Using data assimilation in mesoscale numerical modeling to map offshore wind resource

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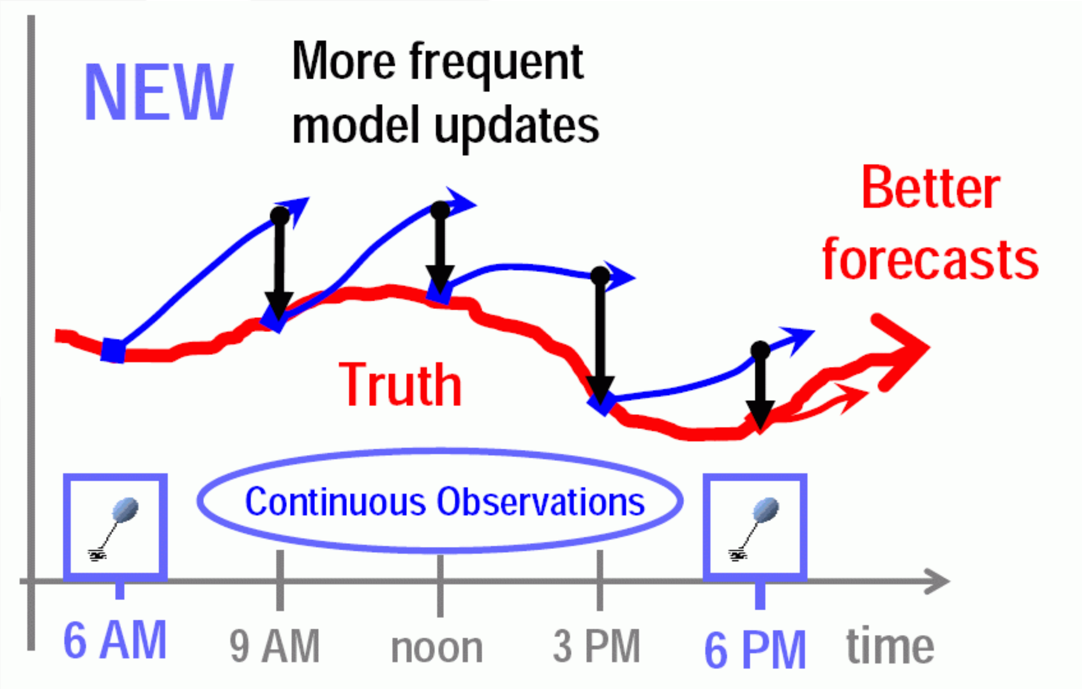
Objectives

- Use an assimilation technique coupled with an mesoscale model to ingest winds retrieved from satellites to improve the generation of offshore wind atlases on the Northern Seas area;
- Use satellite derived wind and sea surface temperature analysis to improve First Guess (FG) fields of the mesoscale model;
- Validation results performed with FINO-1 for two case studies: a summer and a winter month

Assimilation scheme

Why assimilate wind data?



- **Assimilation of observations will reduce model error forecasts**
- **Reducing errors in forecasts means getting better forecasts!**

Assimilation scheme

A “newtonian” technique...

A simple and an efficient assimilation scheme to ingest asynoptic data;

Can be used on atmospheric mesoscale models for wind atlas generation or even for weather forecasting purposes ;

It’s a 4-DVAR assimilation scheme here used for ingesting satellite data

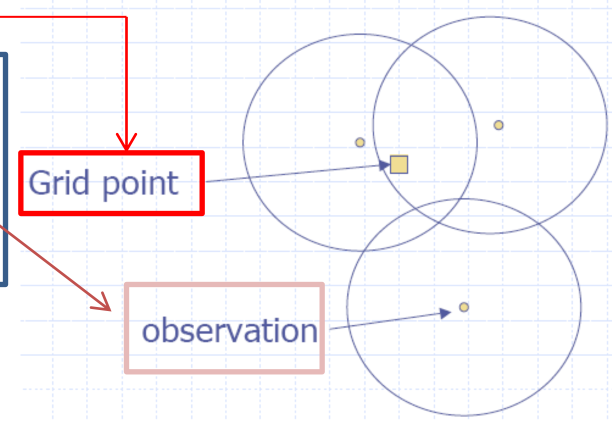
Assimilation scheme

Add a weighted term depending on error deviations between observations and model solution.

dependencies on: distance; height and time window;

$$\frac{\partial \alpha_i(\mathbf{x},t)}{\partial t} = F(\boldsymbol{\alpha},\mathbf{x},t) + G_i \cdot \frac{\sum_{j=1}^{N} W_j(\mathbf{x}-\mathbf{x}_j, t-t_j) \cdot W_j(\mathbf{x}-\mathbf{x}_j, t-t_j)\left[\alpha_j - \alpha_i(\mathbf{x}_j, t_j)\right]}{\sum_{j=1}^{N} W_j(\mathbf{x}-\mathbf{x}_j, t-t_j)}$$

Model equations



$$W_j = w_{xy}(D_j) \cdot w_\sigma(\sigma - \sigma_j) \cdot w_t(t - t_j)$$

Distance **Height** **Time window**

Already implemented on WRF-ARW model!

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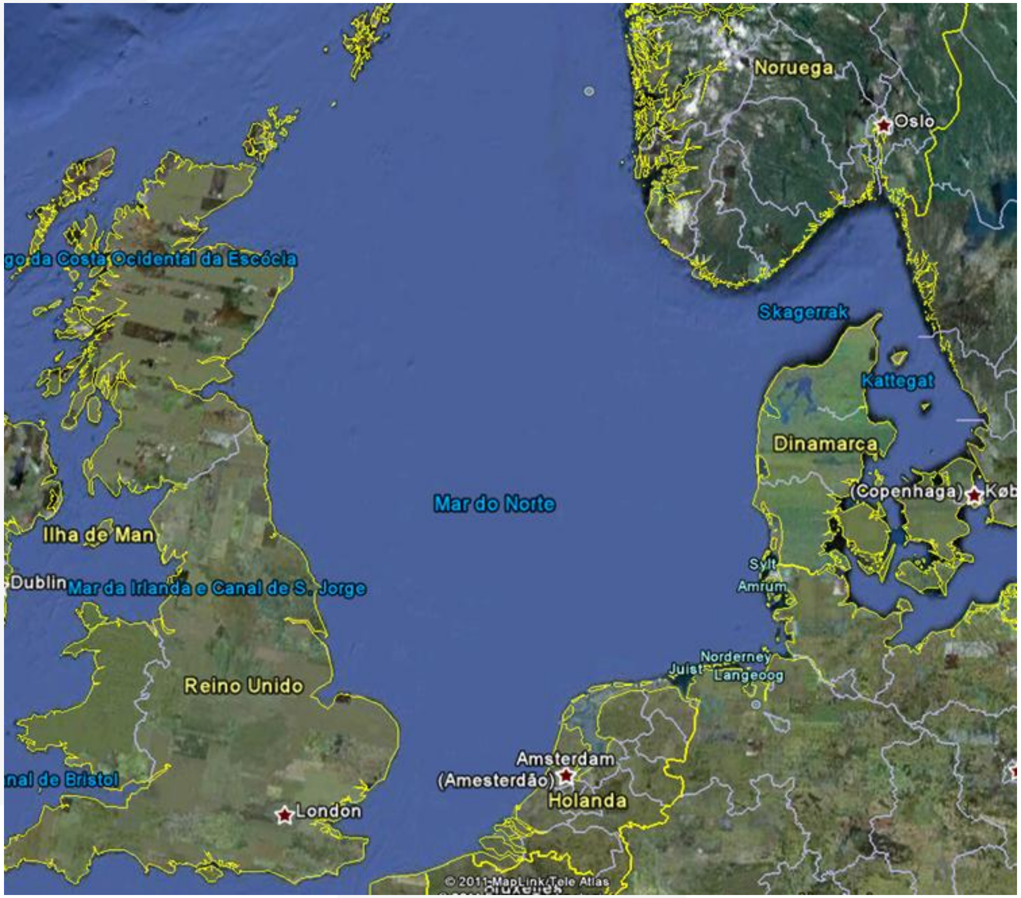
Case Study

