SafeWind

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Abstract:

A methodology is proposed and tested, if additional/supplementary distributed offshore weather observation will have a benefit for better shortest-term wind and wind power forecasts for large-scale wind parks. The integration of these supplementary observations was done with data assimilation in WRF using FDDA (Four-Dimensional Data Assimilation). Since the temporary installation of supplementary offshore observations as buoys or met masts in a research campaign is far too expensive, the only way to demonstrate a benefit is a simulation study like this. 36 supplementary offshore observations in the German Bight are assimilated utilizing hourly analysis data of the German Weather Service (DWD) including u, v wind components, temperature and dew point temperature at 3 different heights.

The analysis increments in wind speed and pressure show that the 36 supplementary observations are able to change the initial fields considerably. Continuous nudging to the observation brings the WRF simulation closer to the verifying DWD analysis in terms of RMS difference. A RMS difference reduction of 1.9 m/s to 1.6 m/s has been observed in certain areas. In particular downstream and south-eastward of the supplementary observations the highest reductions/improvements can be noted. It can be assumed that the corrective impact of the observations has been advected with the main flow in south-eastwards direction.

As soon the nudging to the observations is stopped the corrective impact of the supplementary observations decrease very rapidly. This means that on average with the 36 assimilated observations no positive impact on wind or wind power forecasts for look ahead times larger than two hours can be gained.

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Content

1. Introduction

The ambitious plans for offshore wind power deployment are a financial and technical challenge with respect to the safe integration into the power system. Without any doubt the integration is technical feasible but it is necessary that the amounts of balancing and backup power (most likely by conventional power plants) can be justified with respects to the economics of wind power. In that sense, a high concentration of offshore wind power, for example in the German Bight, is highly vulnerable to weather related errors in the short-term wind power forecasts. In particular, phase errors in combination with severe ramps of wind power can be very costly for the grid operator and finally for the public.

The aim of this Task is to propose and to test a methodology, if additional offshore weather observation only for the sake of shortest-term wind power prediction can improve wind or/and wind power forecasts substantially. The use of additional upstream wind observations for wind power purposes has been studied by various authors. *Wessel el al., 2009* and *Larson and Westrick, 2006* gained little improvements in shortest-term wind power forecasts when upstream wind power observations served as additional input, besides NWP data, to statistical wind power prediction tool.
Similar to the study presented here *Liu et al., 2010* report an experiment when they assimilated wind farm data with the built-in data assimilation in the Weather and Research Forecast (WRF) Model. They gained improvements for lead times of 0-3h up to 17% in wind power RMSE and up to 6% for lead times 3-6h.

A key difference between the investigations in this task and the study of *Liu et al., 2010* is that in this study the additional observations are “synthetic”, i.e. they are simulated. No one will build an observing system for wind power in the German Bight without knowing the benefits. Thus, an often used trick in testing the impact or benefit of new observation types in data assimilation systems is done by simulating the future coming observations. This practise is often used to study the impact of new meteorological satellites, in so-called ‘Observing Simulated System Experiments’ (OSSE). The impact of distributed and targeted observations to improve the predictability of extreme weather was studied by *Leutbecher et al., 2002*. They simulated soundings of wind and temperature over the North Atlantic and included them as supplementary observations in the data assimilation system. As they were interested in large-scale predictability of two severe storms, they found that supplementary observations in an area of about $3x10^6$ km^2 are required to achieve a significant forecast improvement.

This report describes an data assimilation experiment with synthetic observations using the WRF data assimilation system (*WRF, 2009*) that was set up in Task 4.2 of SafeWind. Following the work in Task 4.2 the most promising data assimilation approach (four-dimensional data assimilation FDDA) is chosen to analyse the impact of spatially distributed observations on short-term wind and/or wind power forecasts.

2. Methodology

In this section the methodology is described including the details on the design of the experiment, details on the data assimilation approach and on the generation of the simulated observations’ data set.

2.1 WRF Setup

The data assimilation runs with WRF are initialized with ECMWF forecasts on pressure levels in a domain covering the German Bight (Figure 3). The retrieved ECMWF horizontal resolution is 0.225 x 0.225 degrees on 16 pressure levels up to 70hPa. The study period is from 1^{st} to 21^{th} January, 2007.
The horizontal resolution in WRF is set to 3km and the domain extends 100 grid boxes in North-South direction 100 grid boxes in West-East direction. 44 vertical levels have been used. The surface layer scheme is Monin-Obukhov (Janjic Eta) scheme and the PBL scheme is Mellor-Yamada-Janjic Eta TKE scheme. For the land surface the module Noah LSM is used.

2.2 Synthetic observations

Figure 1 shows the locations of the 36 synthetic observations. In our simulation the u,v wind speed components, temperature and dew point temperature are available at these sites in 3 different heights (surface, 120m, 970m). The hourly DWD analysis fields with a horizontal resolution of 7 km have been used as proxies for the observations and have been interpolated to each specific observational site.

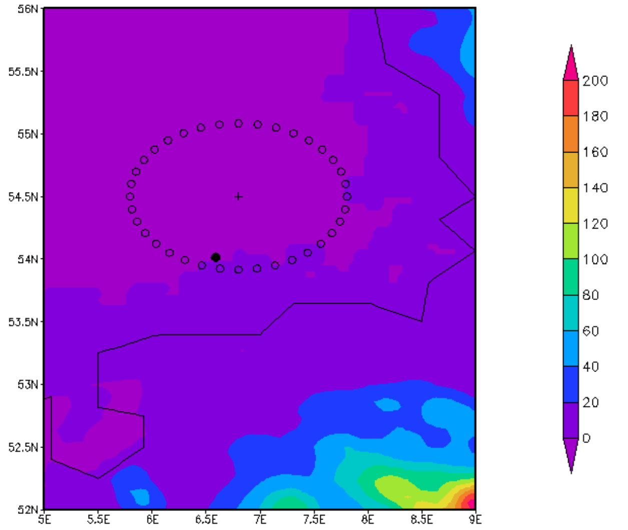

Figure 1 Location of 36 sites (open circles) in the German Bight used for synthetic observations generated from DWD analyses. The filled circle is the FINO1 sites. In fact the 36 observations are located on a circle, but with the used plotting projections it looks as if they are located on an eclipse.

