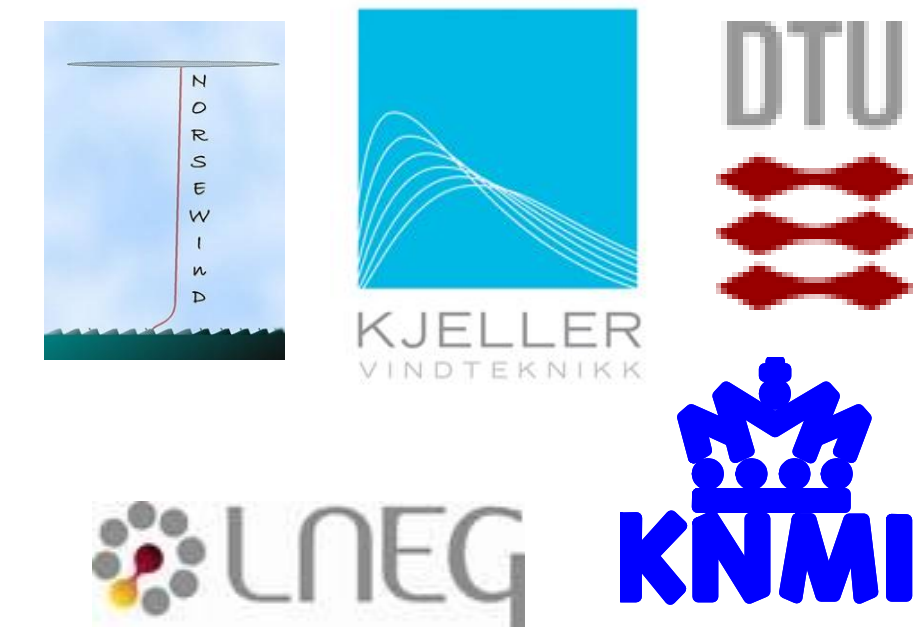


On the utilization of meso-scale models for offshore wind atlases

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Abstract

Two different offshore wind atlases based on the meso-scale model WRF are presented and discussed in this paper. The Work is part of the EU-funded project NORSEWIND (Northern Seas Wind Index Database). Validations show that annual average wind speeds and wind-roses at hub-height (100m) are well represented by the model, while the model accuracy is poorer for vertical wind profile, wind shear parameters and static stability.

Objectives

The overall objective is to gain insight into the quality of the meso-scale model derived wind conditions such as wind speed, wind direction, Weibull-k and wind shear.

Methods

East North Sea Wind Atlas.

The WRF (Weather Research and Forecast) model set up by Kjeller Vindteknikk is seen in Figure 1. The innermost domain corresponds to Focus Area 1 of NORSEWIND. The model has 3 nested domains and 32 layers in the vertical. The horizontal resolutions are 2 km, 6 km and 18 km for the inner, the middle and outer domain respectively. We apply the YSU scheme for the PBL-parameterization (see Table 2). The model is run for 1 year (01.05.2006-30.04.2007). Initial and boundary values are obtained from NCEP.

