Joint European Research Infrastructure network for Coastal Observatories

D9.2 : WP9 first report on OSE

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1. Document description

REFERENCES

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2. Executive Summary

The Observational System Experiments (OSEs) in the WP9 are already in a full development. Most of the experiments have already produced the first results. They are now studied for estimating the impact of coastal observations. The experiments cover most of the European Seas and a large spectrum of methodologies for estimating the impact of existing observations.

3. Introduction

The main objective of this report is to evaluate the state of the OSE experiments in the WP9 in order to coordinate the future development of the experiments and the writing of the scientific report. The experiments are applied in most European coastal areas. They use different numerical methods, but the common feature is that the observations are assimilated in data assimilation systems with numerical models.

4. Main Report

4.1. Adriatic Sea

4.1.1 Experiment set-up

In the OSE experiment a twin experiment is made in order to estimate the impact of existing coastal observations in the Adriatic. The experiment is prepared for the period 2006-2008. The observations are available from various international projects in the Adriatic Sea. The major areas with observations are the coast of Emilia-Romagna performed by the Regional Agency for Environmental Protection (ARPA), along the coast of Montenegro in the Southern Adriatic, along the coast of Dalmazia in the Middle Adriatic and along the coast of Istria in the Northern Adriatic. Fig. 4.1.1 shows the distribution of coastal observations performed in the 2006. The aim of OSE experiments is to estimate how the information from those observations impact both locally and remotely the state estimates of the Adriatic Sea. In particular it will be interesting to assess the longer term impact after several months of the assimilation.

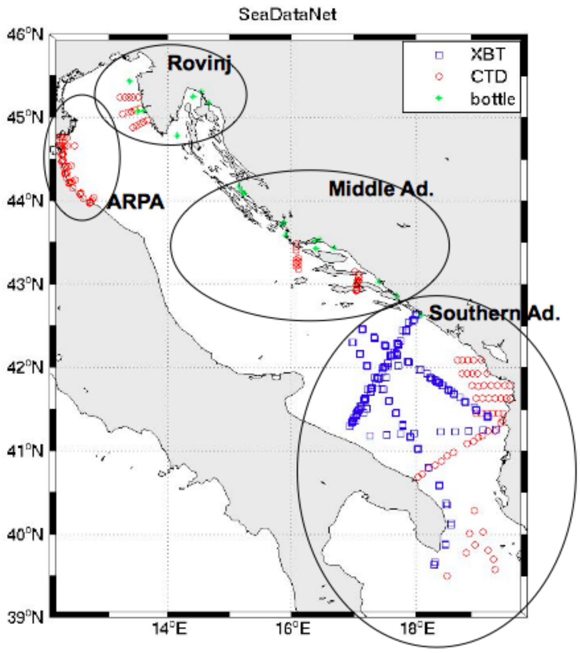

Figure 4.1.1: Positions of coastal observing networks in the Adriatic in the 2006.

Another experiment will test the impact of these observations on the basin scale data assimilation system in the Mediterranean. This system has a three times coarser horizontal and vertical resolutions than the Adriatic system. It is therefore much less suitable for the assimilation of coastal observation. It is, however used operationally and any benefit from coastal observations can be important.

4.1.2 Ongoing developments

In the first couple of twin experiments selected costal observations are either assimilated or they are not assimilated in the data assimilation system. The experiment started on 01 March and ended on 31 December 2006. In this period there was a large number of observations in the Northern Adriatic. Only the coastal observational platforms named Middle Adriatic, Rovinj and ARPA in Figure 4.1.1 were assimilated.

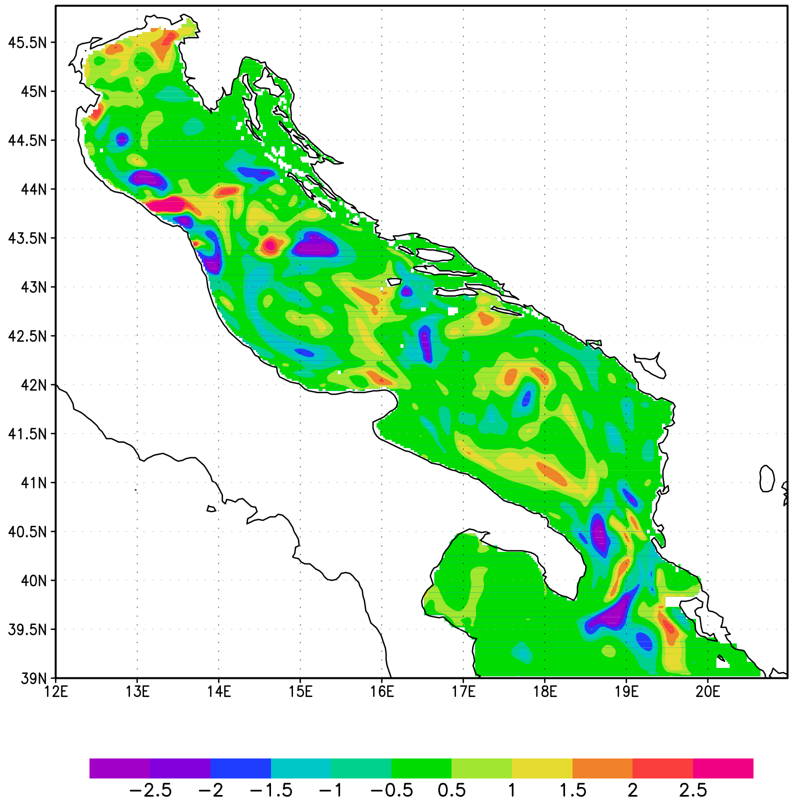

Figure 4.1.2: Difference between temperatures at 10m depth (0C) estimated by the two experiments on 01 August 2006.