2.3 Data Assimilation Approach

Data assimilation is the technique to combine observations with fields from an atmospheric model. Usually, the atmospheric model is a numerical weather prediction model (NWP) and a short-term forecast is used as a first guess (or background fields) of the current state of the atmosphere. In order to improve this state observations are assimilated considering the special error statistics of observations and of the first guess. The generated atmospheric fields are called analysis. The analysis is considered the best known state of the atmosphere.

Four-dimensional data assimilation (FDDA), also known as nudging, is a method of keeping simulations close to analysis values and/or observations over the course of an forward integration (*Liu et al., 2008*). The method provides a four-dimensional analysis (three spatial dimensions plus time) that is somewhat balanced dynamically, and in terms of continuity, while allowing for complex local topographical or convective variations. The four nudged fields are the two horizontal wind components U and V, temperature, and specific humidity.

The method is implemented through an extra tendency term in the nudged variable's equations (Stauffer et. al.1990, Stauffer et. al.1994). For example,

$$\frac{\partial\theta}{\partial t} = F(\theta) + G_\theta W_\theta(\hat{\theta}_0 - \theta)$$

Where $F(\theta)$ represents the normal tendency terms due to physics, advection, etc., G_θ is a time-scale controlling the nudging strength, and W_θ is an additional weight in time or space to limit the nudging, which is a value that can be set by users, while $\hat{\theta}_0$ is the time- and space-interpolated analysis field (or observation) value towards which the nudging relaxes the solution (see Skamarock et.al 2008).

In WRF model settings/namelist, the parameters for set up "G" can be set for wind components, theta, and specific humidity. For our experiment, "G" is set for wind components, theta, and specific humidity, to 0.0003 s^{-1}. Experiments with increased nudging strength "G" gave similar results.

FDDA was chosen as data assimilation approach in favor of 3DVar because the experiments in Task 4.2 of the SafeWind Project (*SafeWind Deliverable 4.2, 2011*) have shown that the assimilation of observations via FDDA over the North Sea outperforms 3DVar with respect to the mean sea level pressure (MSL). Furthermore the run time of WRF in FDDA mode is considerably less than 3DVar runs.

2.4 Cycling and WRF Experiments

Three different runs (experiments) with WRF have been conducted. The reference (**Control**) experiment is a forecast run with WRF initialized with ECMWF forecasts. ECMWF forecasts serve as initial and lateral boundary conditions. The control experiment is necessary to assess the two further experiments when the synthetic observations are assimilated and to identify improvements by the 36 observational sites. The assimilation experiment **12hFDDA** can be regarded as another control experiment as it contains continuous nudging to the observations. By doing so a forecast in time is in principle not possible because observations are assumed to be available in real-time.
The most important experiment is **6hFDDA** in which nudging to the synthetic observations is done in a nudging period and during hour 5 and 6 the nudging is ramped down. This means that after hour 6 a six hour forward integration (i.e. usable forecast period of six hours) without nudging is following. This time design of the experiment is required to circumvent a cold start and to allow the model to spin-up and to become dynamically balanced.

Every day four model runs are started (00UTC, 06UTC, 12UTC, and 18UTC). Basetimes 00UTC and 12UTC of the ECMWF forecast are used. Figure 2 shows a sketch of the cycling in **6hFDDA**.

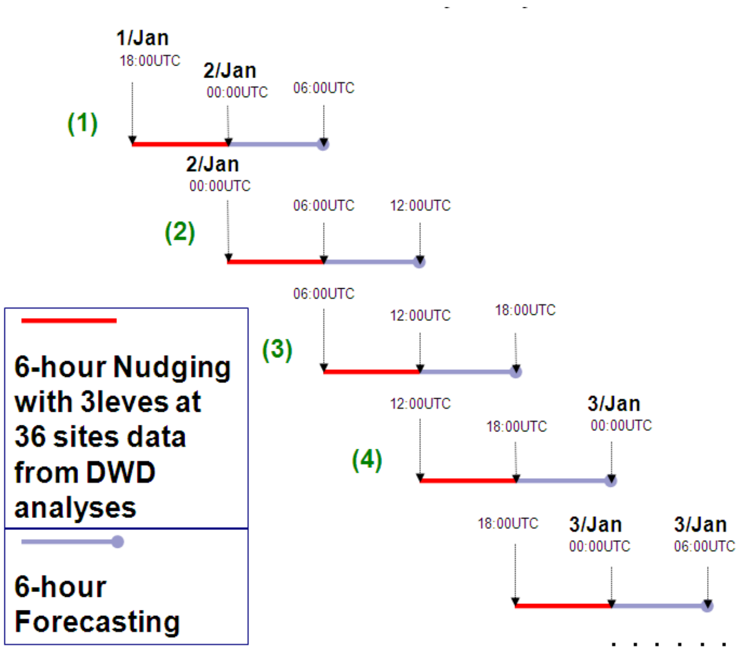

Figure 2: *Sketch of the experiment "6hFDDA". WRF starts every 6h with a pre-forecast period of 6h that is used for nudging (FDDA) the model to 36 sites with synthetic observations. Afterwards the model is run for another 6hours in forecasting mode.*

3. Results

The presentation of results of the three WRF data assimilation experiments is done in four subsections. Firstly, in Section 3.1, the difference between the initializing ECMWF forecast and the DWD analysis is shown. This is of particular interest, because the DWD analysis is used two-fold in the

study: i) the synthetic observations are taken from DWD analysis and ii) the DWD analysis is used to verify if the observations have an impact on WRF shortest-term forecasts.

