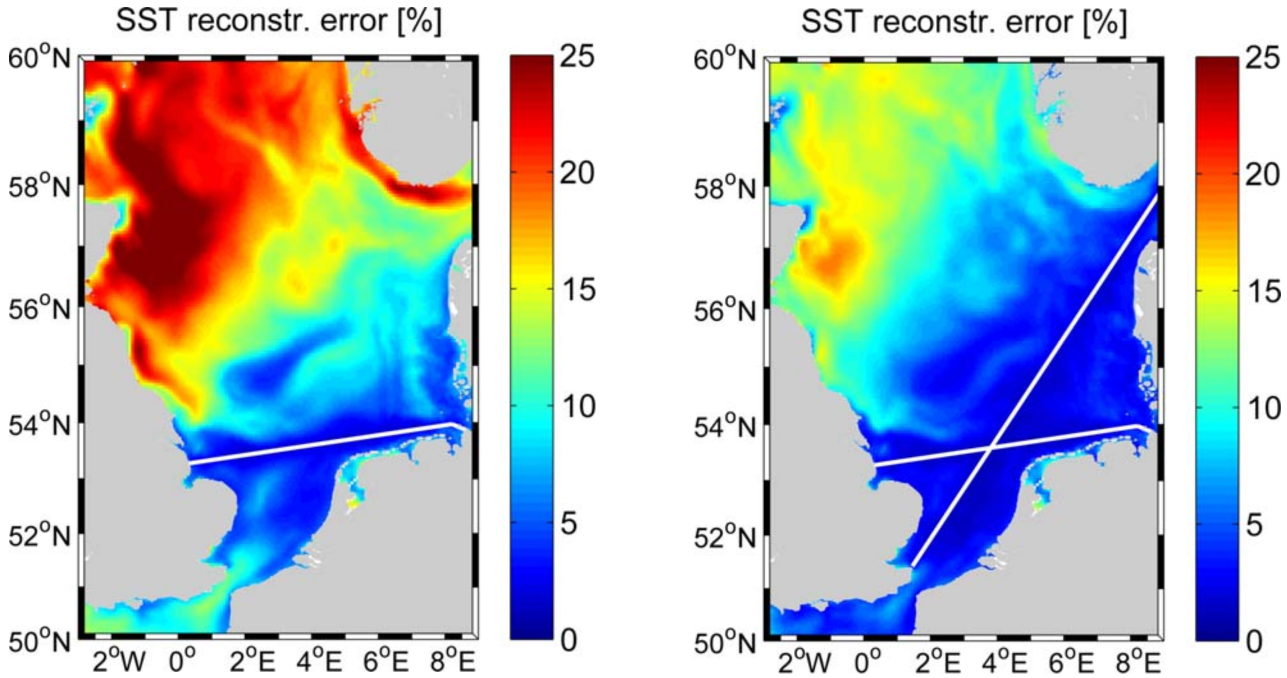

Figure 4.4.2: Relative re-construction errors for sea surface temperature using one (left) and two (right) FerryBox lines.

4.4.3. Ongoing developments and problems

There are no significant problems with the OSSE experiments. One important issue is the additional use of satellite based SST maps (e.g. OSTIA data) in the analysis. The quantification of the benefit of FerryBox SST data inrelation to these data needs some further careful analysis. The situation is different for FerryBox surface salinity observations for which no space-borne counterpart for the coast yet exists, i.e. there are not many alternatives to the FerryBox. The analysis of SSS data is more challenging than the use of SST observations, because the correlation length are in general shorter, i.e., it is more difficult to spread the information provided by the observations.

4.5 Bay of Biscay and Irish Sea

4.5.1. Experiment set-up

Experiments are based on the MARS3D model. MARS3D (http://wwz.ifremer.fr/mars3d) is a coastal model based on primitive equations (Lazure and Dumas, 2007; Duhaut et al., 2008). The model was designed to simulate flows in various coastal areas from the regional scale down to the inshore scale of small bays or estuaries where circulation is generally driven by a mix of processes. The spatial grid resolution is 4Km and sigma vertical coordinates (30 levels) are used.