- The area under study is the North Sea Area



Use WRF mesoscale model;

simulation tests cover two complete months, with and without satellite data assimilation:

- a winter month: (2008 November)
- a summer month (2009 June).

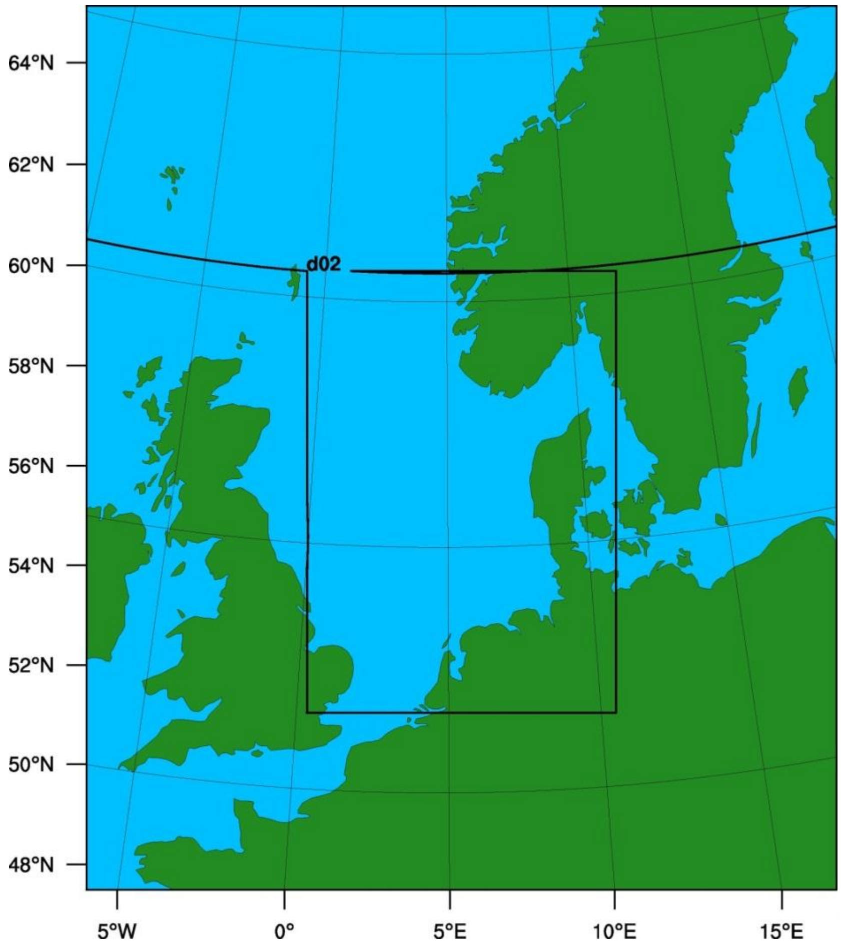
Case Study

WRF model 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

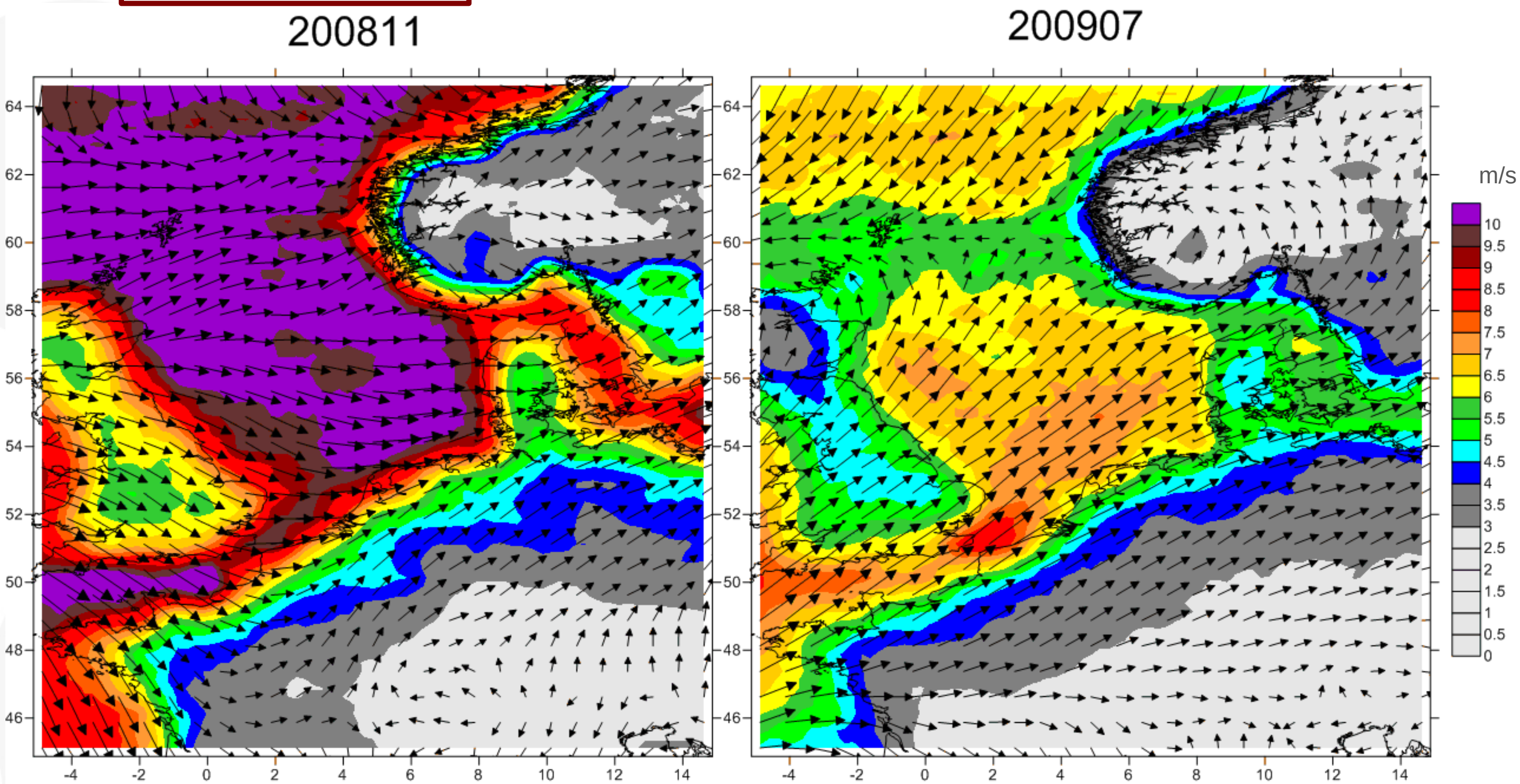
First guess (FG) fields for D1:
(Initial and boundary conditions)