It can be seen in Fig. 4.1.2 that 6 months after the beginning of the assimilation the differences in the temperature fields are not only located nearby or spread downstream close to the observations in the North Adriatic, but they cover the whole Adriatic Sea. A more detailed investigation of the reason for this spread of the differences is ongoing.

4.2. North Sea - Deltares

4.2.1. Experiment set-up

In this study, we are working on a storm surge forecasting and data assimilation system based on the new Dutch Continental Shelf Model (DCSMv6; Zijl et al. 2008). Selection of the observing stations used for the first Kalman filter setup for the DCSMv6 have been made by making use of (1) information about whether an observing station will stay operational for a longer term, (2) insight on physical processes underlying the system modeled by the DCSMv6, and (3) estimates of observation impact on the forecast accuracy improvement of the DCSMv6.

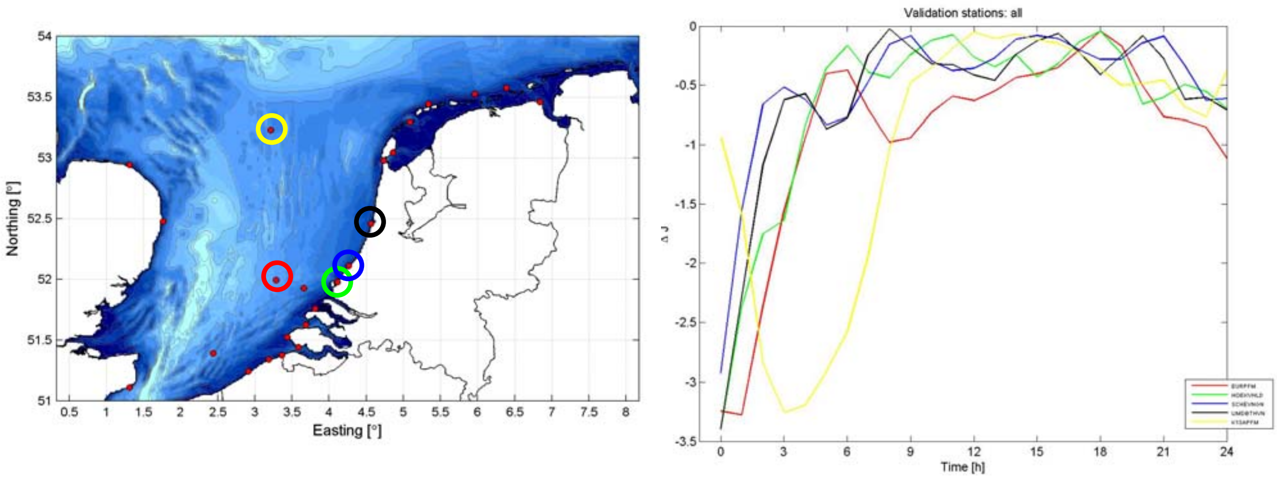

Figure 4.2.1. Selected observing stations nearby the Dutch coasts (red dots; left panel) and averaged impact of five stations (right panel; color of each line corresponds to the color of the circle surrounding each station on the left panel).

Here, we use a forecast sensitivity to observations technique to estimate the impact of data assimilation on forecasts accuracy that is originally proposed by Langland and Baker (2004). This technique is expected to give similar information about observations impact as one would get by performing observing system experiments (OSEs), without having to perform data withdrawal experiments. In particular, we used an observation impact analysis technique developed by Sumihar and Verlaan (2010). This technique uses time series of sea level observations and the corresponding model output generated without data assimilation. Therefore, it is applicable without actually implementing a Kalman filter. The method estimates the time-averaged impact of data assimilation on forecast accuracy, where the measure of forecast accuracy is defined as a quadratic cost function of observation-minus-model residuals. Here the cost function is defined over ten stations located along the Dutch coasts.

The analysis was performed using data in the whole year of 2007. The technique is used to estimate accuracy improvement of hourly forecasts up to the next 24 hours from assimilation time. In doing the analysis, we grouped the observing stations according to their relative locations. One reason for doing this is that some observing stations have a lot of missing data in the analysis period, which would reduce the effective sample size considerably if analysis was done on all stations at once. Secondly, impact of further away locations is likely to be independent from each other. Therefore, we would expect that by grouping nearby stations this analysis will not hide possible interactions between stations. Note that by grouping the stations and performing observation impact analysis for each set of stations is similar to performing OSEs, but with much smaller computational costs. In fact, in our case it is practically not possible to carry out analyses and forecasts by actually implementing a Kalman filter for each set of the observing stations with the DCSMv6.