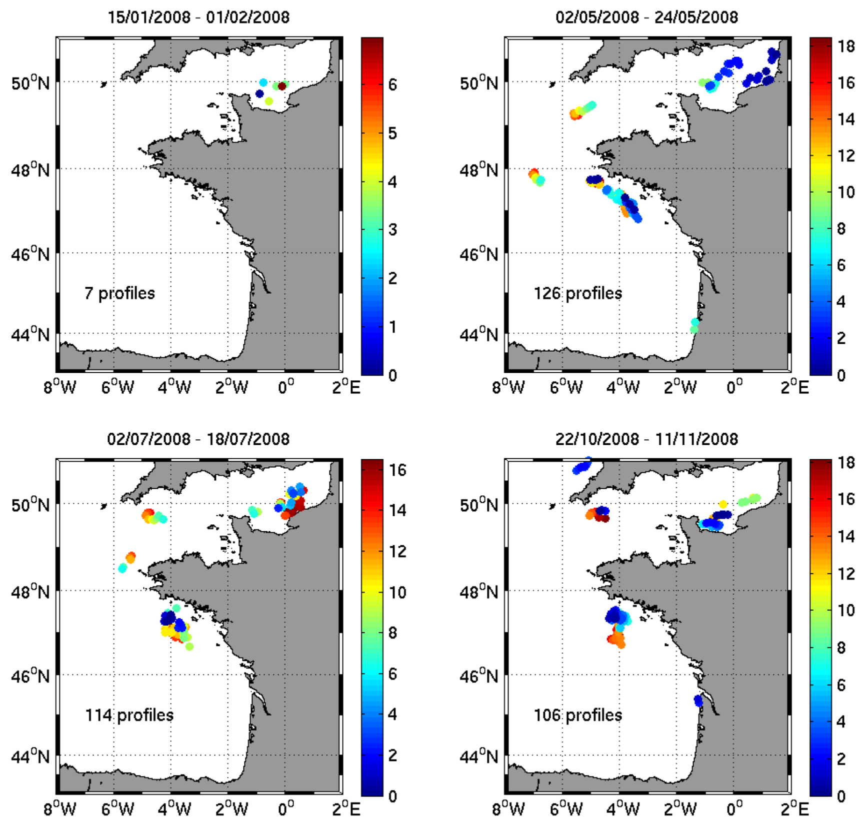

Figure 4.9.1: Position of RECOPESCA vertical profiles observed in 2008 during the four studied periods. Color scales are in days from the beginning of the considered period.

Based on this model, ensemble experiments have been performed using the Representer Matrix Spectra (RMS) method (Le Hénaff et al., 2009) to optimize a network design without running a fully assimilated system.

Experiments have been driven based on two observation networks:

- the RECOPESCA network, based on voluntary vessels (Figure 1)
- a local network to monitor the Loire river plume, based on glider and fixed mooring (Figure 2)

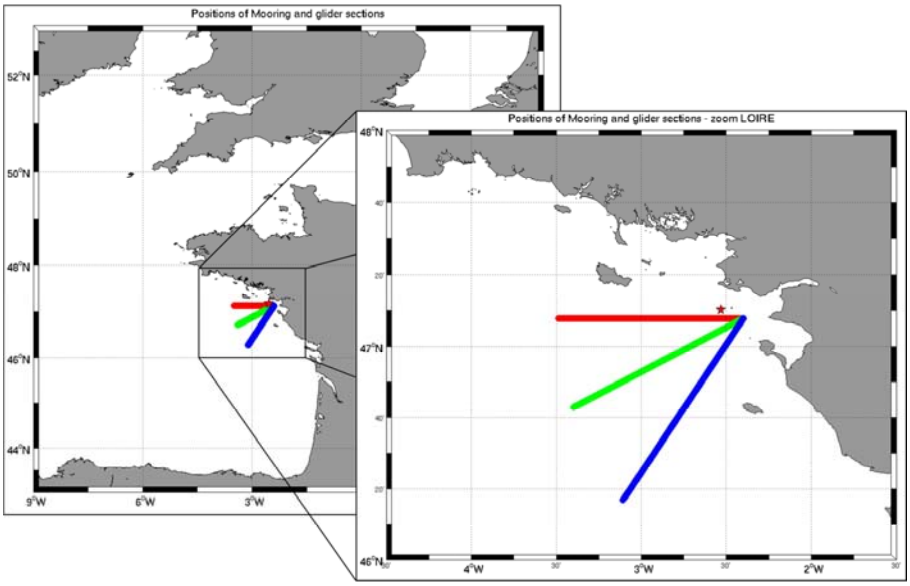

Figure 4.5.2: Design of the observation network to monitor the Loire river plume including a fixed mooring (red star) and a glider section (3 possible trajectories: East-west reference section – red, first option – green, second option – blue).

4.5.2. Ongoing development

Following the areas where the model errors are larger, another experiment will be implemented in the western Channel combining Ferryboxes, a glider section and a moored buoy. This last experiment will supplement the global study aiming to design the most efficient coastal observation network in the Bay of Biscay and the Channel.

4.5.3. Discussion on some results

The use of the RMS method allows exploring the model error subspace and highlighting major group of profiles to constrain these uncertainty cells.