P, T, Td, U,V, PMSL, SOILM, SOILT, SST, from NCAR's Reanalysis datasets.
4 times per day @ 2.5x2.5º



Sources of surface data

First guess (FG) fields for main model Domain *(Initial and boundary conditions)*



Wind

4 times per day

@ 00h;06h; 12h;18h UTC

Cross-Calibrated Multi-Platform Ocean Surface Wind Vector L3.0 First-Look Analyses

(CCMP_MEASURES_ATLAS_L4_OW_L3_0_WIND_VECTORS_FLK)

Surface Winds

Platform/Sensor:

Processing Level: 4

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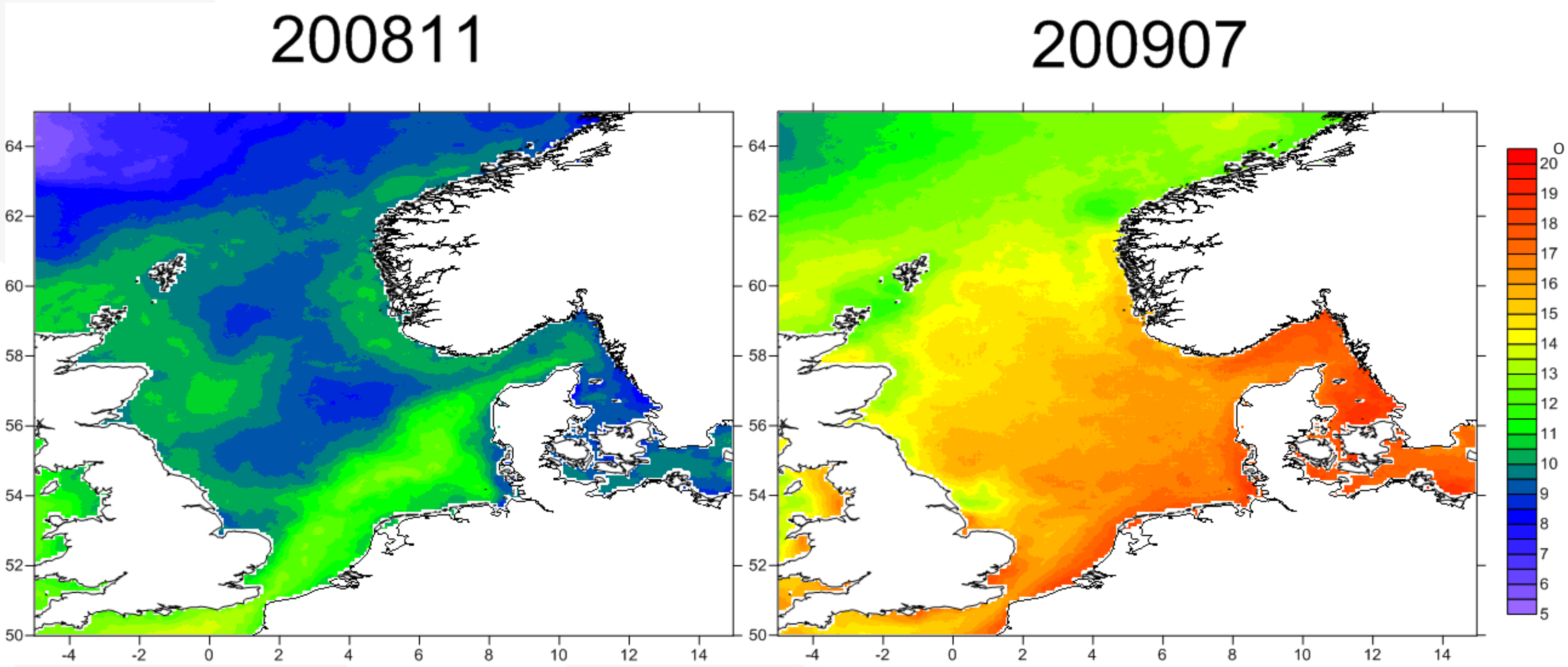
Sources of surface data

First guess (FG) fields for main model Domain *(Initial and boundary conditions)*



SST

1 time per day @ 00h UTC

GHRSST Level 4 DMI_OI North Sea and Baltic Sea Regional Foundation Sea Surface Temperature Analysis (DMI-L4UHfnd-NSEABALTIC-DMI_OI)