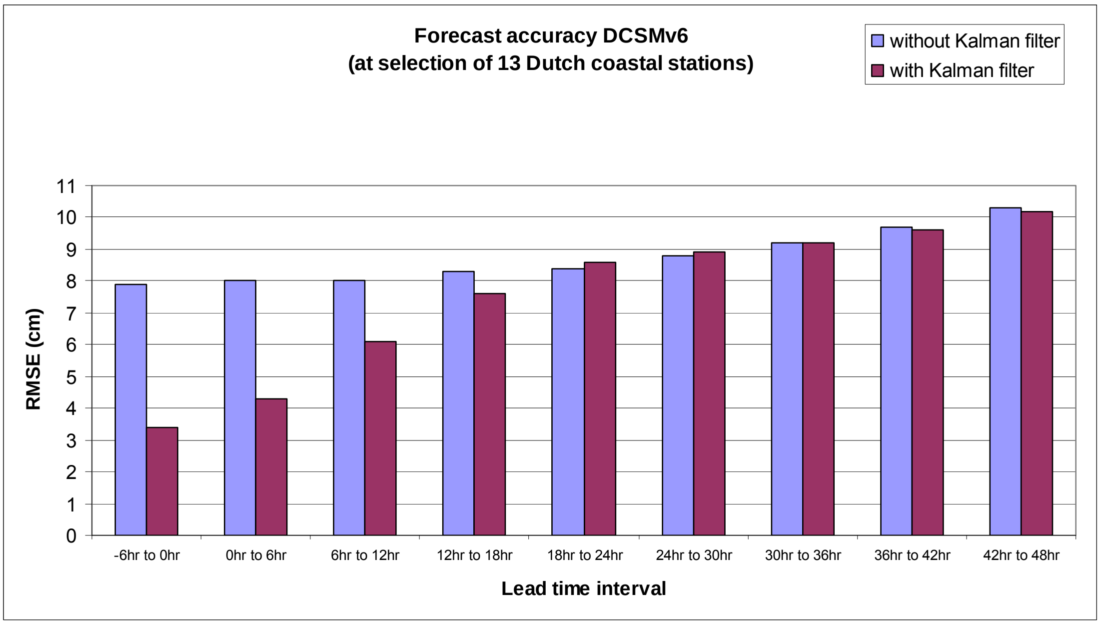

Figure 4.2.2. Performance of DCSMv6 without and with Kalman filter, in term of root mean square of water level residuals averaged over 13 stations along the Dutch coasts.

4.2.2. Ongoing development

Ongoing study includes inclusion of more stations located in the northern area of the DCSMv6. This will include stations located on the northern of Scotland as well as stations on the Irish Sea. Assimilating data from these stations is expected to improve the accuracy at longer forecasts horizons.

At the moment, we are extending the study with the new domain decomposition model DCSMv6-ZUNOv4. The ZUNO model covers only the North Sea area, but with a finer grid size. It uses the output of DCSMv6 for specifying the open boundary conditions. Coupling the two models is expected to give more accurate forecasts than DCSMv6 alone.

4.2.3. Discussion on some results

We have selected 32 observing stations to use for data assimilation with the DCSMv6. Most of these stations are located along or nearby the Dutch coasts that are expected to give impact on short term forecasts (Figure 4.2.1). Some stations are located along the British coasts and expected to give impact on longer term forecast (Figure 4.2.1). One station is located at North Cormorant and expected to give impact on specific events where storm surge enters the North Sea through this location. For the same reason two stations along the English Channel are selected.

We have developed a steady state Kalman filter with this set of stations. The Kalman filter is executed every six hours to assimilate all observations from the last analysis cycle. We have tested its performance on the whole period of 2007. The evaluation shows that data assimilation improves the forecast accuracy of the DCSMv6 up to forecast lead time of 18 hours. The improvement decreases gradually in forecast lead time and the performance converges eventually to that of DCSMv6 without data assimilation (Figure 4.2.2). Note that this system is now running pre-operationally.

4.2.4. Eventual problems with experiments and plans to solve them

Some stations are indicated to give negative impact when analyzed together with certain stations. This requires further investigation. Nevertheless, it should be noted that the observation impact analysis indicated positive overall impact within the forecast horizons, where the impact of such stations is expected to take place.

We are going also to validate the results of observation impact analysis to the actual OSEs. Here, a smaller model will be used to reduce the computational costs.

4.3. North Sea – MUMM

4.3.1. Experiment setup

The North Sea domain under consideration is located between 4°W to 10°E in longitude and 48.5°N to 60°N in latitude. Simulations are carried out for September 2001.

Eight stations were selected amongst the existing network of stations in the North Sea. Their impact on the model forecasts is compared to that of an optimally designed network of eight stations and two variants of the existing network. To this aim, data from model simulations performed with a higher horizontal resolution are assimilated. Four observational networks are considered:

- the existing network,
- the existing network + 1 station,
- the existing network in which 3 stations are moved,
- the optimally designed network.