For the first experiment based on the RECOPECA network, we showed that the reference network (based on 2008 profile distribution) is efficient most of the year (during spring, summer and autumn) except in winter where observations are missing. In the present case, the RMS method highlighted strengths and weaknesses of the RECOPESCA network. Indeed, the experiment confirmed the importance of measurements in the southern part of the domain, along the Landes coast or in the western part of the Channel.

In the second experiment, focusing on the Loire river plume area, the RMS method was implemented to estimate the ability of the observation to constrain model errors in this region trying three different glider sections. First results, under investigation, showed that for a glider flying cross-shore, results and mainly degrees of freedom “seen” by the network are not sensitive to the trajectory direction.

5. Conclusions

The report describes the state of OSSE experiments in the WP9. Most of experiments are in the preparation phase. However, the OSSE experiments in the Bay of Biscay and in the North Sea show quite interesting preliminary results. We may expect that in the next phase of the project most of the other systems will produce the first findings.

References

Berg, P., and J. W. Poulsen (2011), Implementation details for HBM, DMI Technical Report, (12-11).

Burchard, H. and Bolding (2002), K., GETM - a General Estuarine Transport Model, European Commission, No EUR 20253 EN, printed in Italy.

Christensen, O. B., M. Drews, J. H. Christensen, K. Dethloff, K. Ketelsen, I. Hebestadt, and A. Rinke (2006), The HIRHAM regional climate model version 5 (β), Techical Report, 6–17.

Duhaut, T., Honnorat, M., and L. Debreu, (2008) Développements numériques pour le modèle MARS. Report INRIA Rhône-Alpes Laboratoire, 198pp.

Evensen, G.: Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics, Journal of Geophysical Research, 99, 10,143-10,162, 1994.

Grayek, S. and Staneva, J. and Schulz-Stellenfleth, J. and Petersen, W. and Stanev, E.V. (2011), Use of FerryBox surface temperature and salinity measurements to improve model based state estimates for the German Bight, J. Marine Syst., doi:10.1016/j.jmarsys.2011.02.020, No. 88, pp. 45-59.

Gurgel, K.-W. and Antonischki, G. and Essen, H.-H. and Schlick, T. (1999), Wellen Radar (WERA): a new ground wave HF radar for ocean remote sensing, Coastal Engineering, 37, pp. 219134.

Lazure, P, and Dumas F (2008). An external-internal mode coupling for a 3D hydrodynamical model for applications at regional scale (MARS). Advances In Water Resources, 31(2), 233-250. http://dx.doi.org/10.1016/j.advwatres.2007.06.010

Le Hénaff M., De Mey P., Marsaleix P., (2009) Assessment of observational networks with the Representer Matrix Spectra method-application to a 3D coastal model of the Bay of Biscay. Ocean Dynamics, 59, 3-20 http://dx.doi.org/10.1007/s10236-008-0144-7

Luyten, P.: COHERENS – A coupled Hydrodynamical-Ecological Model for Regional and Shelf Seas: User Documentation. Version 2.1.2 RBINS-MUMM Report, Royal Belgian Institute for Natural Sciences, 2011.

Mourre, B., P. De Mey, Y. Ménard, F. Lyard and C. Le Provost: Relative performance of future altimeter systems and tide gauges in constraining a model of North Sea high-frequency barotropic dynamics, Ocean Dynamics, 2006 – DOI 10.1007/s10236-006-0081-2

Papadopoulos, A., G. Kallos, P. Katsafados, S. Nickovic, 2002. The Poseidon weather forecasting system: an overview. Glob. Atmos. Ocean Sys., 8, 218-237.

Schulz-Stellenfleth, J. and Stanev (2010), E.V., Statistical assessment of ocean observing networks - A study of water level measurements in the German Bight, Ocean Modelling, 33, 10.1016/j.ocemod.2010.03.001, pp. 270-282.

She, J., B. Armstrup, K. Borenas, E. Buch, L. Funkquist, P. Luyten and R. Proctor: ODON: Optimal Design of Observational Networks, Scientific report, 2006.

Staneva, J. and Stanev, E. and Wolff, J.-O. and Badewien, T. H. and Reuter, R. and Flemming, B. and Bartholomae, A. and Bolding, K. (2009), Hydrodynamics and sediment dynamics in the German Bight. A focus on observations and numerical modeling in the East Frisian Wadden Sea, Cont. Shelf Res., No 29, pp 302-319

Wei, J. and P. Malanotte-Rizzoli: Validation and application of an ensemble Kalman filter in the Selat Pauh of Singapore, Ocean Dynamics, 60, 395-401, 2010 – DOI 10.1007/sl0236-009-0253-y