Sea Surface Temperature

Platform/Sensor: AQUA/AMSR-E , AQUA/MODIS , ENVISAT/AATSR ... **more**

Processing Level: 4

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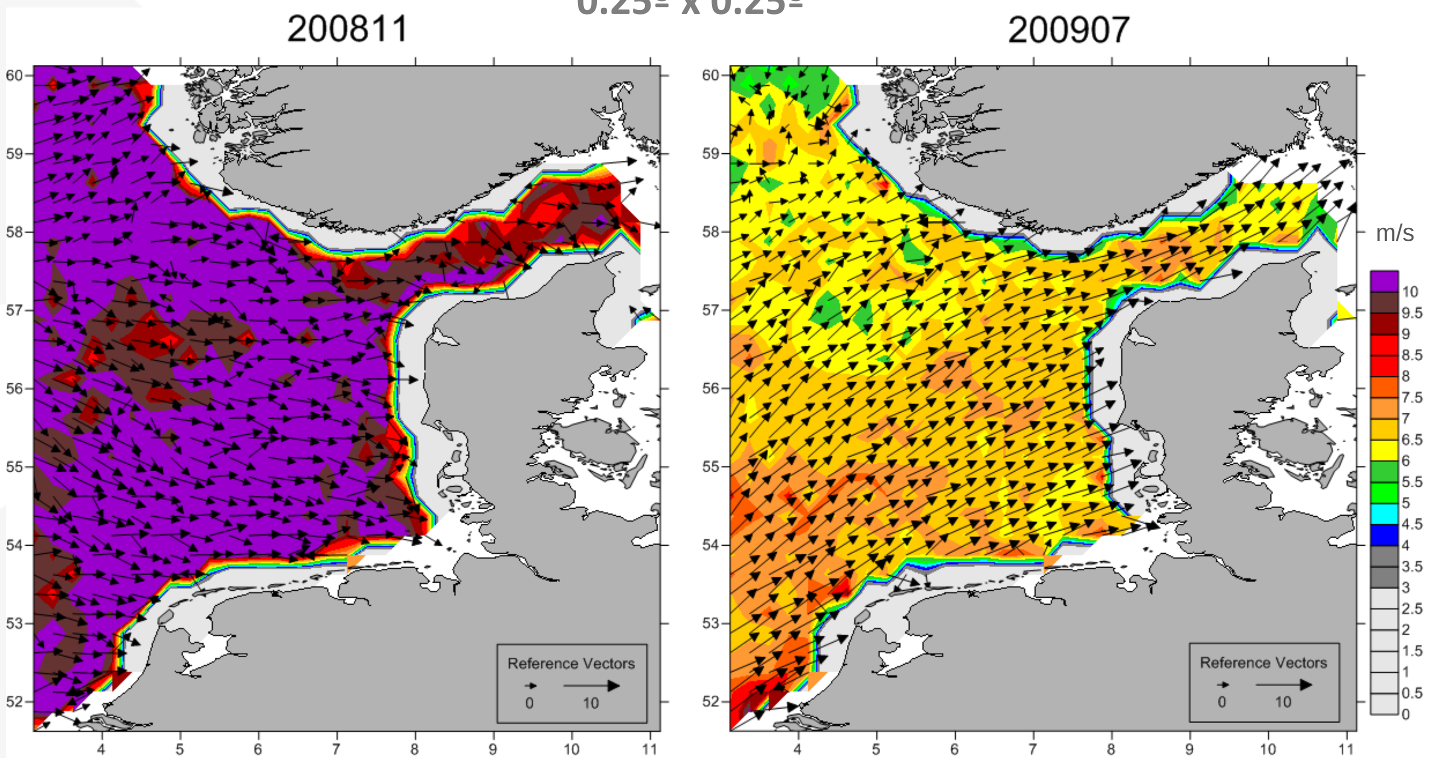
Sources of surface data

Assimilation winds retrieved from QuiKSCAT satellite (2 times per day)

0.25º x 0.25º



Wind

2 times per day

(varying in time)

SeaWinds on QuikSCAT Level 3 Daily Gridded Ocean Wind Vectors (JPL) (QSCAT_LEVEL_3)

Surface Winds

Platform/Sensor: QUIKSCAT/SEAWINDS

Processing Level: 3

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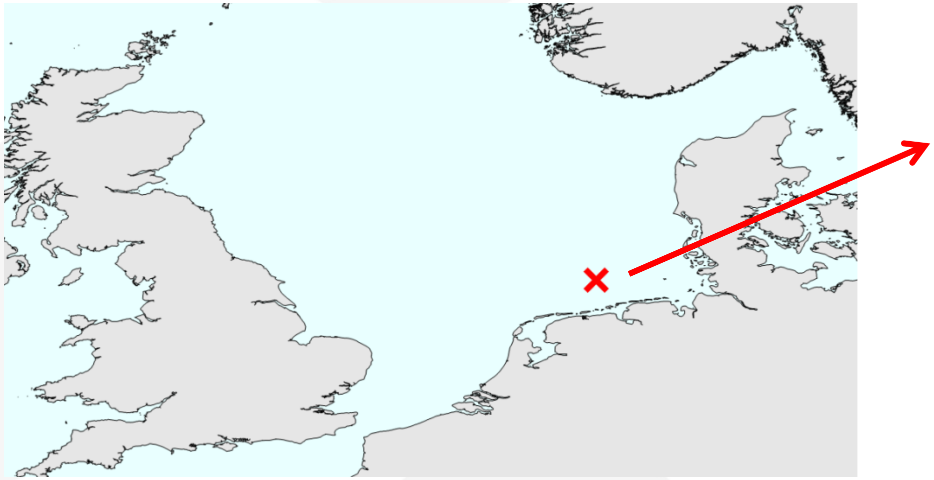
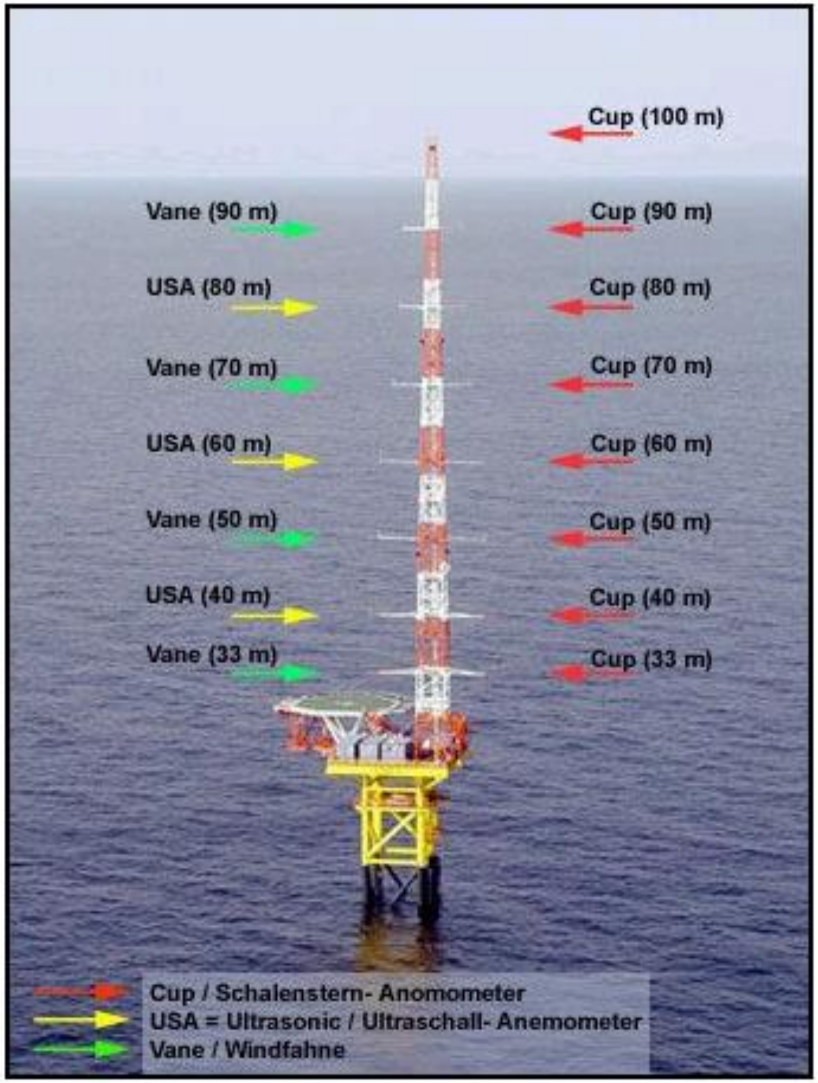
Validation site

