Validation of an offshore wind atlas using satellite data available at coastal regions of Portugal

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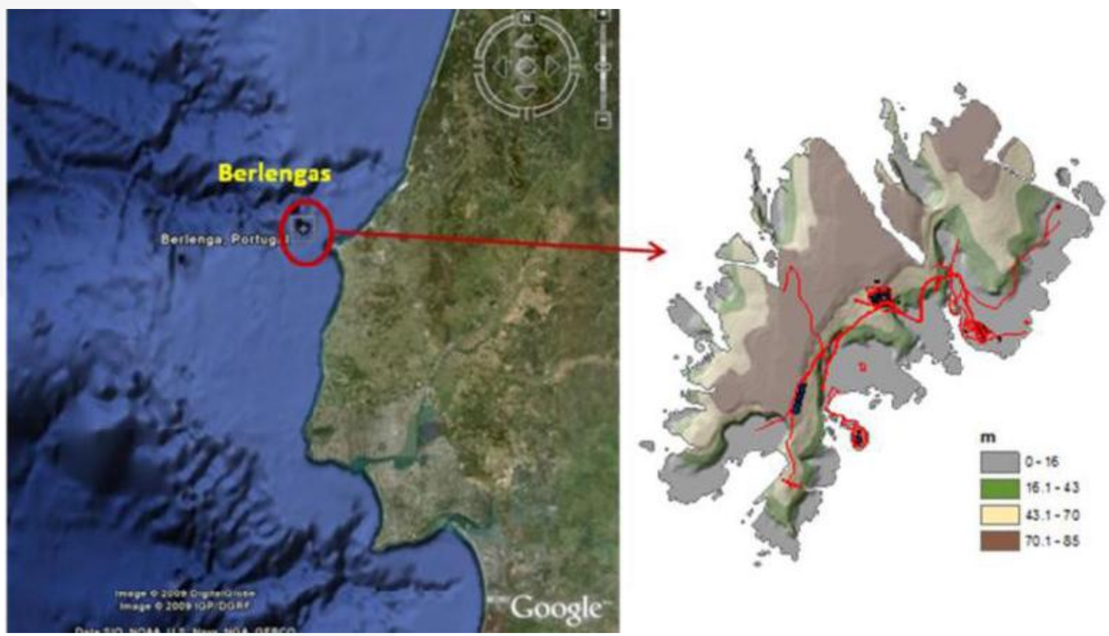
Objective

- The objective of this work is to compare two different spatial interpolation schemes – Kringing and a innovative composite method developed for spatial validation purposes;
- A long term wind flow simulation provided by the WRF mesoscale model and an observational source of surface wind data retrieved from the QuikSCAT satellite will be used on the evaluation of this spatial validation methodology.

Test Site

- To access the quality of the validation methodology, one evaluation test was performed with an anemometric mast installed on the Berlenga Island.



- The Berlenga Island is a small rocky island located about 10 miles away to the west coastal region of Peniche, in the vicinity of the Lisbon region.

Methodology

- First it was computed the mean bias at each QuikSCAT location using the nearest WRF grid point:

$$\text{BIAS}(x) = \frac{1}{N}\sum_{i=1}^{N} \text{Wind}_{\text{WRF}}(x) - \text{Wind}_{\text{QuikSCAT}}(x)$$

- Secondly, a spatial deviation matrix was computed with the help of the spatial interpolation schemes:

  - Kriging interpolation method

  - New Composite method

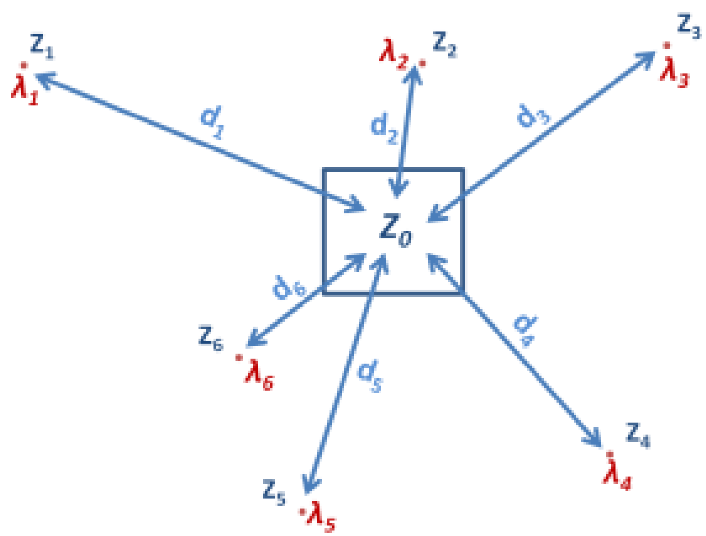
Methodology - Kriging

Kriging interpolation method

- The Kriging interpolation scheme is a best linear unbiased estimator (BLUE) that minimizes the spatial variance with a stochastic spatial function known as variogram. A simple formulation of this method can be expressed by:

$$z_0^* = z^*(x_0) = \sum_{i=1}^{N} \lambda_i \, z(x_i)$$

z_0^*: predicted value at x0;
λi: weight at location xi;
di: distance between xi and x0;
N: Number of sample values used in prediction;



Methodology - Composite

Composite method

- The Composite method is a spatial interpolation tool developed by LNEG where the deviation matrix is computed as a weighted linear combination of several data points.
- The linear coefficients associated to each grid point are calculated according to the inverse distance but applied to the nearest points.
- The distance is automatically computed via a radius of influence which depends on the spatial variance of the data.

Methodology

- Finally, the quality of each spatial interpolation method is inferred with the wind data available from the anemometric mast on the Berlenga Island.

- The BIAS and MSESS (Mean square error skill score) are the statistical parameters for score the validation results.

- (Score) $$MSESS = \frac{MSE_{WRF} - MSE_{WRF+Deviation}}{MSE_{WRF}}$$

Where MSE are defined as:

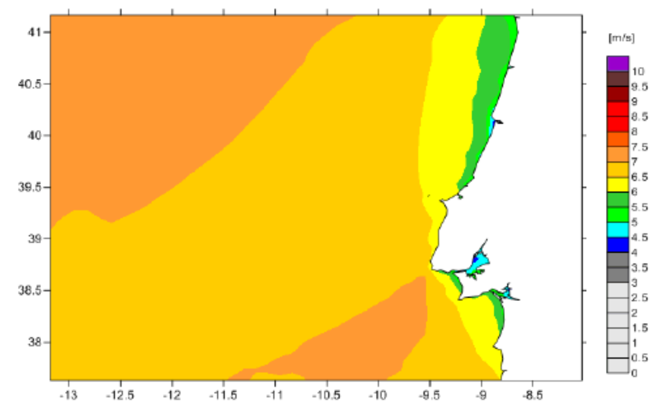
$$MSE(x) = \frac{1}{N}\sum_{i=1}^{N}\left[\left(Wind_{WRF}(x) - Wind_{QuikSCAT}(x)\right)\right]^2$$

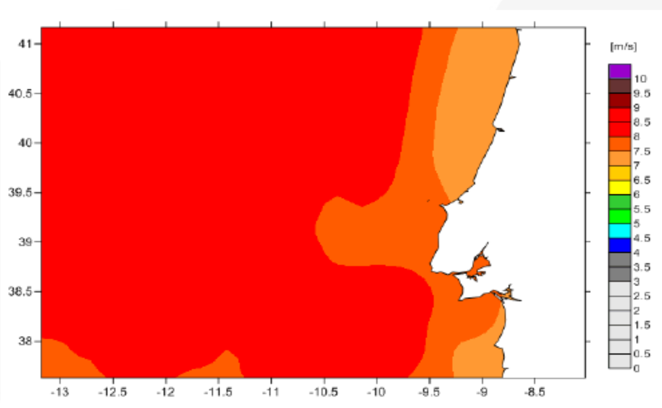
$$MSE_{WRF+Deviation} = \frac{1}{N}\sum_{i=1}^{N}\left[Wind_{WRF}(x) + BIAS(x)\right]^2$$

Case Studies: Data

Data used for both spatial interpolation schemes:

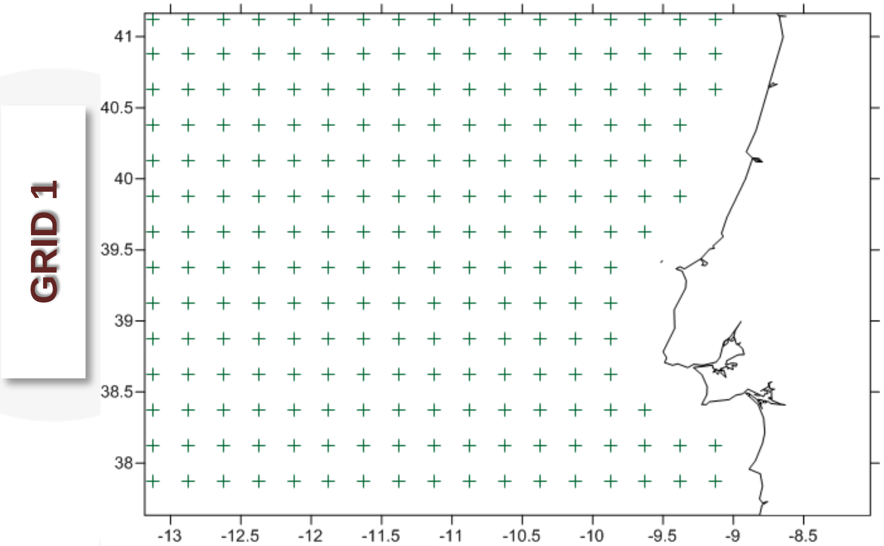
- Ten years of wind data (2000-2009) simulated with the WRF mesoscale model, @ 10x10Km resolution for 21m height (a.g.l).





- Ten years of QuikSCAT satellite data (2000--2009) on the same model domain area. Wind data were extrapolated to 21 m (a.g.l.) with an alpha coefficient of 0.104.

