Improving offshore wind resource assessments using a data assimilation technique

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Abstract

Wind research and industry partners in collaboration with the EU have created the FP7 NORSEWInD project with the main objective of delivering to the North, Baltic and Irish Sea areas high quality wind atlases for offshore wind resource assessment.

The state-of-the-art atmospheric mesoscale model WRF is used to map the wind resource at 90m a.g.l. for the North Sea area. A model domain with a spatial resolution of 20x20 km is used to simulate a winter and a summer month (November 2008 and July 2009). It is coupled with a Newtonian relaxation assimilation technique to ingest surface wind data provided from QuikSCAT (QS) satellite and sea surface temperature (SST) data from GHRSST Level 4 analysis. Wind results from the model are validated against observational data from the anemometric mast FINO1 and the spatial improvement of the average wind field at 90 m a.g.l is calculated.

Improvements of more than 5% were obtained from using data assimilation on the overall domain. Each source has shown a distinct impact on the analyzed periods. The QS assimilation had higher impact during the summer period whereas SST assimilation was significant during the winter period. At FINO 1 location, improvements on the vertical wind profile were obtained from the SST assimilation. The MAE and RMSE statistical parameters were slightly improved.

1.0 Introduction

The Offshore wind resource assessment is one of the primary key tools used by offshore wind farm promoters for decision making investments of offshore wind parks. In Europe, due to the renewable energy policies recently established by the European Commission (EU) for the wind sector, it is expected an interesting growth of offshore wind parks along the European coasts. To support the expected investments, wind research and industry partners in collaboration with the EU have created the FP7 NORSEWInD project [1] with the main purpose of delivering to the North, Baltic and Irish Sea areas high quality wind atlases for offshore wind resource assessment.

An experimental offshore wind resource assessment study for the North Sea area coupled with a data assimilation technique was setup, aiming to improve atmospheric mesoscale model results from which the regional wind atlases will be constructed. The state-of-the-art atmospheric mesoscale model WRF [2] was used to map the wind resource at 90 m a.g.l. A model domain with a spatial resolution of 20x20 km was used to simulate a winter and a summer month, November 2008 and July 2009. The numerical model was coupled with a Newtonian relaxation technique to assimilate QuickSCAT (QS) surface winds [3] and realistic sea surface temperature (SST) data from GHRSST level 4 analyses [4].

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The observational data from the FINO 1 anemometric mast (Figure 1) was used to perform point validation at the main height of analysis. The vertical profile was assessed using the levels of 33, 50, 60 and 90 m a.g.l available at the met mast. An assessment of the spatial improvement of the assimilation techniques on the average wind field was calculated.

2.0 Methodology

The WRF model was configured using 2 nested domains, a coarser (D1) with a 100x100 km and the nested (D2) with 20x20 km. The domains coverage area is displayed in Figure 1. Initial and boundary conditions were ingested into D1 from NCAR Reanalysis datasets at a frequency of 4 times per day with a spatial resolution of 2.5x2.5º. The numerical model was parameterized using the options described in table 1.

Table 1 - WRF parameterization setup.

	D1	D2
Horiz. Res [km]	100	20
NX x NY	18x21	36x51
Vert. Levels	28	28
Micro-physics	WSM6	WSM6
LW radt.	RRTM	RRTM
SW radt.	Dudhia	Dudhia
Land-Surface	Noah	Noah
Surface	Eta	Eta
PBL	MYJ	MYJ
Cumulus	KF	KF

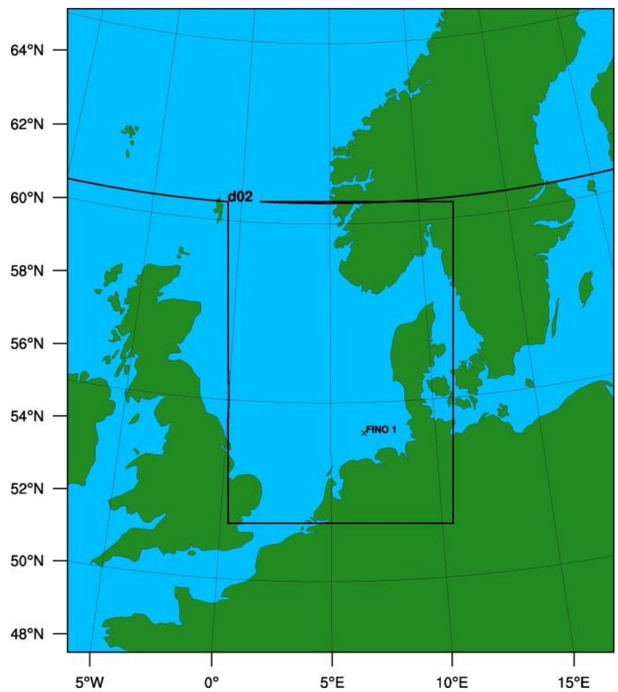

Figure 1- WRF domains setup and location of FINO 1 anemometric station.