FINO 1

offshore anemometric mast





Results: winter month

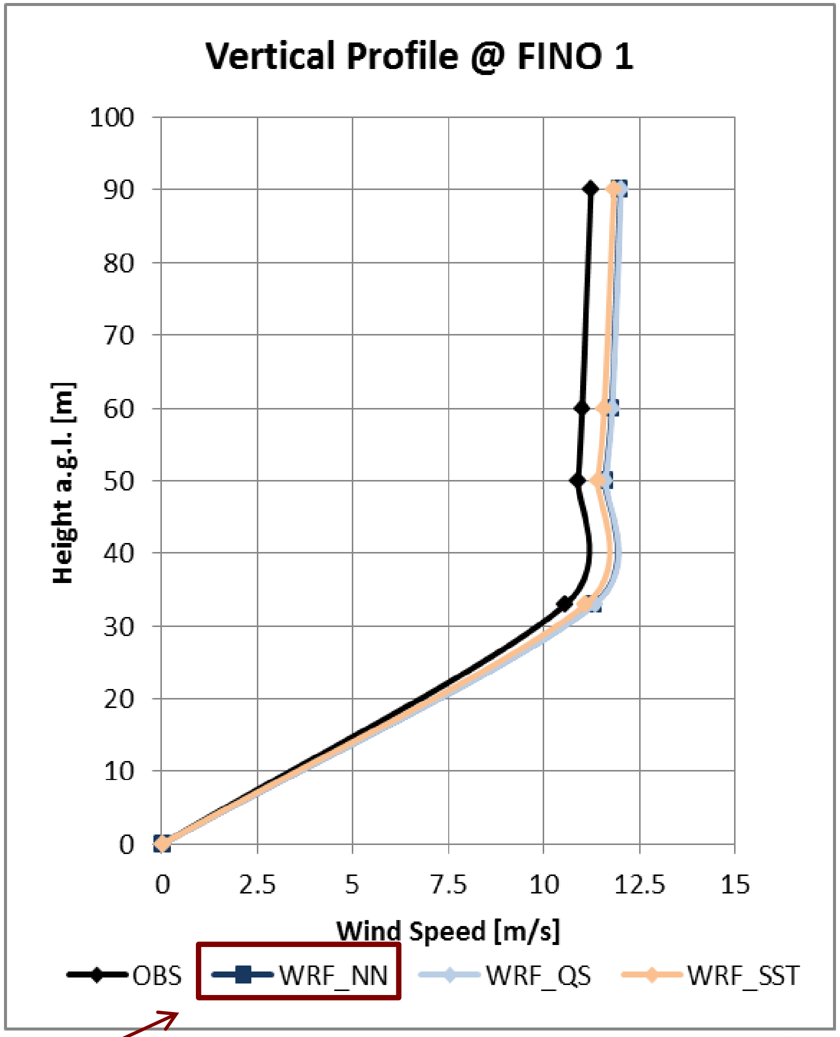
Validation statistics @ 90m (a.o.l.) with 10 min. interval

		OBS	90 m a.g.l. WRF_CR	WRF_QS	WRF_SST
WBL	AVG [m/s]	11.23	12.00	12.02	11.83
WBL	STDEV [m/s]	4.53	4.43	4.20	4.40
WBL	A [m/s]	12.62	13.46	13.45	13.20
WBL	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
WSPD	RMSE [m/s]	-	2.82	2.65	2.62
WDIR	MAE [°]	-	12.39	12.96	11.83
WDIR	RMSE [°]	-	17.14	18.10	16.48

Control run ingested with FG fields

QSCAT assimilation (only)

SST assimilation (only)



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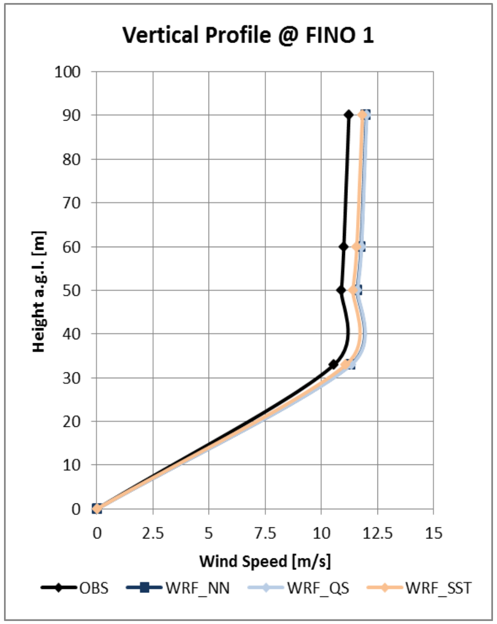
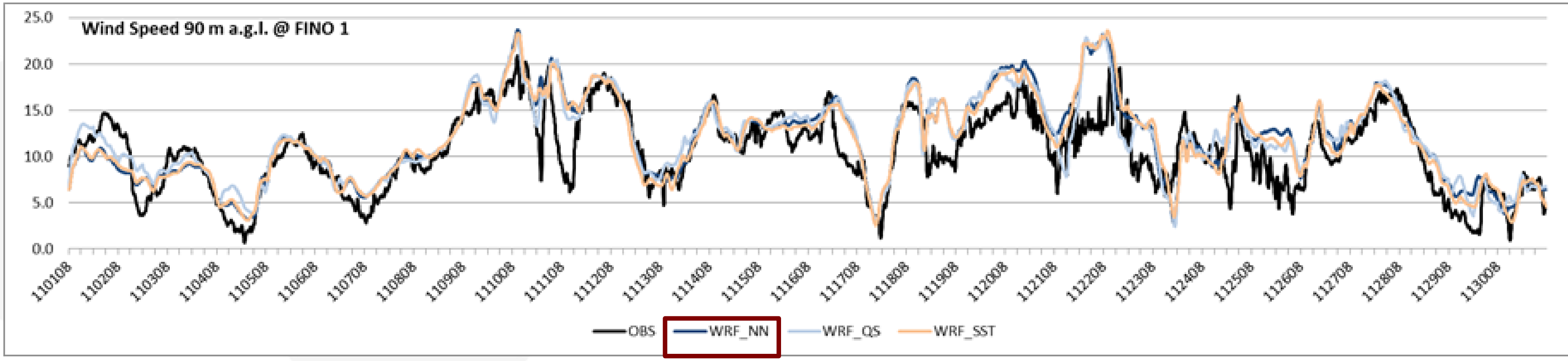
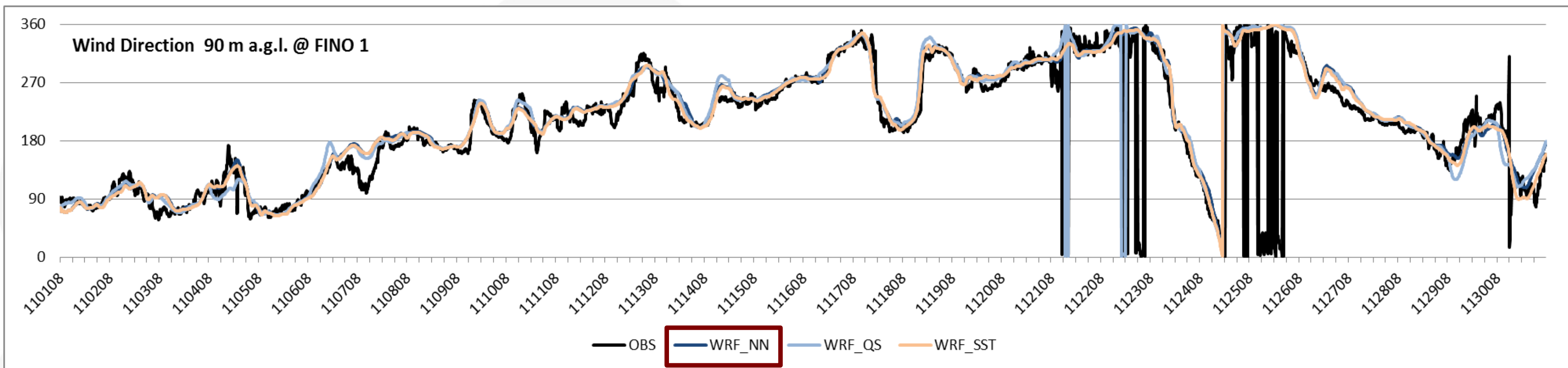