Case Study A

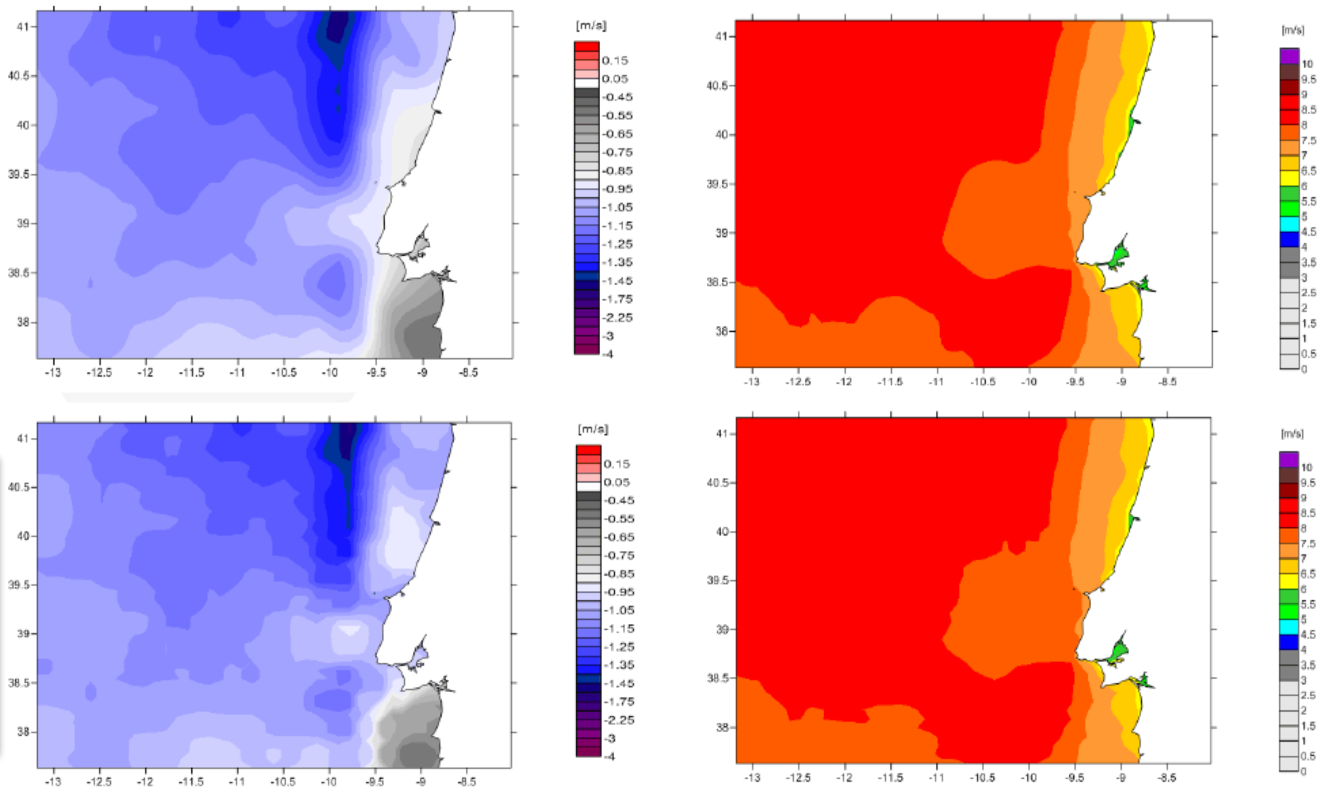


- This is the grid with all the available QuikSCAT data points on the area were the computation of the deviation matrix – GRID 1 – will be performed.

Case Study A – Kriging and Composite Results

KRIGING

COMPOSITE

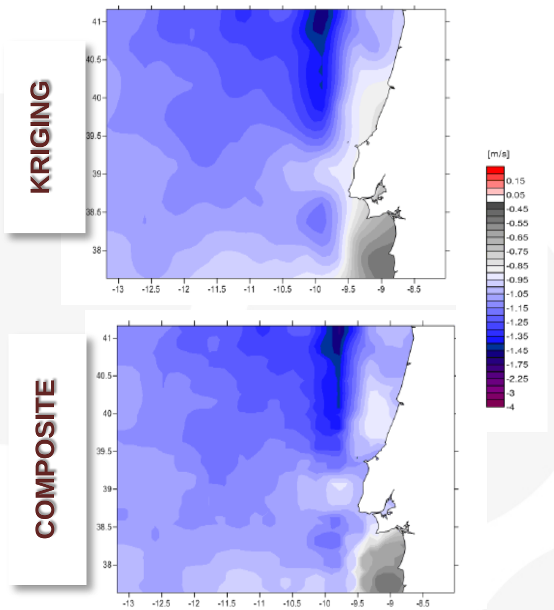


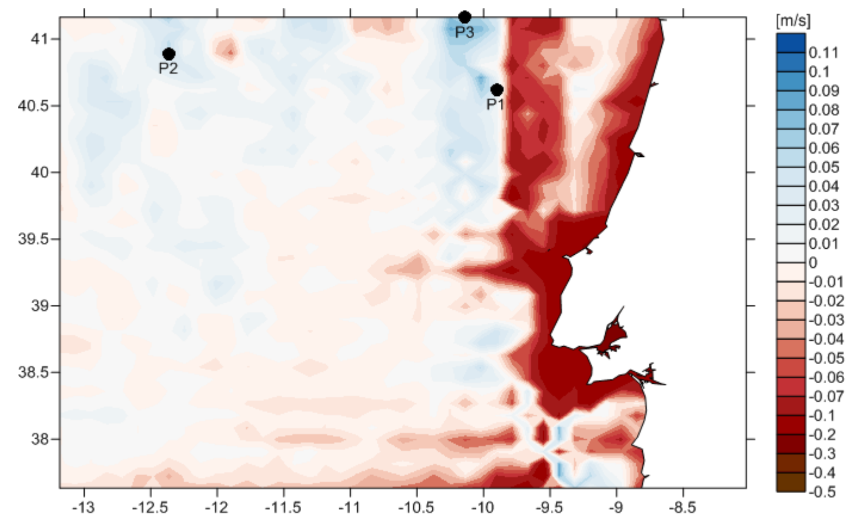
DEVIATION MATRIX

WRF wind map + DEVIATION MATRIX

Wind Speed (m/s)