In Section 3.2 the impact of the synthetic observations on the objective analysis and in FDDA is discussed. The impact of data assimilation on differences in the three experiments is analysed in Section 3.3. In Section 3.5 it is investigated how long the impact of additional observations remains in the model after the assimilation has been stopped. This is important to estimate how long a positive impact is achievable.

3.1 Difference between ECMWF forecast and DWD analysis

During the study period 1-20 January a substantial systematic difference between the ECMWF forecast and DWD analysis in 10m wind speed exists (Figure 3, right). In the German Bight and parts of Lower Saxony and Schleswig-Holstein DWD speeds are 0.5-1.0 m/s higher than the corresponding ECMWF 10m wind forecasts. Higher systematic deviations (bias) can be seen at the coast attributed to the lower horizontal resolution of the ECMWF model (25 km) compared to DWD (7 km). Locally, ECMWF forecast are up to 2.5 m/s higher than DWD analyses. However, at certain areas ECMWF forecast are up to 2.5 m/s lower than DWD. It can be speculated that the assimilation of DWD synthetic observation will tend to increase WRF wind speeds.
The RMS difference (Figure 3, left) between ECMWF forecasts and DWD analyses is lowest for onshore regions while the offshore differences exceed 1.6 m/s over large areas of the Northern German Bight. The average RMS difference in the area of the synthetic observations is approximately 1.3 m/s giving potential to correct WRF in the vicinity of the synthetic DWD observations.

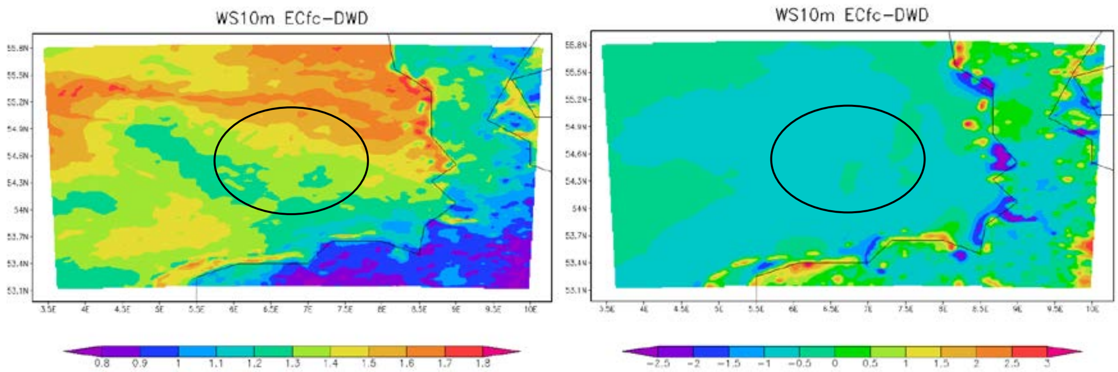

Figure 3: *RMS difference (left) and bias (right) in m/s between 10m ECMWF forecast and DWD analysis.*

3.2 Increments of objective analysis

Analysis increments are a suitable measure to assess if new observations alter the initializing atmospheric fields (background fields, here: ECMWF forecast). An analysis increment is the difference between the obtained analysis and the background field. In this experiment the objective analysis was done by Cressman interpolation (*Cressman, 1959*) of the synthetic observations and the initializing ECMWF forecast. Figure 4 and Figure 5 show the analysis increments for 10m wind speed and mean surface pressure (PMSL), respectively. In line with the finding in Section 3.1 that DWD speeds are higher for offshore regions, the bias of 1000hPa wind speed analysis increments are positive (up to 0.4 m/s) as can be seen in Figure 4, right. The RMS of analysis increments is, as expected, highest at the eclipse of synthetic observations with values up to 1.4 m/s (Figure 4, left). In the centre of the eclipse a local amplification of impact by the observations can be observed. This is attributed to the data assimilation scheme that is used to obtain the objective analysis. Cressman assumes that the impact (weight) of observations decreases radial with distance. However, in the centre of the eclipse the impact of each of the 36 observations amplifies.
Figure 5 (right) shows that the synthetic observations increase the average PMSL up to 33 Pa and the RMS of increments is at maximum 60 Pa (Figure 5, left).

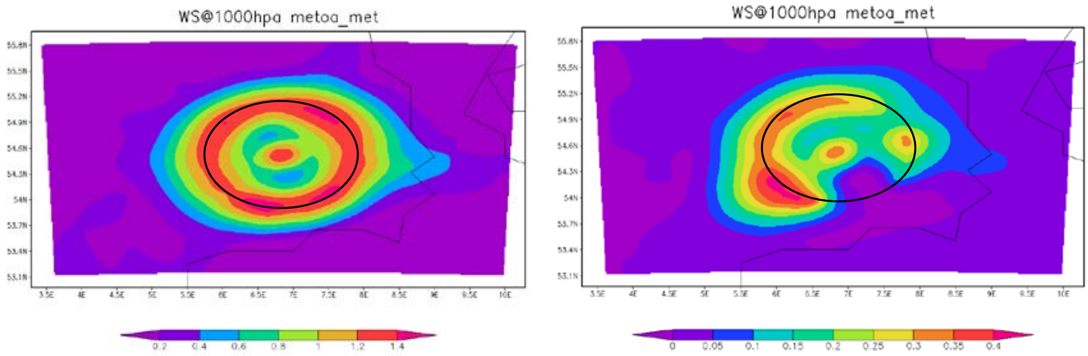

Figure 4: *RMS difference (left) and bias (right) of 10m wind speed (m/s) between objective analysis from WRF and first guess (ECMWF forecast) for January 1-20, 2007.*