- Correlation values of about 83%. WRF model predicts higher wind speed than the observed;
- QuiKSCAT assimilation had a low but positive impact on improving simulated winds at 90m (a.o.l.);
- SST data assimilation contributed to improve the wind fields at all levels observed at FINO 1.

Results: winter month



Control run



Control run

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Results: summer month

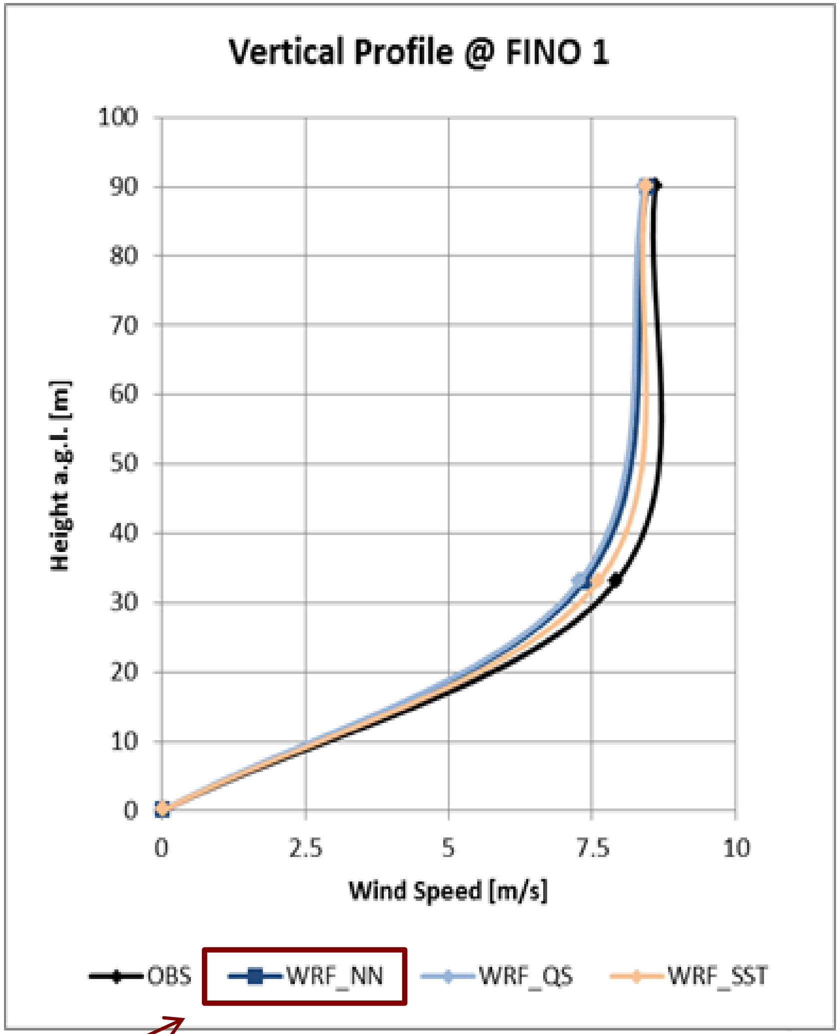
Validation statistics @ 90m (a.o.l.) with 10 min. interval

		90 m a.g.l.			
		OBS	WRF_CR	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

Control run ingested with FG fields

QSCAT assimilation (only)

SST assimilation (only)



Results: summer month

Validation statistics @ 90m (a.o.l.) with 10 min. interval

			90 m a.g.l.		
		OBS	WRF_CR	WRF_QS	WRF_SST
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	A [m/s]	9.65	9.47	9.38	9.60
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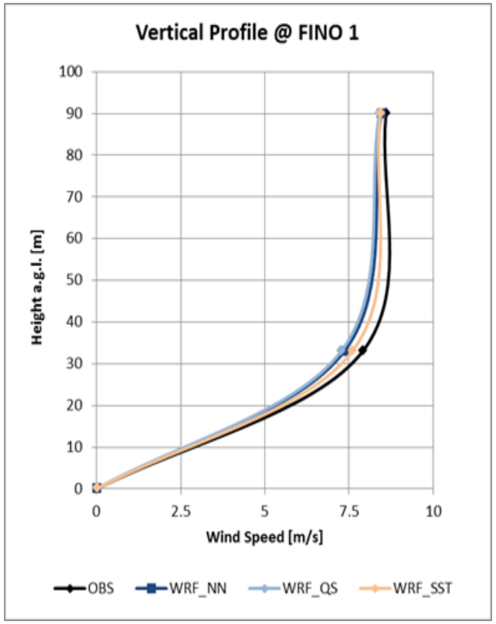

- Correlation values of about 68%. WRF running @ 20x20km spatial resolution tends to not correctly represent the thermal stratification phenomena activity on summer months. Model predicts less wind speed than the observed;

- QuiKSCAT and SST assimilation runs revealed a lower impact on improving simulated winds at 90m (a.o.l.);

- High resolution runs (e.g. 2x2km) should be investigated for improve the predicting of summer phenomena's in the North Sea.