Case Study A - Results





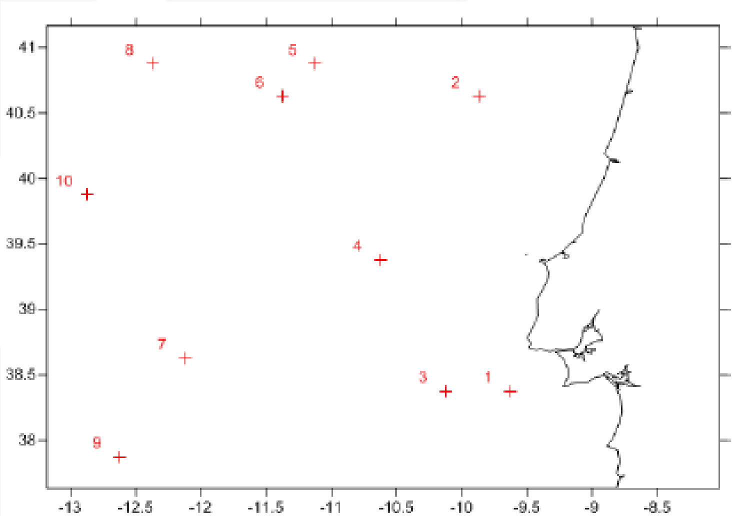
“KRIGING “ – “COMPOSITE” DEVIATION MATRIX

		QuikSCAT	WRF	Kriging	Composite
P1	Wind speed (m/s)	8.04	6.75	8.15	8.11
	Bias (m/s)	-	-1.29	0.11	0.07
P2	Wind speed (m/s)	8.12	7.19	8.44	8.38
	Bias (m/s)	-	-0.94	0.32	0.26
P3	Wind speed (m/s)	8.01	6.79	8.32	8.27
	Bias (m/s)	-	-1.22	0.31	0.26

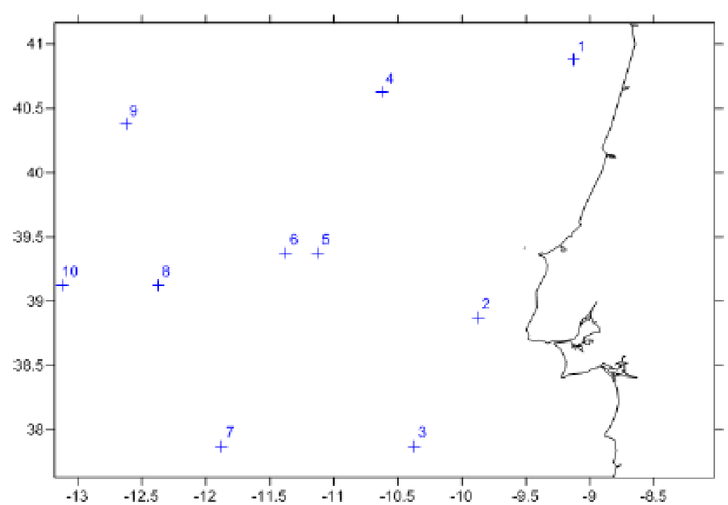
- Spatial validation assessment quality with 3 independent QuiKSCAT data points.

Case Study B

- This case study is based on two different spatial grid generation (GRID2 +GRID3) with the interpolation schemes from a selection of ten QuikSCAT data points to compose the final deviation matrix