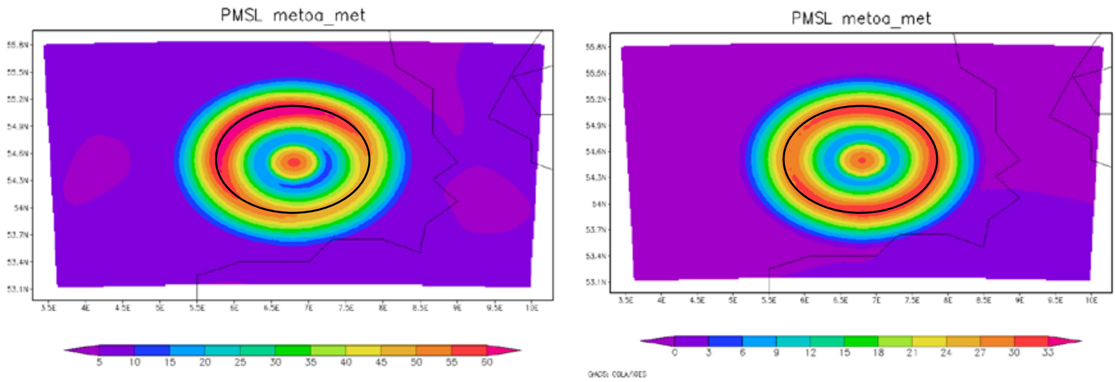

Figure 5: *RMS difference (left) and bias (right) of mean sea level pressure (Pa) between objective analysis from WRF and first guess (ECMWF forecast) for January 1-20, 2007.*

The objective analysis was done in both experiments **6hFDDA** and **12hFDDA** to ingest the synthetic observations into the initializing ECMWF fieldsat the start of each model run. Then the nudging tendency term for FDDA is determined based on the objective analyses when running the WRF model with FDDA. During the following forward integration of 6h and 12h WRF, respectively for experiments **6hFDDA** and **12hFDDA**, WRF was nudged to the synthetic observation with FDDA. Note, that **6hFDDA** and **12hFDDA** are identical for the first 6 hours and deviates afterwards, because in 6hFDDA the nudging stops while it continues in **12hFDDA**. Conclusively, after 7 hours **6hFDDA** and **12hFDDA** are different for the first time. The difference between both model runs at that stage is an indicator on the impact of nudging to the synthetic observations. Figure 6 shows the systematic difference (bias) in 10m wind speed (left) and RMS difference of PMSL (right) between **6hFDDA** and **12hFDDA**. The positive bias in 10m wind speed suggests that continues nudging to the synthetic observations lowers wind speeds up to 0.18 m/s. This is surprising as DWD 10m wind speed analysis are higher than the initializing ECMWF forecasts (Section 3.1) and an increase of speed in **12hFDDA** compared to **6hFDDA** was expected. However, the increments of the objective analysis increased wind speeds. Thus, it is believed that the decrease of wind speeds is attributed to FDDA approach.

The RMS difference in PMSL (Figure 6, right) between **6hFDDA** and **12hFDDA** are more than one order of magnitude smaller than the RMS difference between objective analysis and the ECMWF forecast (used as background) (Figure 5, left). This finding makes clear that the corrective impact of FDDA on model fields is much smaller than the impact of observations to alter the objective analysis.

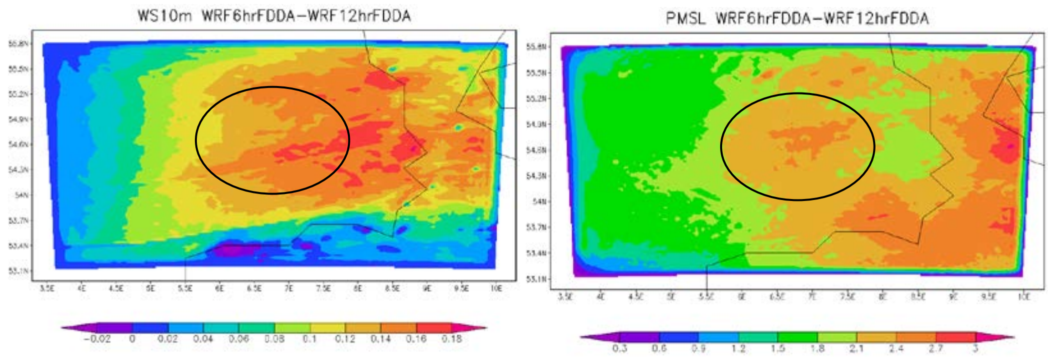

Figure 6: Bias in 10m wind speed (m/s) (left) and *RMS difference of mean sea level pressure (Pa) (right) between experiment **6hFDDA** and **12hFDDA** at time step when assimilation has been stopped in 6hFDDA for January 1-20, 2007.*

3.3 Systematic and RMS Difference

In this section the systematic (bias) and RMS difference between the WRF results and the verifying DWD analysis are presented to demonstrate the benefit of additional distributed observations. The **control** experiment is used as a reference that should be outperformed. Only those forecast steps are validated that follow when the assimilation of observations is stopped in **6hFDDA**. This are 6 forecast steps per model run. Four model runs per day are considered from 1-20 January 2007.

Systematic difference (bias)

The slight systematic underestimation of wind speed (here: in 73m height) over the German Bight compared to DWD analysis is almost identical between **Control** and **6hFDDA** (Figure 7, top and left, respectively). In **12hFDDA** the underestimation of wind speed has increased by about 0.5 m/s. This is in line with the previous finding that longer FDDA does not eliminate/reduce a systematic difference between the synthetic observations and the initializing ECMWF forecast, but deepens the systematic difference.