Three experimental runs were performed, a control run without ingesting satellite data, a second run assimilation QS satellite data and a third assimilating SST satellite data. The QuikSCAT surface winds dataset contains 0.25º gridded ocean surface wind vector fields from daily ascending and descending satellite passes [3]. It is a level 3 processed product and is available from PODAAC-NASA. A contour plot of the monthly averaged QS sea winds speed and direction is displayed in Figure 2.

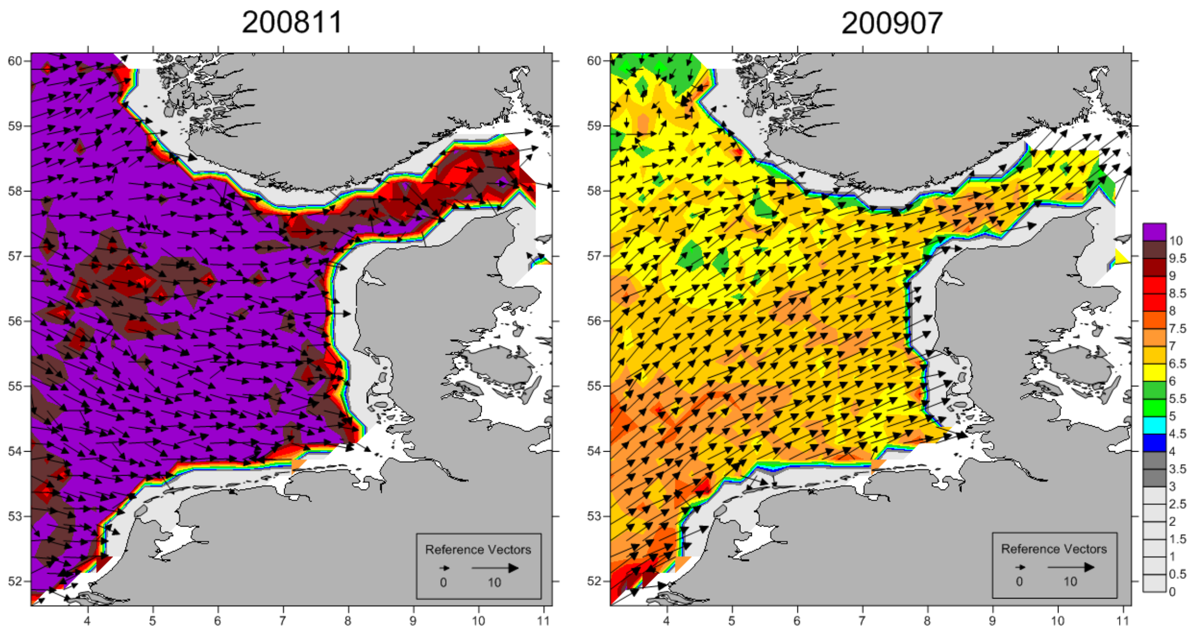

Figure 2 - QuikSCAT monthly average wind speed and direction to assimilate on D1 and D2.

The SST data used in this work is a product from the Group for High Resolution Sea Surface Temperature (GHRSST) Level 4 sea surface temperature analysis produced daily on an operational basis by the Danish Meteorological Institute [4]. This product is available once a day at 00h. Figure 3 is a plot of the monthly SST average of the study area.