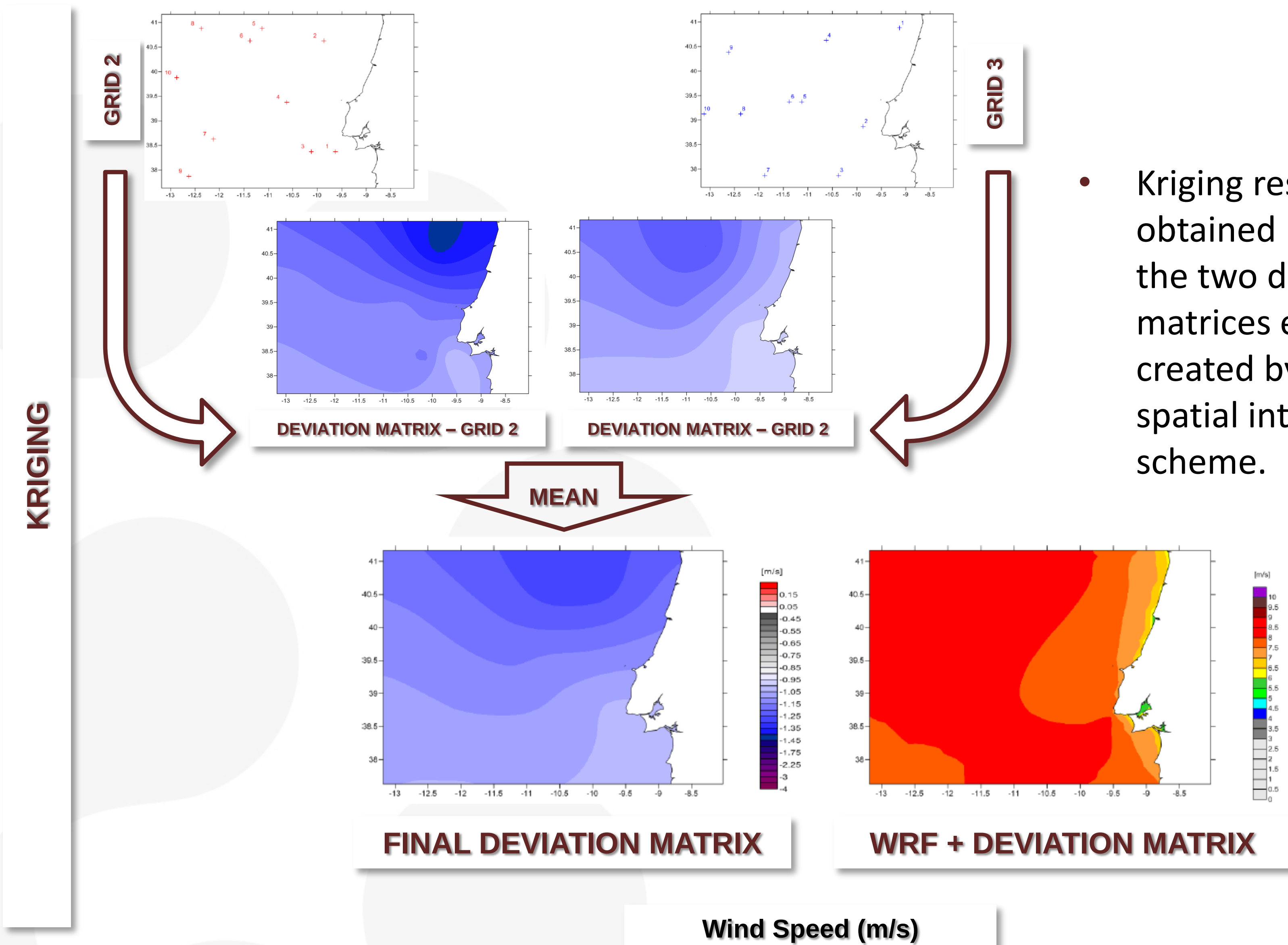
GRID 2



GRID 3

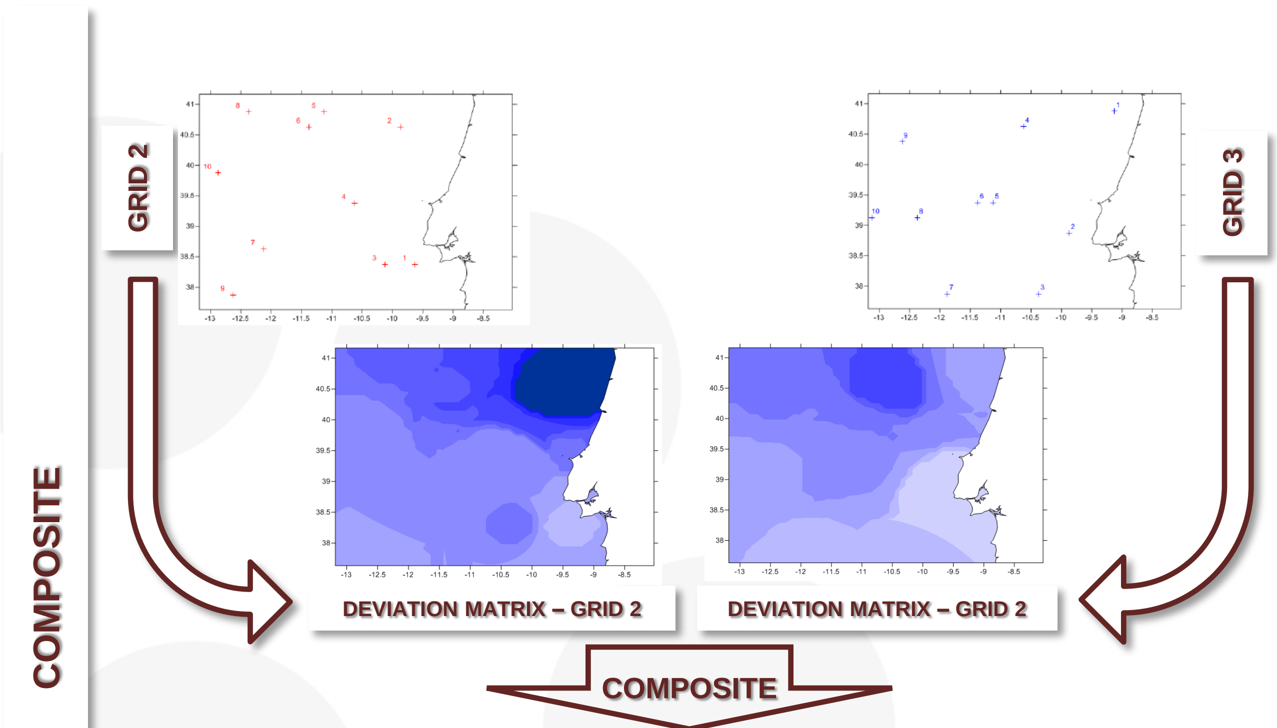
- This approach can be very useful when is available other sources of wind satellite data unsynchronized in space (e.g. SAR data).