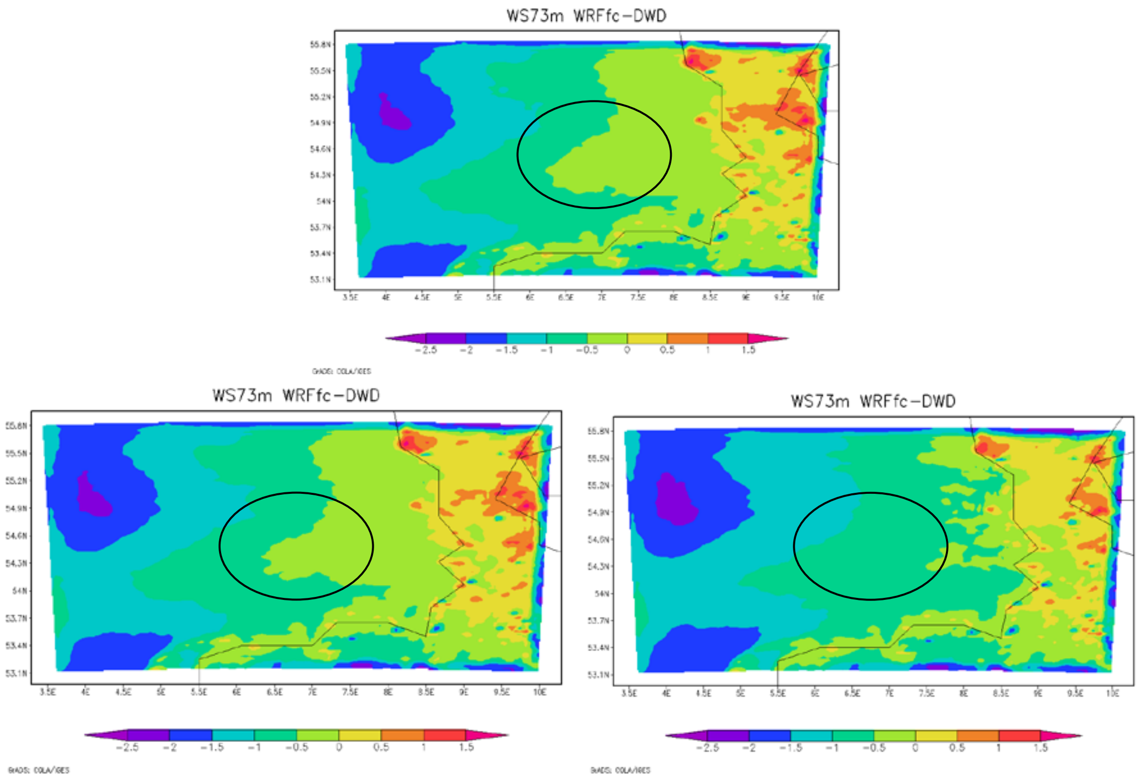

Figure 7: *Bias in 73m wind speed (m/s) of **Control** (top), **6hFDDA** (left) and **12hFDDA** (right) experiment verified with DWD analysis for January 1-20, 2007.*

RMS difference

Figure 8, top shows the RMS difference in 73m wind speed between **Control** and DWD analysis. The deviation is smallest in the German Bight and increases sharply at the left and upper edge of the model domain. This is probably attributed to the fact that the model edges are continuously nudged to the lateral conditions that are given by the ECMWF forecasts. Figure 8, right has the smallest RMS differences in the area of the synthetic observations. This is expected and proves that the WRF model has been brought closer to the synthetic DWD observations. In some areas the RMS differences decreased from 1.9 m/s to 1.6 m/s. However, it must be stressed again that this **12hFDDA** is no forecast, the WRF result is obtainable at the time when the synthetic observation is taken.

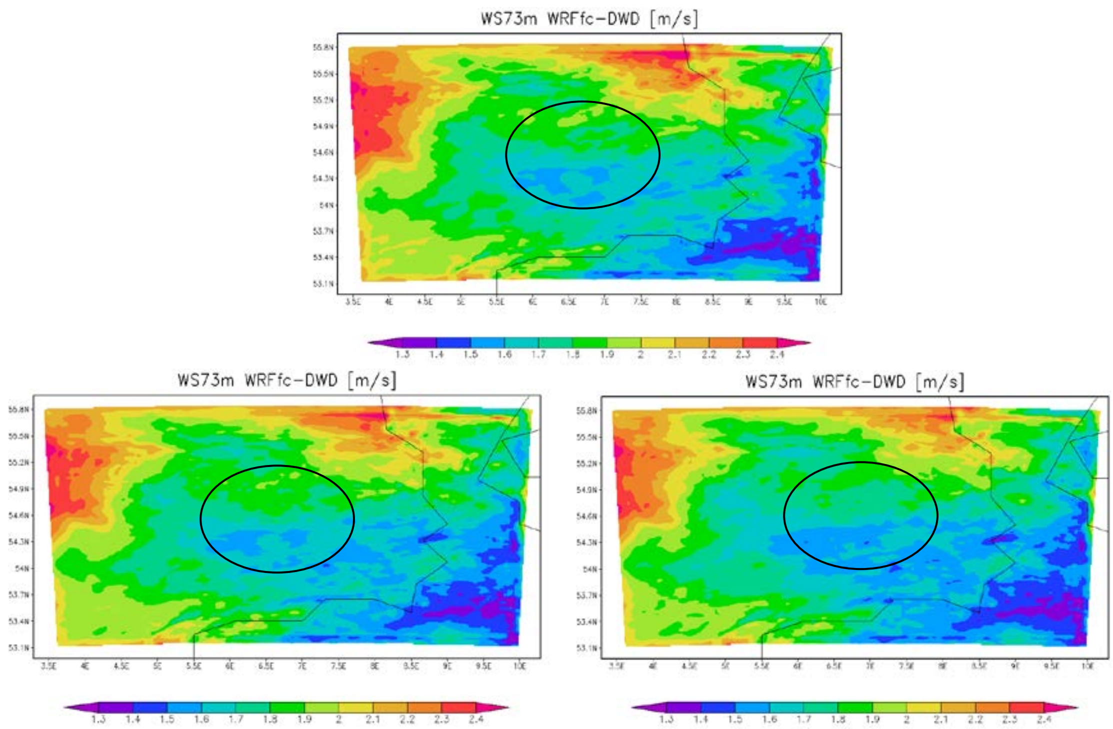

Figure 8: *RMS difference in 73m wind speed (m/s) of* ***Control*** *(top),* ***6hFDDA*** *(left) and* ***12hFDDA*** *(right) experiment verified with DWD analysis for January 1-20, 2007.*

Therefore it is important to note that in **6hFDDA** (Figure 8, left) RMS differences are smaller than in the Control, but slightly larger than in **12hFDDA**. It can be seen very clearly that the highest improvements are south-east of the assimilated observations. This result is in particular interesting that the beneficial/corrective impact of the observations has been carried downstream with the mean flow.