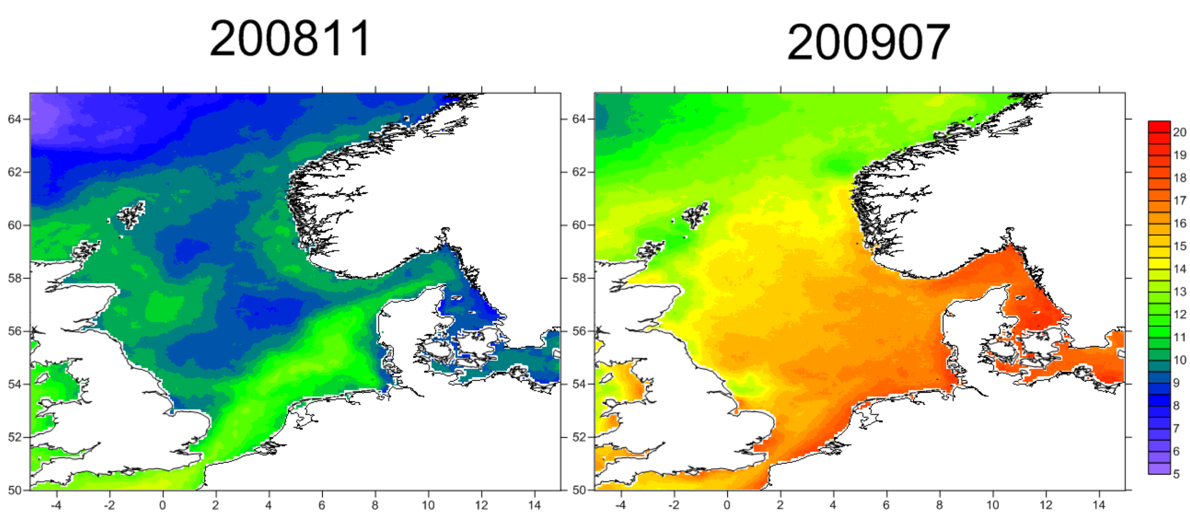

Figure 3 - Monthly SST average of the study area.

The FINO 1 anemometric mast was the chosen for point validation since only a few offshore wind stations with available data for the same area are available on both analysis months. The spatial improvement assessment for the wind speed was measured by calculating the proximity of the assimilation versus control run with QS observations. The respective equation used was:

$$I_{WIND}\ (\%) = 100\ \times \frac{\|NN - QS\| - \|N - QS\|}{\|NN - QS\|} \tag{1}$$

For the SST assimilation improvement, only the comparison between control run and assimilation run were accessed. For this case, it was used the following equation:

$$I_{SST}\ (\%) = 100\ \times \frac{\|NN\| - \|N_{SST}\|}{\|NN\|} \tag{2}$$

3.0 Results

3.1 Validation against anemometric mast

The time series obtained from the WRF model at FINO 1 are ten-minute instant values which were compared with the 10 minute averaged values at the physical site. The time series for November 2008 as displayed at figure 4. In the winter month a correlation of 83% for the wind speed values was obtained with WRF predicting stronger winds than the observed. The wind direction is well reproduced by the model, even though the mean absolute error (MAE) was of approximately 12º on all runs. Table 2 presents the statistics for point validation of November 2008.

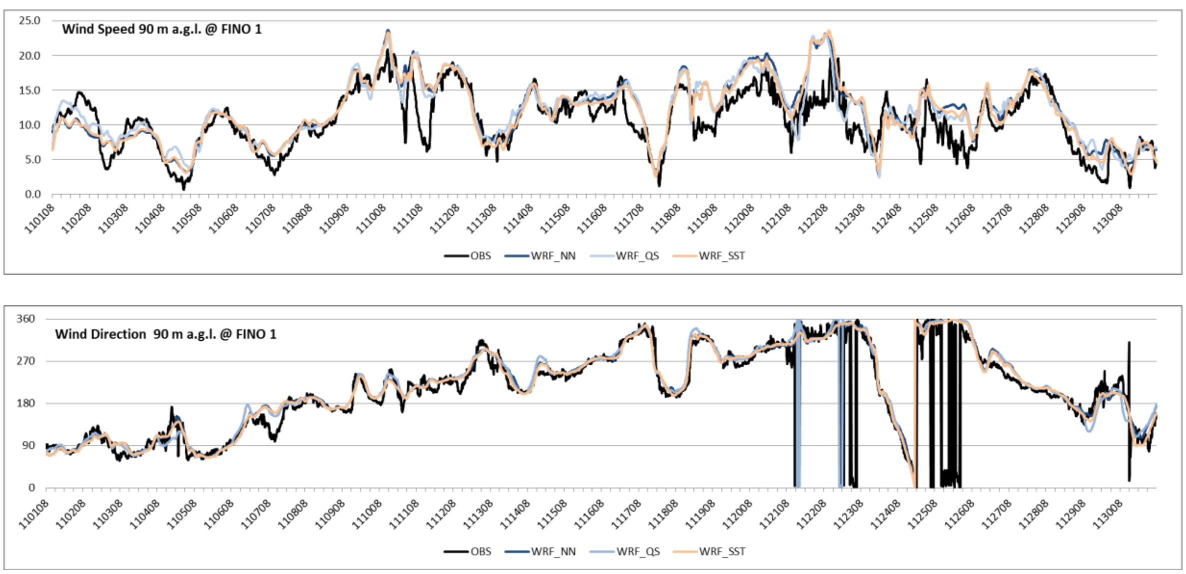

Figure 4 - Time series of wind speed (above) and direction (below) for November 2008 at FINO 1. Time series of observations (OBS), control run (WRF_NN), QS assimilation (WRF_QS) and SST assimilation (WRF_SST).