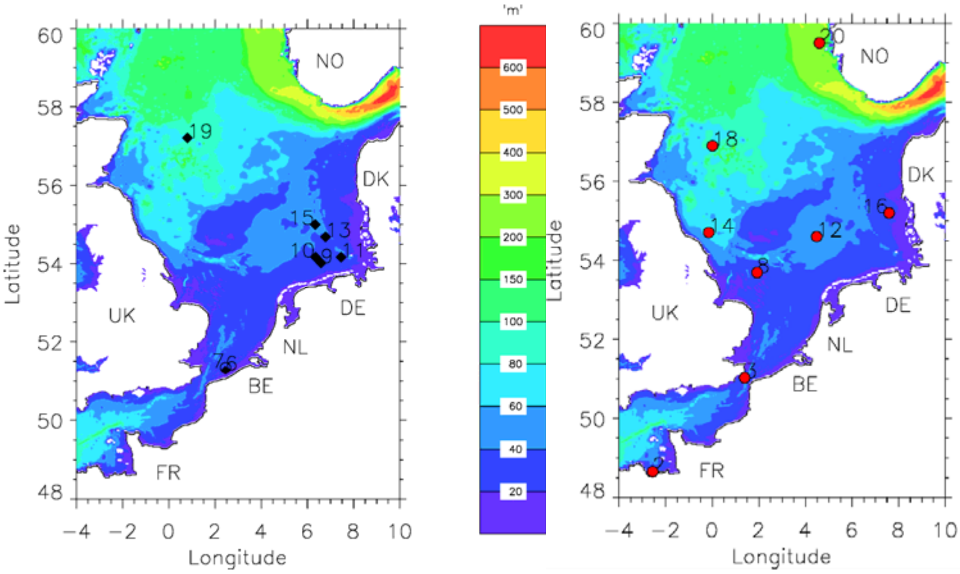

Figure 4.3.1. The figure illustrates the locations of the 8 stations for the existing network (left) and for the optimally designed network (right).

The impact of the assimilation of data from these networks on model forecasts will be assessed in terms of two 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].

Model

The simulations are 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 is 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 are assimilated, they are derived using the above mentioned model setup with a horizontal resolution of one nautical mile. They show significant differences in comparison to the temperature derived from model simulations with a four nautical miles resolution [She et al., 2006]:

- eddy structures with scales of a few kilometres, visible along the thermal fronts in the one nautical mile resolution simulations, are not resolved by the coarser grid,
- large vertical displacements of the thermocline: this feature of the North Sea dynamics is induced by winds and tides, the amplitudes are much larger in the high resolution run.

They are assimilated with the ensemble Kalman filter, [Evensen, 1994]. A low rank square root algorithm allowing an ensemble representation of the observations' error is applied at the analysis step.

4.3.2. Ongoing developments

The simulations for the four networks have been performed. The assessment of their impact in terms of the above mentioned criteria is ongoing.

4.3.3. Discussion of some results

For the existing network, the assimilation process reduces strongly the root mean square errors between the modelled temperature and the assimilated data. At the surface, for the non assimilative runs, the standard deviation of the ensemble is of about 0.6°C. At the locations where the assimilation takes place, it is reduced to about 0.3°C in an area corresponding to the influence zone of the assimilation (assimilation radius).

4.4. Aegean Sea

4.4.1. Experiment set-up: Model, observations, time of integration, differences between experiments

The system under consideration in this report includes an observing platform (HF Radar) that provides observational data (surface currents between the island of Lemnos and the Dardanelles exit) on a regular basis, the Aegean Sea hydrodynamic model and a filter algorithm that produces an analysis of the model fields by synthesizing the background information the observations and the evolving error statistics.

a) The hydrodynamic model

The Aegean Sea model is based on the Princeton Ocean model (POM) and was developed as part of the Poseidon system. The model domain covers the geographical area 19.5oE – 30oE and 30.4oN – 41oN with a horizontal resolution of 1/30o and 25 sigma layers along the vertical with a logarithmic distribution near the surface and the bottom. The model is forced with hourly surface fluxes of momentum, heat and water provided by the Poseidon - ETA high resolution (1/10o) regional atmospheric model [1] issuing forecasts for 72 hours ahead.

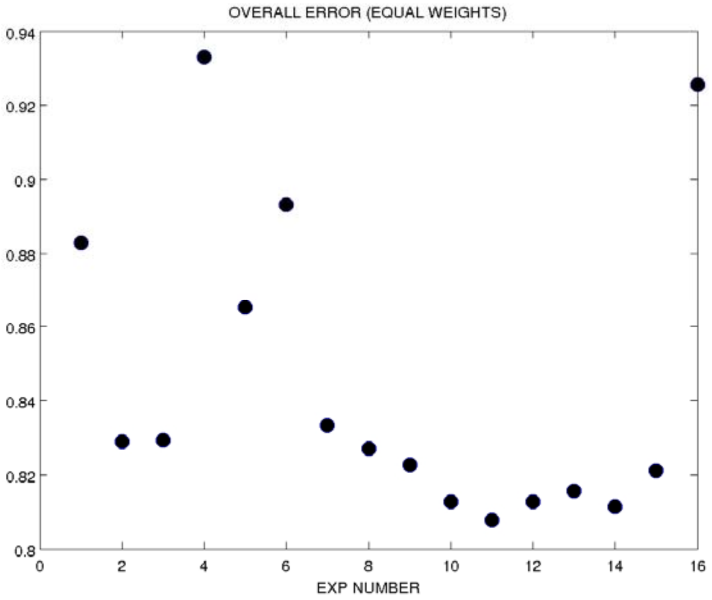

Figure 4.4.1: Combined model error (with respect to SSH, SST and HF Radar current measurements) for a series of 16 experiments performed over year 2010. Error minimization is achieved of EXP11.

b) Dardanelles inflow/outflow characteristics and sensitivity runs

In the Aegean Sea model the Dardanelles inflow/outflow is parameterized as an open boundary where a two layer system is explicitly prescribed with inflow of fresh Black Sea Water (BSW) in the upper layer and outflow of saline Aegean waters below.