3.4 Statistics at FINO1 site

Figure 9 shows the distribution (left) and the cumulated distribution (right) of simulated WRF winds in 100m height at the FINO1 site for **Control**, **6hFDDA** and **12hFDDA**. As reference the analysis wind speeds of DWD are given which have been used as synthetic observations. In general, DWD wind speeds are higher and in particular speeds exceeding 22m/s are more frequent (Fig. 9, left) than in the WRF simulations. The three WRF runs are in principle indifferent, except that the reduction in wind speed for **12hFDDA** can be noted marginally in the cumulated distribution (Fig. 9, right).

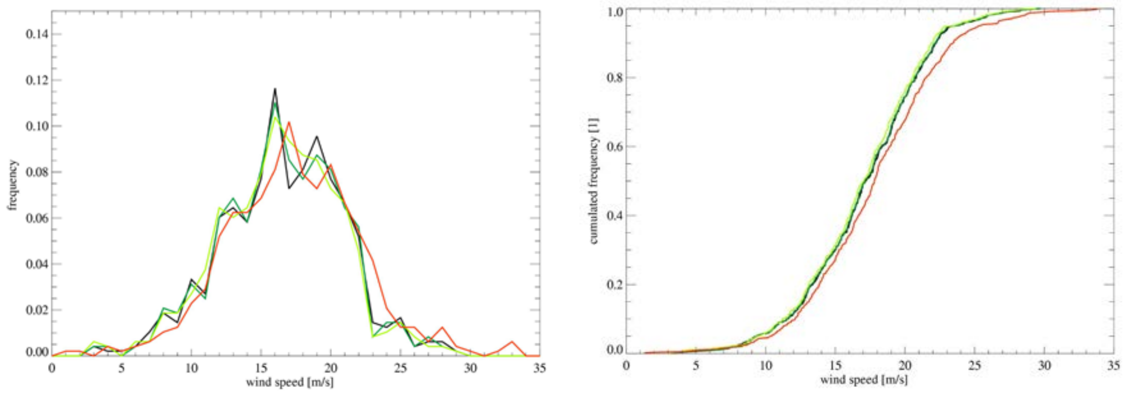

Figure 9: *Distribution (left) and cumulated distribution (right) of wind speeds in 100m height at FINO1 for **Control** (black), **6hFDDA** (turquoise), **12hFDDA** (light green) and DWD analysis (red). Hourly values in the time period January 1-21, 2007 have been used. The binsize for the distribution is 1m/s.*

3.5 Evolution of the impact of observations in time

In the previous section it was shown that the wind field in 73m height is positively altered when (synthetic) observations are assimilated. Even if nudging is stopped the positive impact of the observations can be seen in the following forecasting period of six hours (Figure 8, left). It is now interesting to analyse, if this impact of the observations is constant during the six hours of forecasting or if the positive impact ceases. The analysis has been done for the FINO1 site and verification is done (again) against DWD analysis (10m height) (Figure 1010).
The **Control** 10m wind speed is slightly systematically lower (0.7 m/s) than the DWD analysis. This was already found in Figure 3 (right) when comparing the ECMWF 10m wind speed with the DWD analysis. Nudging with FDDA changes the systematic deviation to the DWD analysis. The **12hFDDA** wind speed is much lower than the DWD analysis (about 0.95 m/s). In the **6hFDDA** experiment an interesting behaviour of the negative bias can be observed. The negative bias is largest for the first two hours and then approaches asymptotically to the smaller bias of the **Control**, i.e. after 2 hours without nudging to observations the **6hFDDA** behaves like the **Control**.

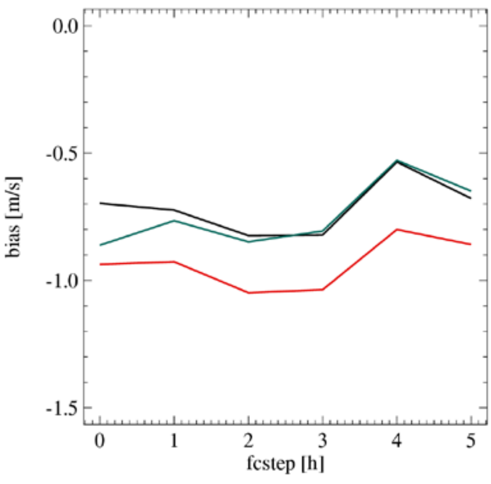

Figure 10: *Bias in 10m wind speed of **Control** (black), **6hFDDA** (blue) and **12hFDDA** (red) verified with DWD analysis at FINO1 for January 1-21, 2007 depending on lead time.*

3.6 Time series

Time series of the WRF results are given in Figure 1 at the FINO1 site and are expressed as differences to the verifying DWD wind speed analysis. In this time series no substantial differences between **Control**, **6hFDDA**, **12hFDDA** can be noted, except at 16 January when **12hFDDA** wind speed is far smaller than the DWD analysis and **Control** and **6hFDDA** performs slightly better.

The 100m winds at the FINO1 site are transformed with a simple wind power curve into wind power and the results are shown in Figure 92 as difference to the DWD analysis. At many times the difference between WRF results and verifying DWD analysis disappears due to the flat shape of the wind power curve exceeding the nominal wind speed. Again no substantial differences between the three WRF experiments can be noted.