During the winter month, the assimilation of QS sea winds had a low impact on winds at 90 m a.g.l. A slight improvement of the intensity MAE and RMSE was observed while the remaining statistics were identical to the control run (Table 2). With the assimilation of SST data, intensity and direction errors diminished slightly. Moreover it was possible to obtain a lower average wind speed thus closer to the observed values at all height levels.

Table 2 - Statistics for FINO 1 point validation for November 2008.

		90 m a.g.l.			
		OBS	WRF_NN	WRF_QS	WRF_SST
WBL	AVG [m/s]	11.23	12.00	12.02	11.83
	STDEV [m/s]	4.53	4.43	4.20	4.40
	A [m/s]	12.62	13.46	13.45	13.20
	k	2.7	2.96	3.14	2.84
	CORREL	-	0.83	0.83	0.84
WSPD	MAE [m/s]	-	2.07	1.99	1.95
	RMSE [m/s]	-	2.82	2.65	2.62
WDIR	MAE [°]	-	12.39	12.96	11.83
	RMSE [°]	-	17.14	18.10	16.48

In the summer, the WRF model was not able to reproduce the wind intensity with the same skill as in the winter. A correlation of 68% was obtained for the three runs. In opposition to the winter period, in the summer the model has predicted less wind than the observed. At lower levels, as can be seen on the vertical profile (Figure 6), the differences are higher and tend to disappear as we go up.

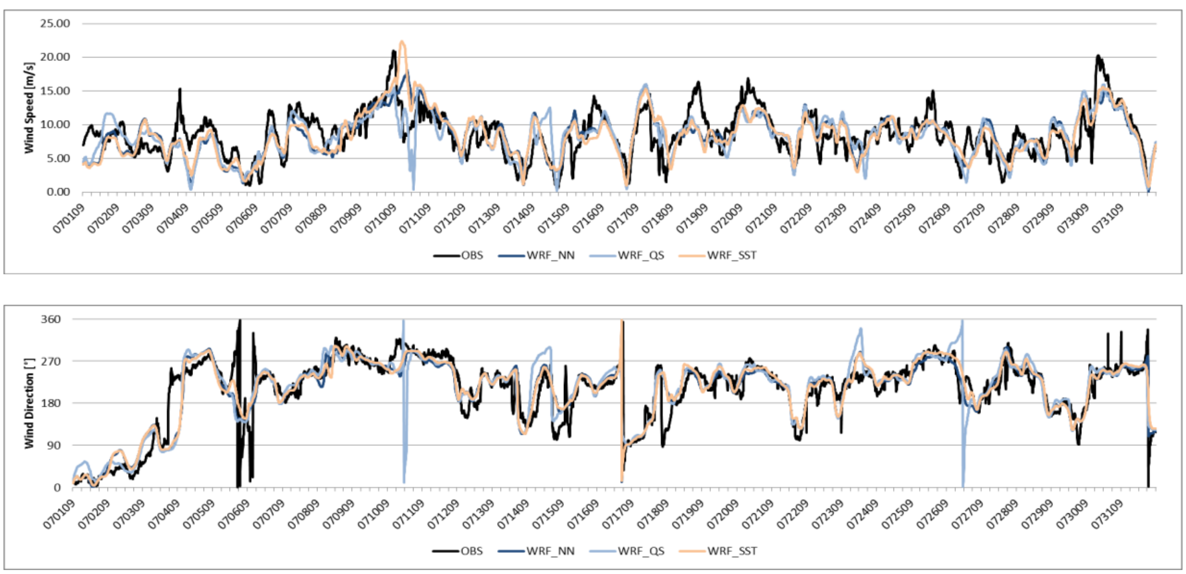

Figure 5 - Time series of wind speed (above) and direction (below) for July 2009 at FINO 1.Time series of observations (OBS), control run (WRF_NN), QS assimilation (WRF_QS) and SST assimilation (WRF_SST).