The inflow/outflow transports follow a seasonal cycle with maximum values of inflow to the Aegean during mid-June (0.01 Sv) and minimum during mid-November (0.005 Sv). The salinity of the upper layer is set to 28.3 psu with a seasonal variation of 2 psu while the interface depth is kept fixed to 25m. The inflow/outflow transport values at the Dardanelles exit and the time of the occurrence of their maximum/minimum values that have been used in the model experiments described in this work differ from the standard version of the Aegean Sea model. In order to choose the optimal values of the above parameters, a series of sensitivity hindcasting experiments have been performed where the criterion of the minimization of the model error with respect to different sets of observations over the North Aegean Sea area has been used. In Figure 4.4.1 we present the combined model error with respect to the three sets of observations (gridded satellite SSH & SST and HF Radar surface current measurements) over the North Aegean Sea for year 2010 and the series of 16 experiments. Error minimization is achieved for S-EXP11 where maximum inflow of 0.01 Sv to the Aegean is assumed at the end of May.

c) The assimilation system

The assimilation scheme used by the Aegean Sea forecasting system, is based on the Singular Evolutive Extended Kalman (SEEK) filter which is an error subspace extended Kalman filter that operates with low-rank error covariance matrices as a way to reduce the prohibitive computational burden of the extended Kalman filter (Pham et al., 1997). The filter is additionally implemented with covariance localization and partial evolution of the correction directions.

d) The observations

The standard assimilation system for the Aegean Sea model inserts on a weekly basis AVISO gridded (1/8o) absolute dynamic topography (ADT) observations for the Aegean Sea area, gridded (1/16o) AVHRR SST data, T/S ARGO profiles and temperature profiles from any available XBTs over the area, using the time evolving filter statistics and the model forecasts in order to estimate the innovations. The AVISO gridded maps of absolute dynamic topography are produced by merging all available satellites into one regional product available at near real time for the Mediterranean Sea. Additionally daily averaged surface currents over year 2010 from the WERA HF radar system installed at the eastern coast of the island of Lemnos are used in order to examine their effect to the estimation of the hydrodynamic state of the Aegean Sea. The method of processing High Frequency (HF) radar measurements from the WERA radar site in Lemnos Island, Greece, is the Open-boundary Modal Analysis, or OMA. We applied this technique to half-hourly total current data for the entire 2010 and then the data were daily-averaged. The OMA method follows the procedure described in [2].

The general idea of OMA is to generate a set of modes for a given domain which can be used to approximate any current field on that domain. These modes are generated by solving two Laplacian eigenvalue problems on the domain with Dirichlet and Neumann boundary conditions and adding a set of boundary modes to account for flow across open boundaries. Any current field in the domain can be described using a combination of these modes. The modal series approximation is determined by minimizing a cost function to find the ideal combination of the modes, which gives the best fit to available measurement data. These modes depend only on the shape of the domain. Once they are calculated, they can be stored for repeated use on the same domain.

Regularization is achieved by an appropriate spectrum cutoff and by penalizing the magnitudes of the remaining low wave-number spectral components. In OMA, the domains of interest need not to be rectangular. Furthermore, the boundary of the domain can be composed of multiple open and closed segments, a feature that is very useful in our case since the domain of interest includes multiple islands. An open segment is one along which the normal component of the velocity can be nonzero. Vector currents are allowed to flow into or out of an open segment. A closed segment is one in which the normal component of the velocity is fixed at zero and no current is allowed to flow through the segment, although currents can flow parallel to a closed segment. The OMA method offers several advantages. The generation of the OMA modes is only done once. Afterwards, when fitting the currents to the OMA modes, one least-squares matrix equation needs to be solved. The modes are defined over the entire domain, even for sparse current measurements. The fit results in a current field which is also defined over the entire domain without gaps. This is a nice feature of the OMA method, but should be utilized with caution. Currents will be reported even in areas with few or no actual measurements. Currents in these areas are an extrapolation of the modal fit to data in other areas and they do not represent the real currents. Attention should be paid to how much real data goes into making the fit, especially when the horizontal size of a data gap is larger than the minimal length scale resolved [3].