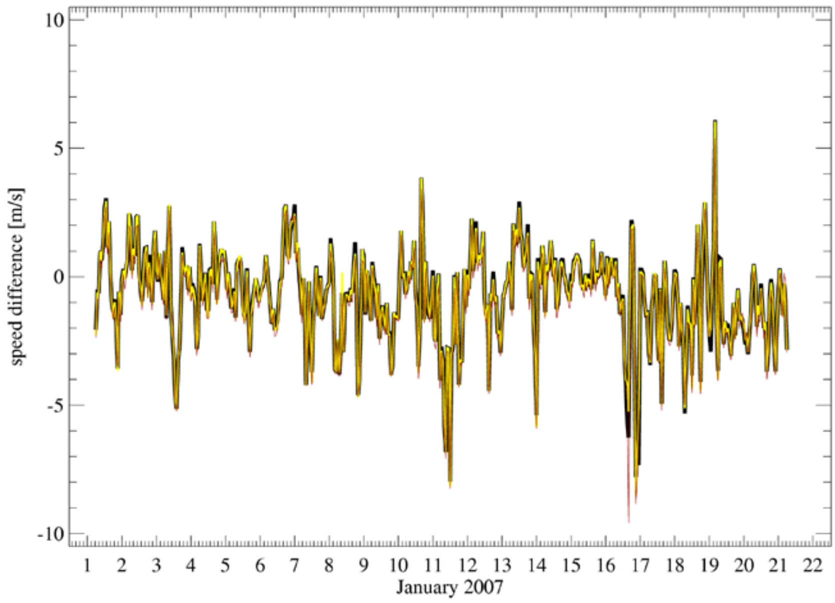

Figure 11: *Time series of wind speed difference between* ***Control*** *(black),* ***6hFDDA*** *(yellow),* ***12hFDDA*** *(red) and verifying DWD analysis in 100m height at the FINO1 site.*

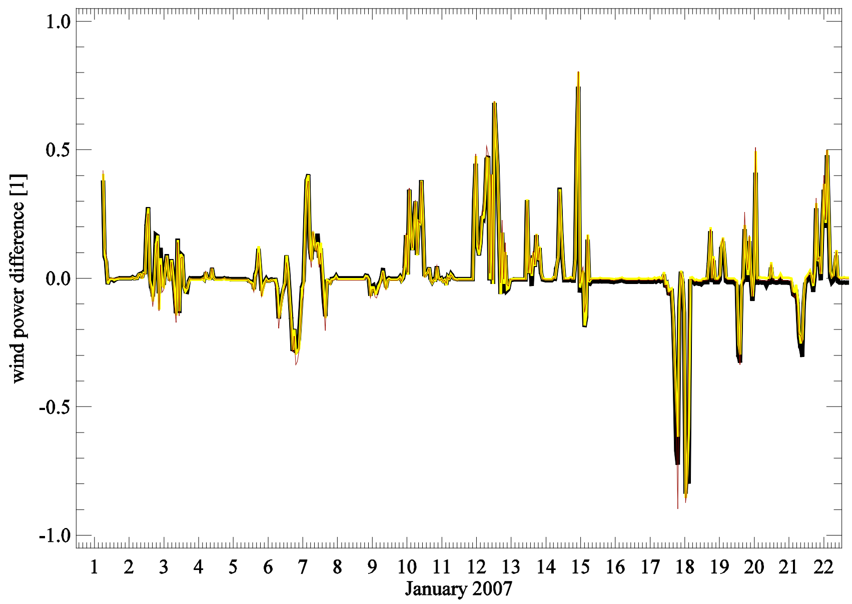

Figure 92: *Time series of wind power difference between* ***Control*** *(black),* ***6hFDDA*** *(yellow),* ***12hFDDA*** *(red) and verifying simulated DWD wind power at the FINO1 site.*

Thus a more sensitive way to highlight differences between the three WRF runs is explored in Figure 103 for wind speed (left) and simulated wind power (right). The difference between **6hFDDA** (blue diamonds) and DWD analysis which can also be called forecast error is plotted against the forecast error of the **Control**. For all cases that lie above the diagonal in the lower left quadrant and for all cases that lie below the diagonal in the upper right quadrant, **6hFDDA/12hFDDA** is superior to the **Control**. In contrary, **6hFDDA/12hFDDA** is worse than the Control when the point lies below the

diagonal in lower left quadrant. It can be seen that **12hFDDA** has in both ways the highest difference to the **Control**, i.e. in one case the improvement of a forecast error of -7 m/s to -2.5 m/s can be observed. However, at another case a high degradation occurs. As expected, the difference between **6hFDDA** and **Control** is smaller. In case of extreme deviations between WRF result and DWD analysis (lower left quadrant), **6hFDDA** can improve the forecasts in three cases. In wind power a reduction up to 20% of rated wind power was obtained for one of the three cases. Note, that the remaining wind power error is still very high for these three cases.