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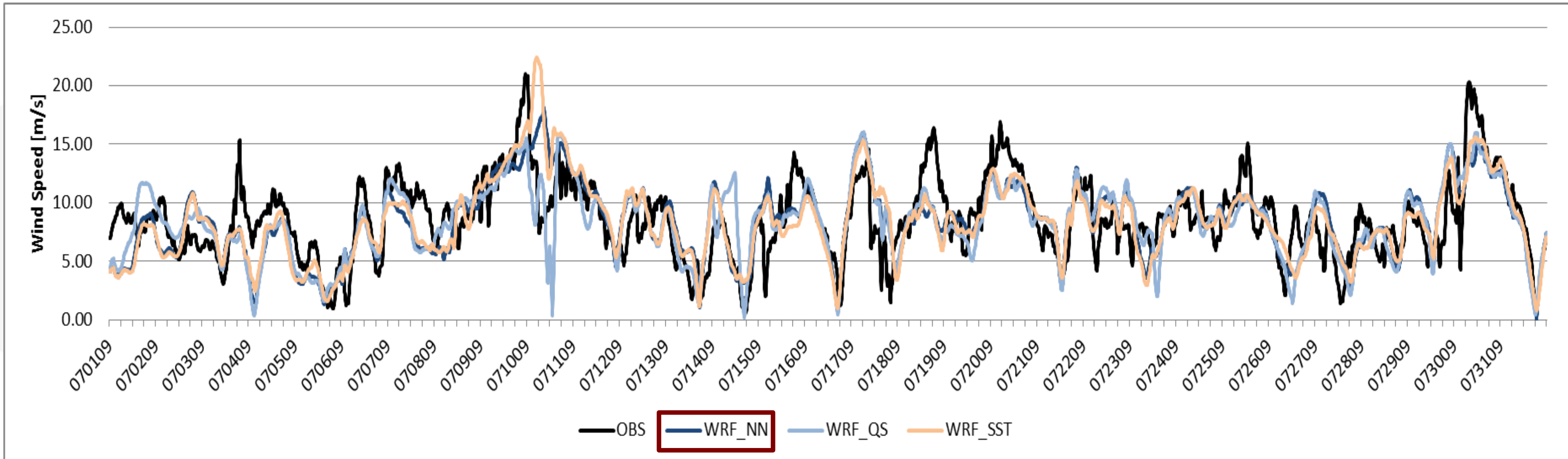
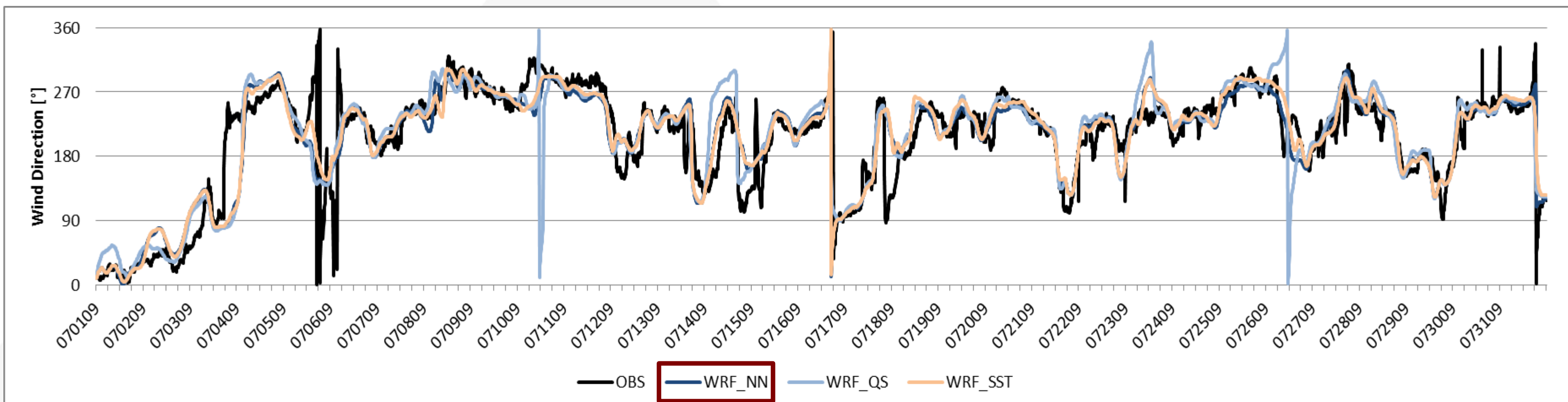
Results: summer month



Control run



Control run

Assimilation spatial improvement

- A spatial assimilation improvement was also performed in this study.
- The improvement consists on assessing the positive or negative benefits of using the assimilation technique by comparing model results with the control run and observations.

Improvement formulation:

$$I_{WIND}\,(\%) = 100 \times \frac{\|CR - QS\| - \|AS - QS\|}{\|CR - QS\|}$$

Iwind = Improvement in wind (%)

CR = control RUN simulation

QS = QuiKSCAT observations

AS = QuiKSCAT assimilation run

$$I_{SST}\,(\%) = 100 \times \frac{\|CR\| - \|AS_{SST}\|}{\|CR\|}$$

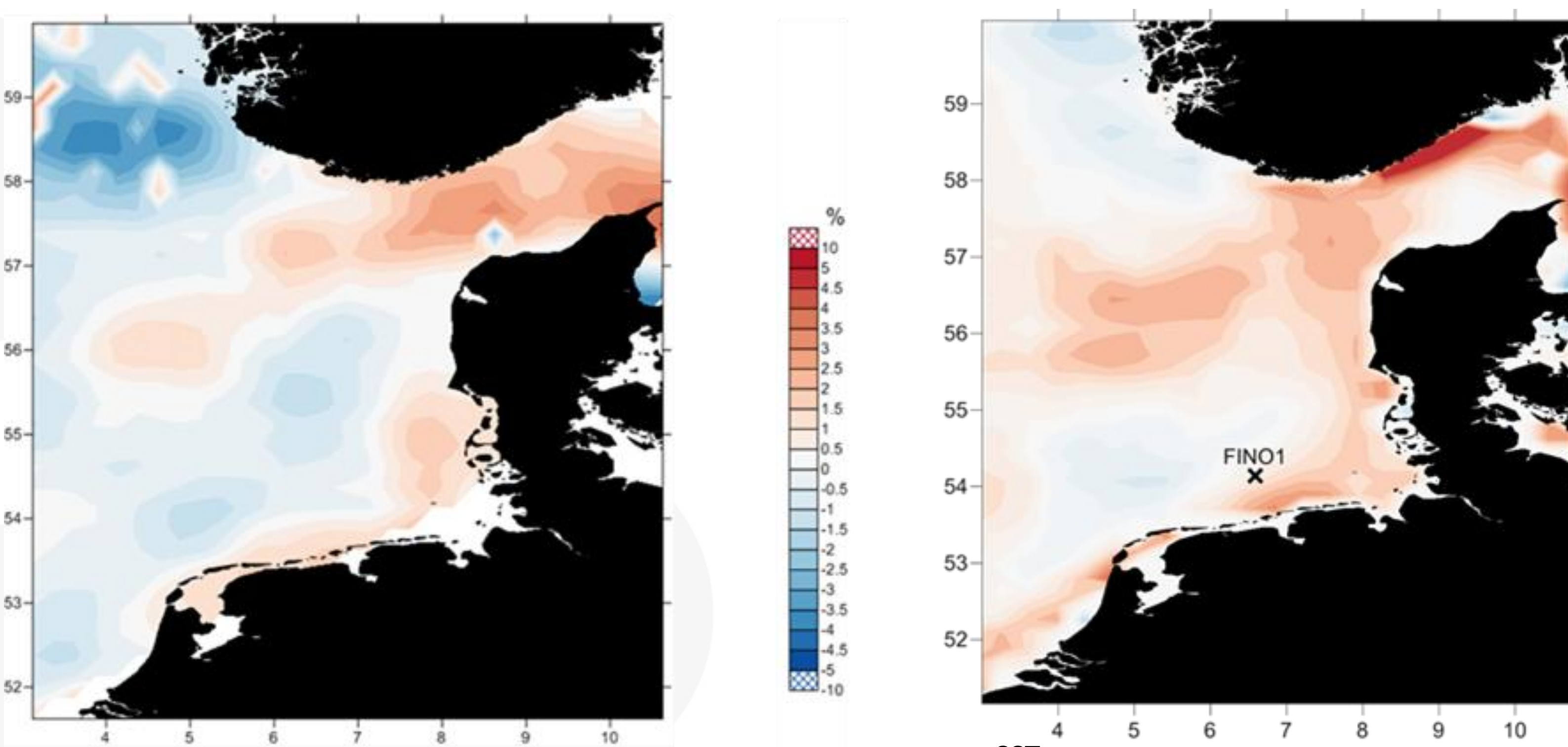
Isst = Improvement in wind by SST (%)