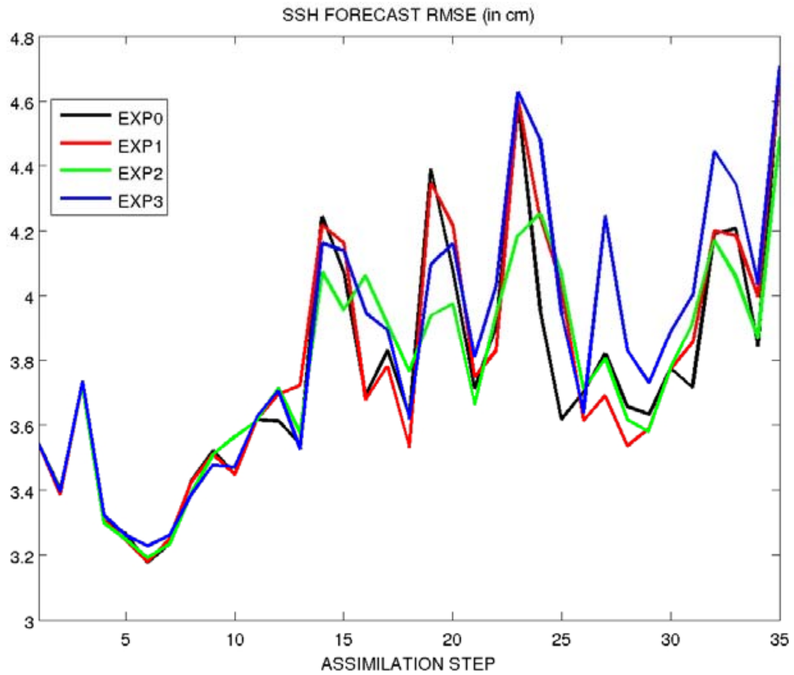

Figure 4.4.2: SSH forecast RMS error (in cm) calculated on a weekly basis (i.e. at each assimilation time step) for the four experiments.

We implemented the OMA algorithm using the code for Matlab from http://www.ucsc.edu/~dmk/software/openMA. The code has two tunable parameters: the modal cutoff length scale L and the regularization weighting constant k. In our case a modal cutoff length scale of 5km was chosen (L=5km) and a value of XX (missing value) was used for the regularization coefficient (k= XX (missing value)).

4.4.2. Ongoing development - Discussion on some results

As this study primarily focuses on the effect of the assimilation of surface currents data in the area in front of Dardanelles Straits on the model state we hierarchically started with a set of sensitivity experiments (briefly discussed in 1.2) which have been performed over year 2010 in order to choose the best values for inflow/outflow at the Dardanalles Straits. The data assimilation study is focused on the period May – December 2010 and uses the model characteristics corresponding to S-EXP11 of the previous set of sensitivity experiments. In order to assess the impact of the surface current measurements from the HF Radar system, we have performed four sets of experiments as shown in Table 2. EXP0 refers to the standard integration of the Aegean Sea model over the period May – December 2010. In this setup the model assimilates on a weekly basis gridded satellite data of SSH & SST and all available ARGO T/S profiles. Standard model performance is discussed in [4]. In EXP1, the model additionally to the standard set of observations of EXP0 assimilates every week the daily averaged zonal and meridional surface velocity components measured by the HF Radar System. EXP2 considers only the zonal component of the surface currents while EXP3 assimilates only the meridional component.

The performance of the assimilation system is assessed by the standard statistic of the RMS error with respect to SSH, SST and the daily averaged surface velocity fields (in the area between the Lemnos island and Dardanelles). On a weekly basis as we consider the model RMS error with respect to observations just before their insertion into the system (forecast RMS error) these observations can be considered as quasi-independent. This is done for the sea surface height. For the surface velocity data the RMS error is calculated on a daily basis and for those dates coinciding with assimilation days the error is calculated before their insertion into the model. Thus the surface velocity can be considered as an independent set for model validation.

In Fig. 4.4.2 we examine the effect of the assimilation of surface velocity components to the forecast RMS error of the sea surface height over the whole model domain. It is very encouraging that EXP2 (additional assimilation of the HF Radar zonal surface component) implies noticeable changes to the SSH RMS error behavior with respect to the control run (EXP0). This error reduction can be explained on the fact that the correction of the Dardanelles outflow introduced by the assimilation of the HF Radar surface currents data into the model induces changes to the surface circulation field in the North Aegean and secondarily to the rest of the Aegean Sea. These changes are then depicted into the SSH field leading to a decrease of 1 – 1.5 cm for certain periods. For the other two experiments, EXP1 shows some marginal improvement with respect to EXP0 while EXP3 (assimilation of the meridional component) deteriorates the behaviour of the SSH error from assimilation step 27 onwards.

4.5. 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

The observations used in the OSE experiments consist of the ICES temperature and salinity profiles from the International Council for the Exploration of the Sea (ICES) and the satellite SST. The two datasets cover a major part of in situ and satellite data in the Baltic Sea. The ICES community now encompasses all coastal states bordering the North Atlantic and the Baltic Sea. The ICES Data Centre accepts a wide variety of marine data and meta-data types into its databases from its members. The SST data is from the DMI database which provides multi-satellite and quality-controlled SST reanalysis data with the resolution of 2 km.

c) Experiments

A few OSE experiments will be carried out with the HBM in the Baltic Sea to explore the relative merits of different observing systems. The integration will cover the whole year of 2009. The temperature and salinity profiles will be assimilated with 3DVAR, referred to as Exp01. The satellite SST will be assimilated with the 3DVAR (Exp02), the other conditions are the same as Exp01. Both SST and profiles are assimilated with the 3DVAR in the experiment (Exp03).

4.5.2. Ongoing development

We are now testing the SST assimilation with the 3DVAR in the Danish water.

4.5.3. Discussion on some results

From some preliminary results, we find that the root-mean square error (RMSE) of SST is notably reduced after the satellite data is assimilated. Fig. 4.5.1 presents the evolution of the RMSE of SST from January 2 to February 5, 2009. The RMSE is generally reduced by 0.2ºC in the Danish waters. In addition, some eddies are more pronounced after the assimilation (figure not shown).