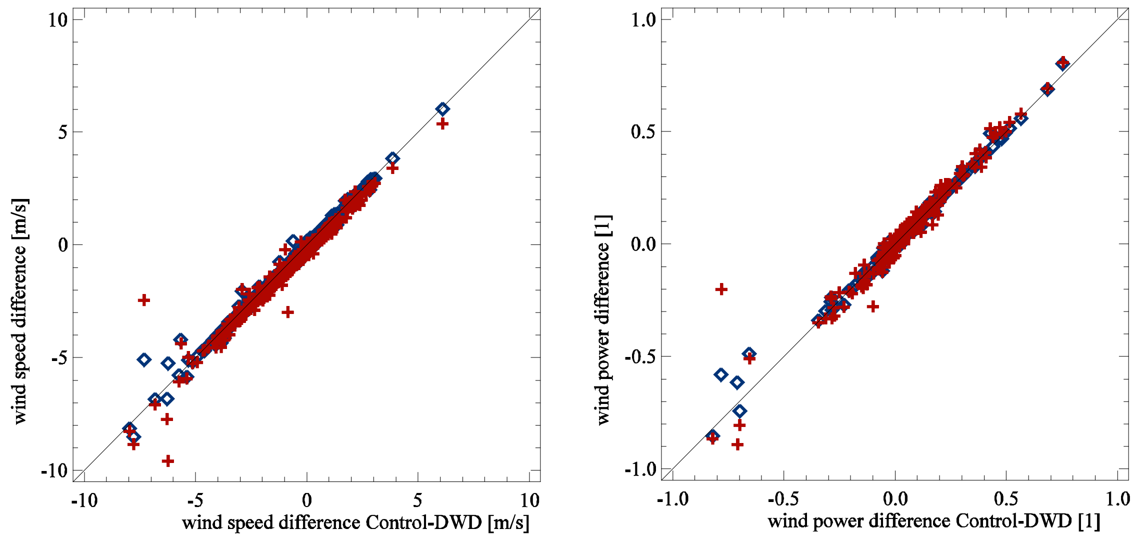

Figure 103: Difference in wind speed (left) and simulated wind power (right) between 6hFDDA (blue diamonds) and DWD analysis versus the difference between Control and DWD analysis. The red crosses are the 12hFDDA experiment.

It turns out that the 36 synthetic observations in three heights are not able to alter the phase of the entire atmospheric model. This is not very surprising, as we have to bear in mind that the WRF model has about 616000 grid points that can't be changed all of a sudden by a few observations. Data assimilation, as it is done at Weather Centres, is normally done with millions of observations (mainly form satellite).

4. Summary

The aim of this Task was to propose and to test a methodology, if additional/supplementary distributed offshore weather observation will have a benefit for better shortest-term wind power forecasts for large-scale wind parks. The integration of these supplementary observations was done with data assimilation in WRF using FDDA (Four-Dimensional Data Assimilation). Since the temporary installation of supplementary offshore observations as buoys or met masts in a research campaign is far too expensive, the only way to demonstrate a benefit is a simulation study. In this study the 36 supplementary offshore observations are simulated utilizing hourly analysis data of the German Weather Service including u, v wind components, temperature and dew point temperature at 3 different heights. These observations are called synthetic observations. However, the potential benefit of real/new observations should be stressed here as well. Observations and in particular in data sparse regions are a very important prerequisite for verification of atmospheric models in short-term forecasting but also for the comparison of long-term statistics. Without verification the improvements in atmospheric modelling would come to a standstill.

The DWD analysis fields are also used for verification of the conducted WRF data assimilation results. A positive impact of the synthetic observation means that the deviation between the WRF data assimilation results and DWD analysis gets smaller than in the control run without data assimilation.

Two further WRF runs (experiments) have been carried out in the German Bight assimilating 36 simulated synthetic observations. Like the **Control** these experiments have been initialized with

ECMWF forecasts and have been computed on a 3 km grid. In the **12hFDDA** experiment the model was nudged continuously to the synthetic observations and is used as a reference to determine the maximal impact by the 36 observations. Thus this experiment can't be integrate ahead of real-time, i.e. is not a forecast. The third model run (**6hFDDA**) is the main experiment as it can be integrated ahead of real-time. After nudging the model to the 36 observations for the last 6h, nudging is ramped down and the model evolves independently for the next 6h. Afterwards the next model run is started. The study period is from 1-21 January 2007.

The analysis increments in wind speed and pressure show that the 36 supplementary observations are able to change the initial fields considerably. Thus, the results of **12hFDDA** are much closer to the verifying DWD analysis than the **Control** in terms of RMS difference. A RMS difference reduction of 1.9 m/s to 1.6 m/s has been observed in certain areas. In particular downstream and outside (south-eastward) the eclipse with supplementary observations the highest reductions/improvements can be noted. It can be assumed that the corrective impact of the observations has been advected with the main flow in south-eastwards direction. The RMS difference reduction in **6hFDDA** is slightly smaller (up to 0.2 m/s).
It has been observed that in **12hFDDA** the mean 10 m wind speed is lowered by about 0.25 m/s relative to the **Control** (at FINO1 site). This happens despite the fact that the mean DWD 10m speed is higher than the initializing ECMWF forecast and it was expected that the nudging to the synthetic observations will increase the mean 10m speed.

As soon the nudging to the observations is stopped the impact of the supplementary observations decrease very rapidly. Roughly after two hours the **6hFDDA** experiment approaches the **Control** in terms of observed systematic difference between model and verification. This means that on average with the investigated setup of the 36 additional distributed observations no positive impact on wind or wind power forecasts ahead of two hours is anticipated. With respect to an operational application it must be noted that constraints on the timely availability of the initializing ECMWF forecasts have not been considered. Normally the 00UTC ECMWF forecast is disseminated at about 6-7UTC. We assumed for this study that the 00UTC forecast was immediately available. Thus, in an operational case WRF would be initialized with higher forecast steps which might degrade results.

In general, the impact/benefit of 36 supplementary observations in three vertical levels is rather limited as the model with about 616000 grid boxes has a huge "inertia" that is very hard to change by a couple of observations. In future studies a filled array of observations should be used or simulated to change the model more effectively. The use of high spatial resolved satellite data (e.g. 10m wind speeds from the Advanced Synthetic Aperature Radar (ASAR) onboard ENVISAT with resolutions down to 150m) can be envisaged over ocean to assimilate high density observations into mesoscale models. Since approaching fronts can be observed with ASAR, it should be possible to improve the timing of fronts for shortest term wind power forecasts. Data from ground based rain radar are already assimilated in the COSMO-DE model of the German Weather Service for better prediction of heavy rainfall (Stephan et al., 2008). Lindskog et al, 2004 assimilated radial wind speeds of a Doppler Radar to the HIRLAM model and showed improved forecast skills. Within the coming years it will be possible to subdivide radial wind speeds in their components through the superposition of Doppler Radar images measured by different instruments. It will be worthwhile to assimilate those new observation techniques into WRF for some study cases.

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