CR = control RUN simulation

ASsst = SST assimilation run

Assimilation spatial improvement

Improvement results for winter month (November 2008)



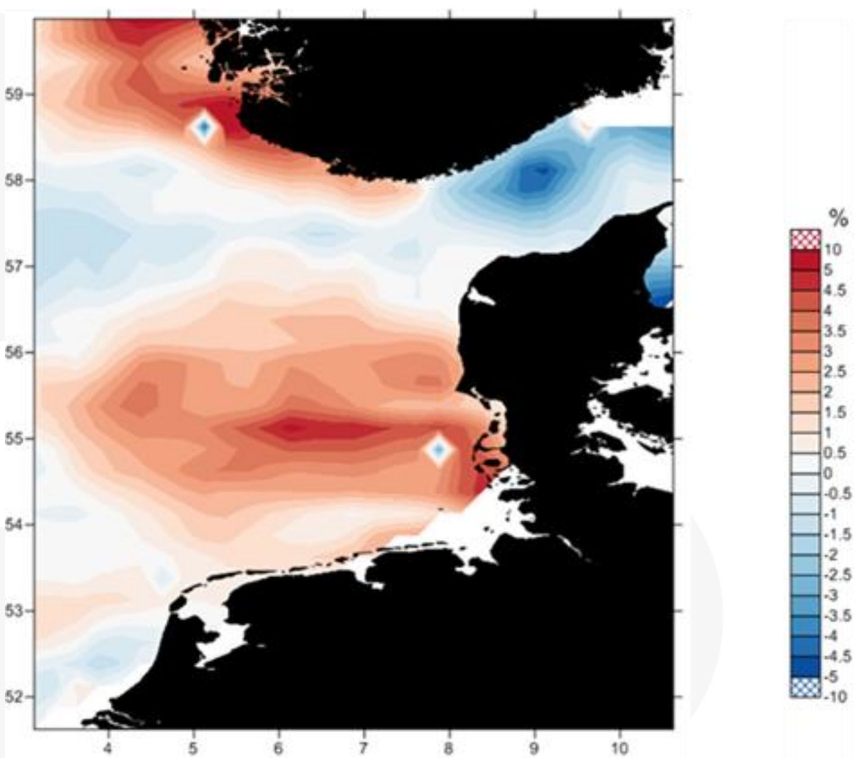
Wind

SST

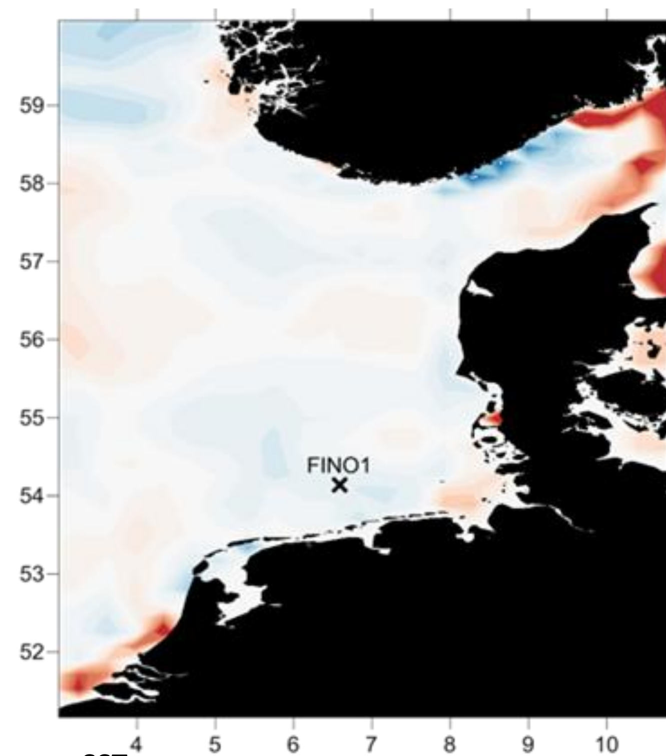
The SST assimilation showed a higher positive impact with large areas having a positive impact over the ocean but especially near the coast.

Assimilation spatial improvement

Improvement results for summer month (July 2009)



Wind



SST

The QuiKSCAT assimilation showed positive impacts over the ocean. SST assimilation had a neutral impact.

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Conclusions

- The assimilation technique here used to assimilate winds from the QuikSCAT and SST from the GHRSST databases has allowed improvements in the range of 5 to 10% for the summer period and 3 to 5 % for the winter period;

- During winter, SST assimilated data tends to show a positive impact while QuiKSCAT data assimilation shows better results during the summer period;

- It should be noticed that the SST data assimilation has demonstrated ability to correct the vertical wind profile on both occasions, during the summer and winter cases;

Conclusions

- In the summer case, correlations of about 68% were obtained. This means that WRF model even coupled with the assimilation technique running @ 20x20km spatial resolution was not enough to capture the thermal stratification phenomena activity on the North Sea;

- Better results could be achieved if they were performed on higher spatial resolutions (e.g. 5x5km).

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Thank You

Aknowledgments:
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