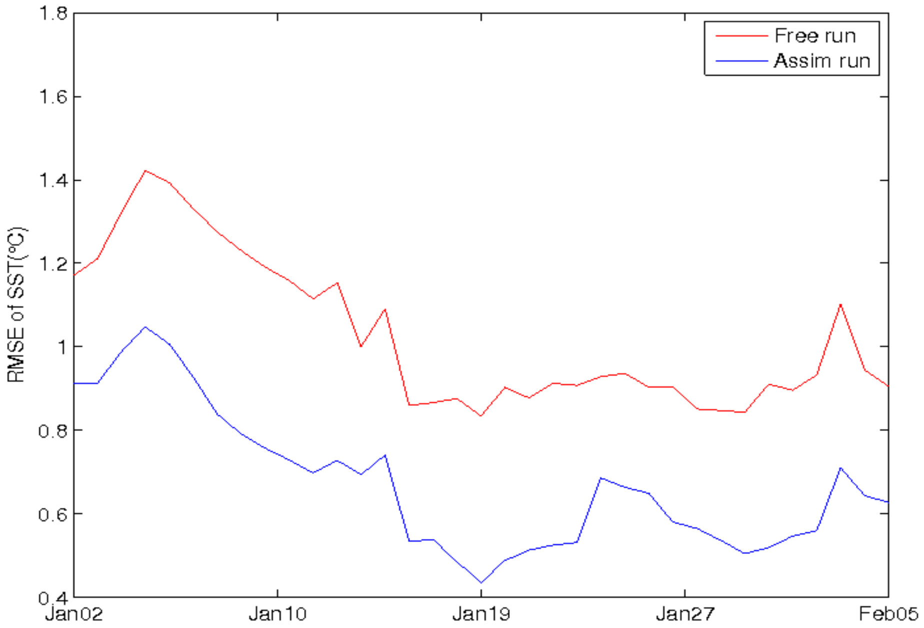

Figure 4.5.1. The Root mean square errors calculated against the satellite SST for the North-Baltic sea.

4.5.4. Problems and plans to solve them

Due to complicated bathymetry, the assimilation is confronted with more challenges in the Danish Water than the open seas. While the assimilation could reduce the root-mean-square error of the SST and subsurface temperature and salinity. There are two problems needed to be properly addressed: first, to avoid strong 'shocks' to the model state, magnitude of the innovation (model-obs) must be limited at the beginning of assimilation; second, spatial smoothing is needed for SST to filter out very small-scale eddies. The problem is caused by the inconsistency of resolutions of model and satellite. The satellite observations with a resolution of 2 km contains some eddies that can not be reproduced by the model. The first problem will be solved by applying some empirical criteria to the innovation based on the past validation results. As of the second problem, the satellite data will be smoothed before being assimilated into the model.

4.6. North Sea - HGZ

4.7.1 Setup of OSE Experiments

a) Numerical Model

The German Bight, which is dominated by tides with a typical tidal range of 2-3 m and a dominant period of 12.4 hrs, is part of the North Sea. The largest non-tidal variations are caused by atmospheric low pressure systems, either as external surges from the North Atlantic or internally generated surges. During strong storm events water levels can exceed 4 m above mean sea level. The German Bight is furthermore characterised by very shallow water with Wadden Sea areas falling dry during low tide.

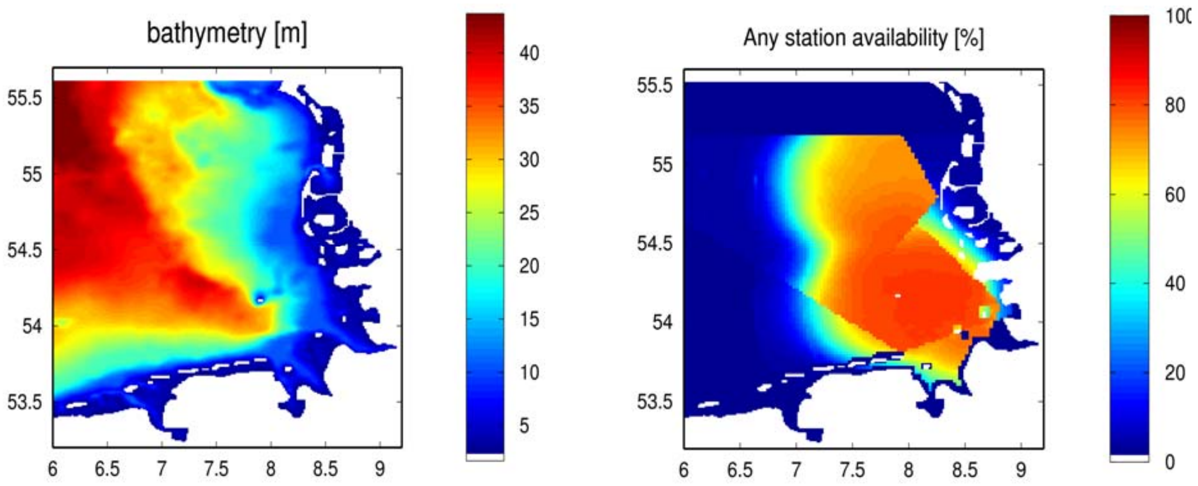

Figure 4.7.1: (left) Bathymetry of the German Bight used in the numerical model runs. (right) Availability of at least one radial component from one of the three existing HF radar stations located at Wangerooge, Buesum, and Sylt.