Case Study B - Kriging

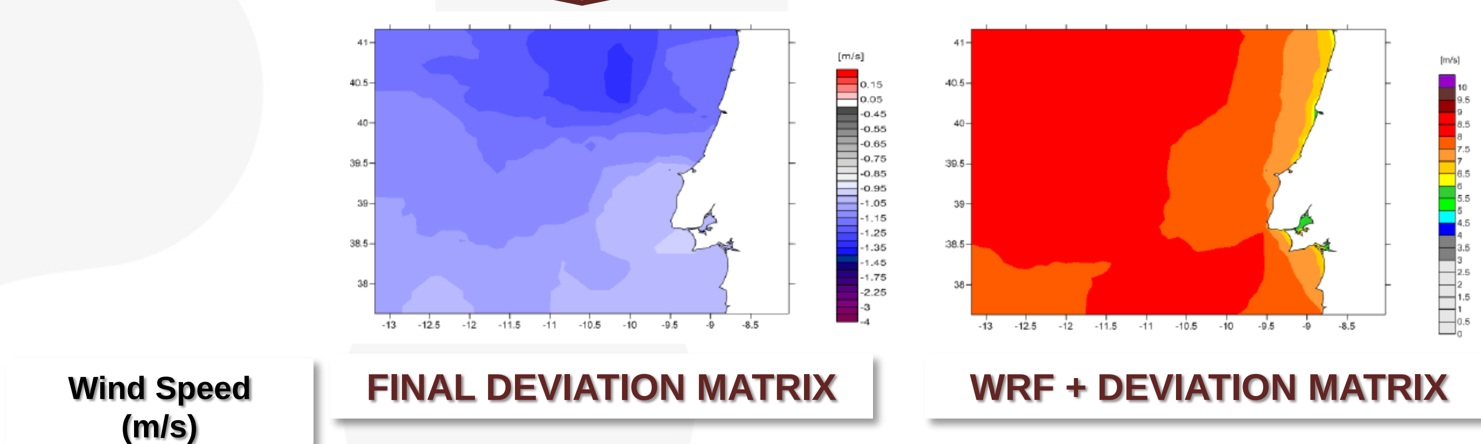


- Kriging results were obtained by averaging the two deviation matrices each one created by the Kriging spatial interpolation scheme.