Further looking at the vertical profiles (Figure 6), the influence of SST assimilation is positive on both months, since it was able to approximate the average wind profiles. As for the assimilation of QS data the vertical profile was not altered in regard to the control run.

Table 3 - Statistics for FINO 1 point validation for July 2009.

		90 m a.g.l.			
		OBS	WRF_NN	WRF_QS	WRF_SST
WBL	AVG [m/s]	8.60	8.46	8.40	8.44
	STDEV [m/s]	3.36	3.08	3.05	3.25
	A [m/s]	9.65	9.47	9.38	9.60
	k	2.71	2.99	3.02	2.66
	CORREL	-	0.67	0.68	0.69
WSPD	MAE [m/s]	-	2.07	2.05	2.00
	RMSE [m/s]	-	2.62	2.59	2.63
WDIR	MAE [°]	-	19.98	23.93	19.35
	RMSE [°]	-	31.28	37.55	30.94

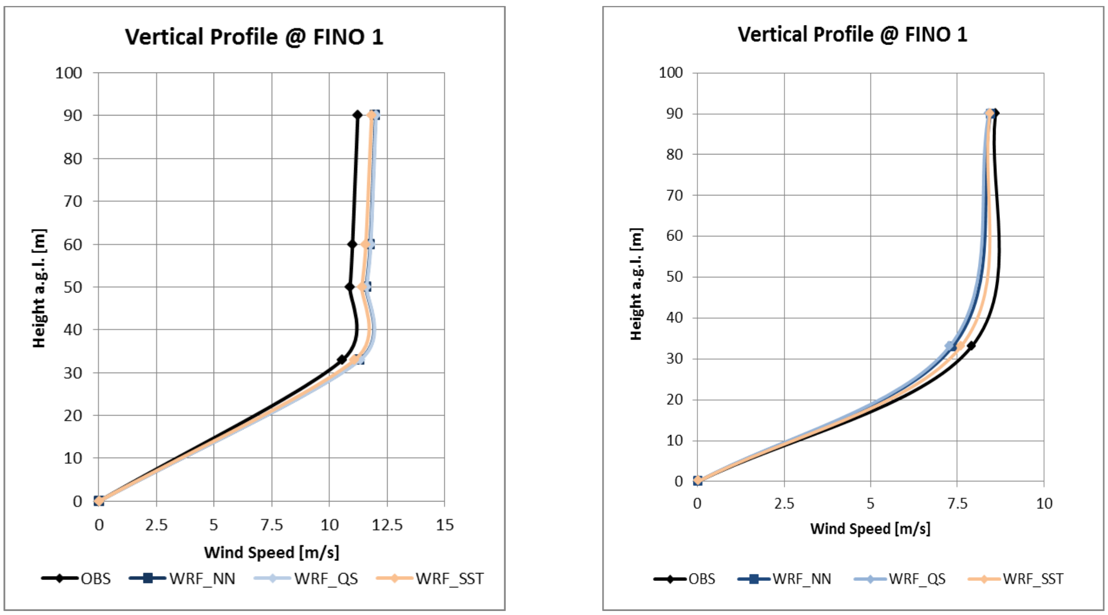

Figure 6 - Average vertical wind profile at FINO 1. Obtained for November 2008 (on the left) and for July 2009 (on the right).

3.2 Spatial Improvement

To assess the positive or negative impact of data assimilation on the overall domain, a spatial analysis was performed. The spatial improvement of the average wind field at 90 m a.g.l. was assessed taking the averaged QS data has observational data and calculating the proximity to the latter between the assimilation run and the control run (see equation 1 and 2, above). Figure 7 presents the spatial improvement for November 2008 and Figure 8 for July 2009.