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 and sea surface height, as well as the equations for turbulent kinetic energy and the eddy dissipation rate are solved. The bathymetry of the 203 km by 258 km model domain is shown in Fig. 4.7.1. The application of the model to the area of our study is described in Staneva et al. (2009). The model is run on a spherical grid with 1 km resolution. Terrain following equidistant coordinates (σ-coordinates) are used in the vertical. The water column is discretised into 21 non-intersecting 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 simulated by the 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.

b) HF radar data

In the framework of the COSYNA project HF radar stations were installed at the islands of Wangerooge and Sylt as well at the mainland near Büsum.

A WERA (``Wellen Radar") system (Gurgel et al., 1999) is used. The Wangerooge station uses either 12.1 or 13.5 MHz depending on transmission and reception conditions. The corresponding radar wavelength range from 22 m to 28 m and the associated ocean wavelength λBragg relevant for the radar scattering process thus have wavelength between 11 m and 14 m. The depth of the ocean surface layer sensed by the radar can be estimated as 1/(4 pi) λBragg ≈ 1m.

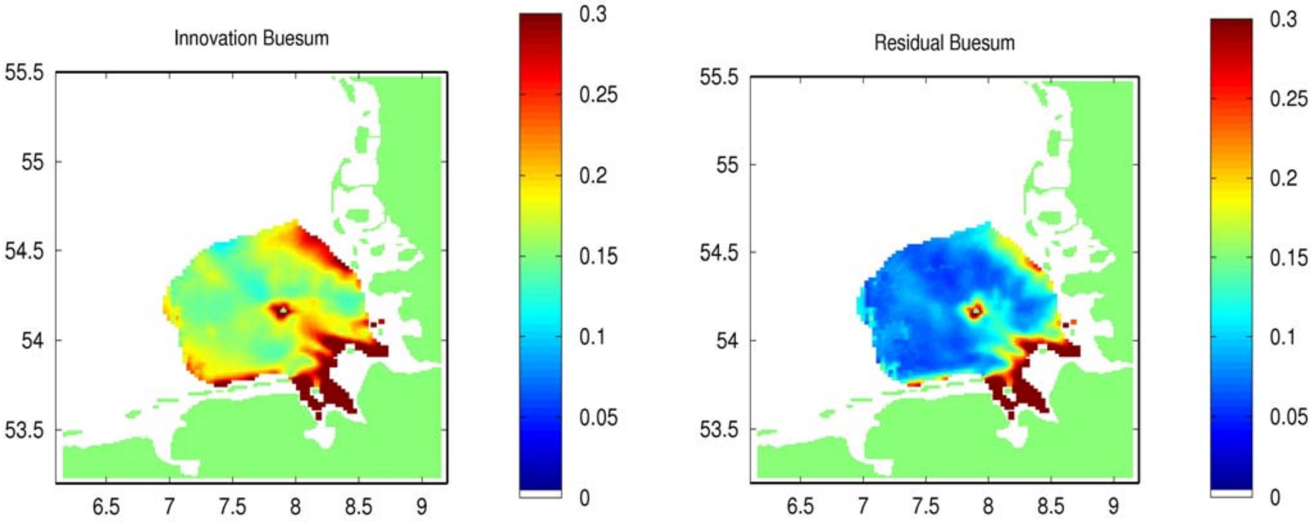

Figure 4.7.2: Innovation (left) and residual for the radial current component of the Büsum station.

Radar measurements are taken by the three stations using an integration time of 9 minutes. The integration windows are centred at 4 min 26 sec, 23 min 26 sec and 43 min 26 sec after each full hour. The range and coverage achieved by the antenna stations is illustrated in Figure 4.7.1 (right). Colors indicate the percentage of available measurements for the three stations. Figure 4.7.1 (right) shows the availability of radial current measurements from at least one station.

c) Analysis Procedure and experiments

Numerical model and HF radar data were combined using a spatio/temporal optimal interpolation (STOI) technique, in which observations and model results available within a certain period typically covering one tidal or more tidal cycles are merged in a single analysis step. The method also enables the computation of short term forecasts. The statistical analysis was performed using measurements and free model runs from the year 2011. Experiments were conducted using 1) different forecast horizons 2) different assumptions about model and observation errors and 3) different length of the analysis windows.

4.7.2 Discussion of some results

It was demonstrated that the method is able to improve the agreement with the HF radar observation data. Figure 4.7.2 shows the respective innovations (difference between free run and observations) and the residual (difference between the analysis and the observations) for the radial current component of the Büsum station. One can see that the rms values are in fact smaller for the residual than for the innovation for the most part. Only in the very shallow water regions close to the coast where both the numerical model and the HF radar are expected to have bigger errors the reduction is not as strong. It was furthermore shown that the HF radar data are able to improve the surface current forecast over a period of at least 6 hours.

4.7.3 Ongoing developments and problems

There are no basic problems with the OSE experiments. The focus of the ongoing work is on the extension of the forecast period. This requires further detailed analysis of the errors in the numerical model an their respective temporal and spatial scales.

The observation and model data to perform this analysis are available and a clear strategy to do the work has been developed.

5. Conclusions

All OSE experiments have been well developed and already produced some results. They demonstrate the impact of coastal observations. In the next period the experiments will be further developed and the impacts of coastal observations will be further studied.

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