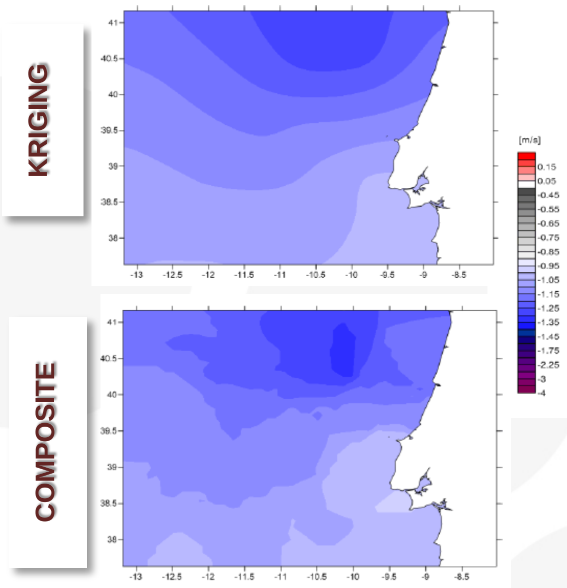
Case Study B - Composite



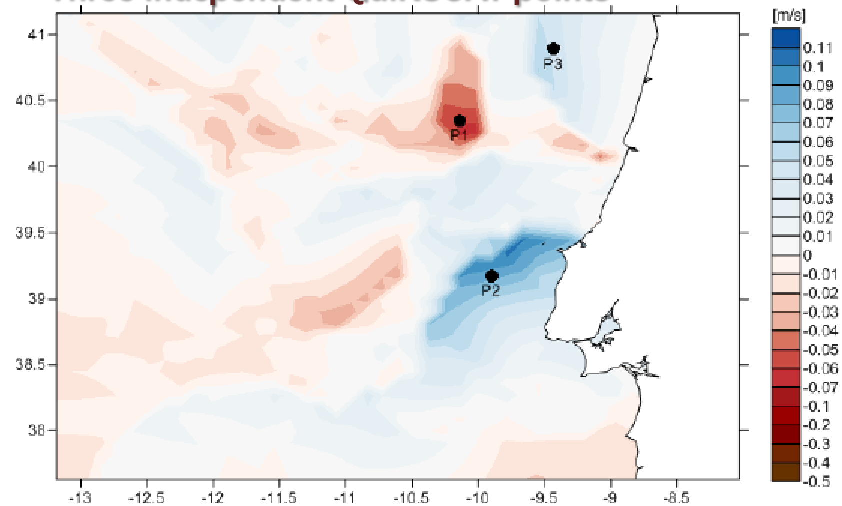
- Results from the Composite interpolation scheme were assessed in a similar approach as kriging ones:



Case Study B - Results



Three independent QuiKSCAT points



"KRIGING " – "COMPOSITE" DEVIATION MATRIX

		QuikSCAT	WRF	Kriging	Composite
P1	Wind speed (m/s)	8.27	6.90	8.03	8.09
	Bias (m/s)	-	-1.37	-0.24	-0.18
P2	Wind speed (m/s)	7.77	6.83	7.78	7.70
	Bias (m/s)	-	-0.94	0.01	-0.07
P3	Wind speed (m/s)	7.58	6.46	7.69	7.64
	Bias (m/s)	-	-1.12	0.11	0.06

- Maximum bias values are obtained by the Kriging interpolation method.

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Evaluation Results

- An evaluation of the quality of the interpolation schemes was performed with the observed wind data from Berlenga anemometric mast (operating period since 2006).

				Case A		Case B	
	WRF	QuikSCAT	Mast	Kriging	Composite	Kriging	Composite
Mean (m/s)	6.58	7.56	7.27	7.33	7.28	7.44	7.31
Bias (m/s)	-0.69	0.29	-	0.66	0.01	0.17	0.04
SCORE (%)	-	-	-	99.24	99.97	93.93	99.66

- Results shows similar behaviors (scores between 99% - 100%) for both spatial methods.
- On case study B, the Composite method has achieved a performance near 100% against the 94% of the Kriging method.

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Conclusions

- For case study A, the bias of the two methodologies at the selected points shows that the Composite method has better performance on all studied cases.

- On case study B, where Kriging shows a better performance on the blue areas and the Composite method shows a better performance on the red areas.

- Comparing all Kriging and Composite results it is noted that maximum bias values are always obtained by the Kriging interpolation method.

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Conclusions

- Case A results show a similar behavior (scores between 99% - 100%) for both spatial methods when all the available reference data was used.

- Case study B, Composite method, has achieved a performance near 100% against 94% by the Kriging method.

- The high scores enhances the fact that:

  - inferred satellite wind data for the region around Berlenga island has good quality for validation purposes;

  - Are also suitable to be assimilated on high resolution mesoscale models for offshore wind atlas generation studies.

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Thank You

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