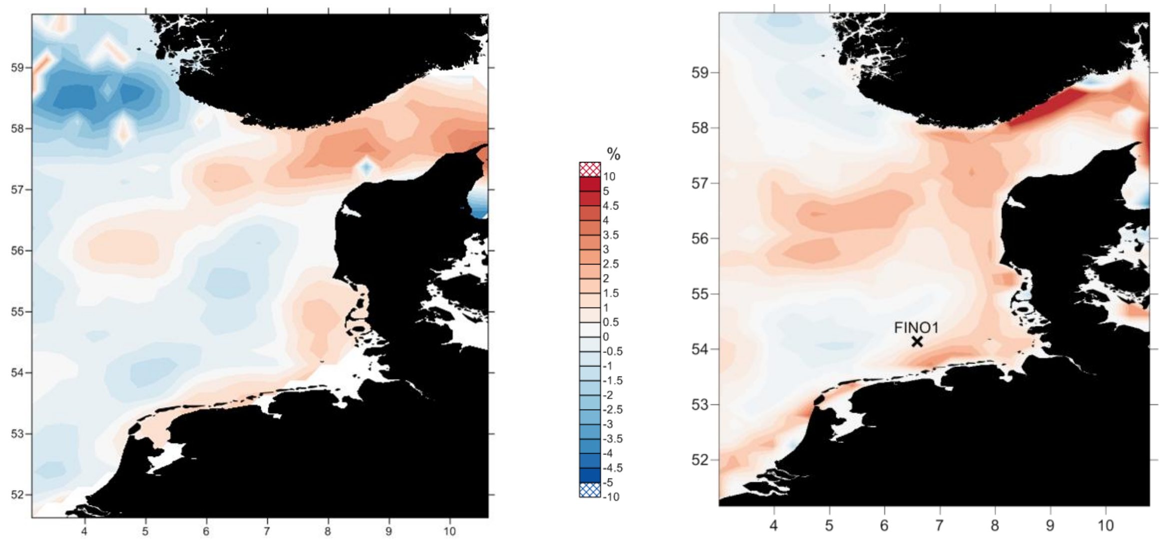

Figure 7 - Spatial improvement for November 2008. On the left the QS assimilation performance and on the right the SST assimilation performance.

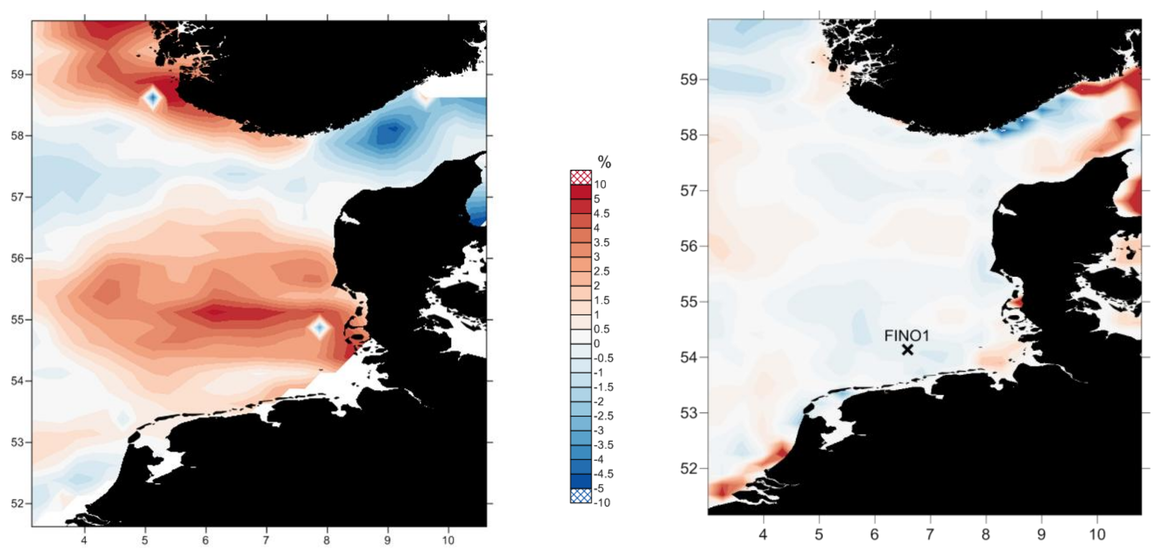

Figure 8 - Spatial improvement for July 2009. QS assimilation performance on the left and SST assimilation performance on the right.

Even though the point validation with FINO 1 met mast hasn’t shown, the QS assimilation has improved the average wind resource by more than 5 % especially in the summer period. The SST assimilation has shown a higher impact during the winter period with large areas improved between 3 and 5 %.

4.0 Conclusions

The Newtonian relaxation scheme used for assimilation in the current work has allowed improvements in the range of 5 to 10% in the summer period and from 3 to 5 % in the winter period. During the winter the assimilation of SST data shower a higher impact while as the QS assimilation shower better results during the summer.

The point validation using met mast FINO 1 did not reflect the improvements displayed by the spatial analysis. This can be explained by the fact that FINO 1 data is part of the assimilation cycles used for reanalysis product therefore being on the initial and boundary conditions ingested to the model. Nevertheless, slight improvements on the MAE and RMSE were obtained. The SST data assimilation has demonstrated ability to correct the vertical wind profile in both occasions.

5.0 References

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