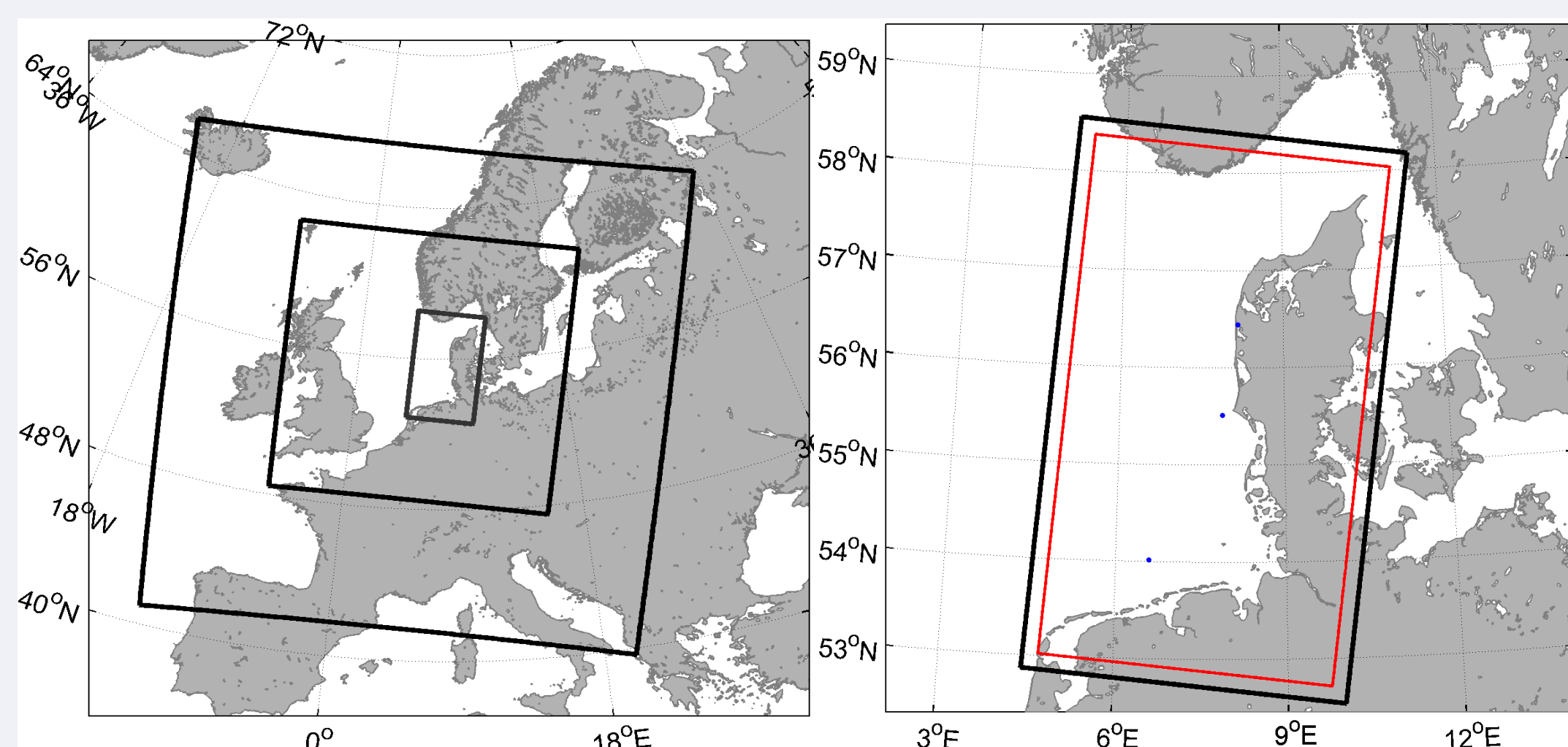


Figure 1. The left figure shows the setup of the model domains for Focus area 1, Norsewind. The inner domain is shown in the right figure, where the red rectangle denotes a distance 20km from the model domain.

South Baltic Wind Atlas.

In the second set-up by Risø DTU the WRF model is run with an inner nest of 5 km and an outer nest of 15 km resolution (see Figure 2) and 42 layers in the vertical. 12 of the layer are below 1 km. An initial run was carried out for 1 month using 6 different PBL parameterization schemes (see Table 2).

Table 2: Summary of PBL schemes used the model sensitivity study.

Scheme	Reference	Closure type	Surface scheme
YSU	Hong et al. (2006)	1st order	M-O scheme
MYJ	Janjic (2001)	TKE 1.5 order	M-O scheme
QNSE	Sukoriansky et al. (2006)	TKE 1.5 order	QNSE
MYNN2	Nakanishi and Niino (2006)	TKE 1.5 order	MYNN
MYNN3	Nakanishi and Niino (2006)	TKE 2.5 order	MYNN
BouLac	Bougeault and Lacarrère (1989)	TKE 1.5 order	M-O scheme

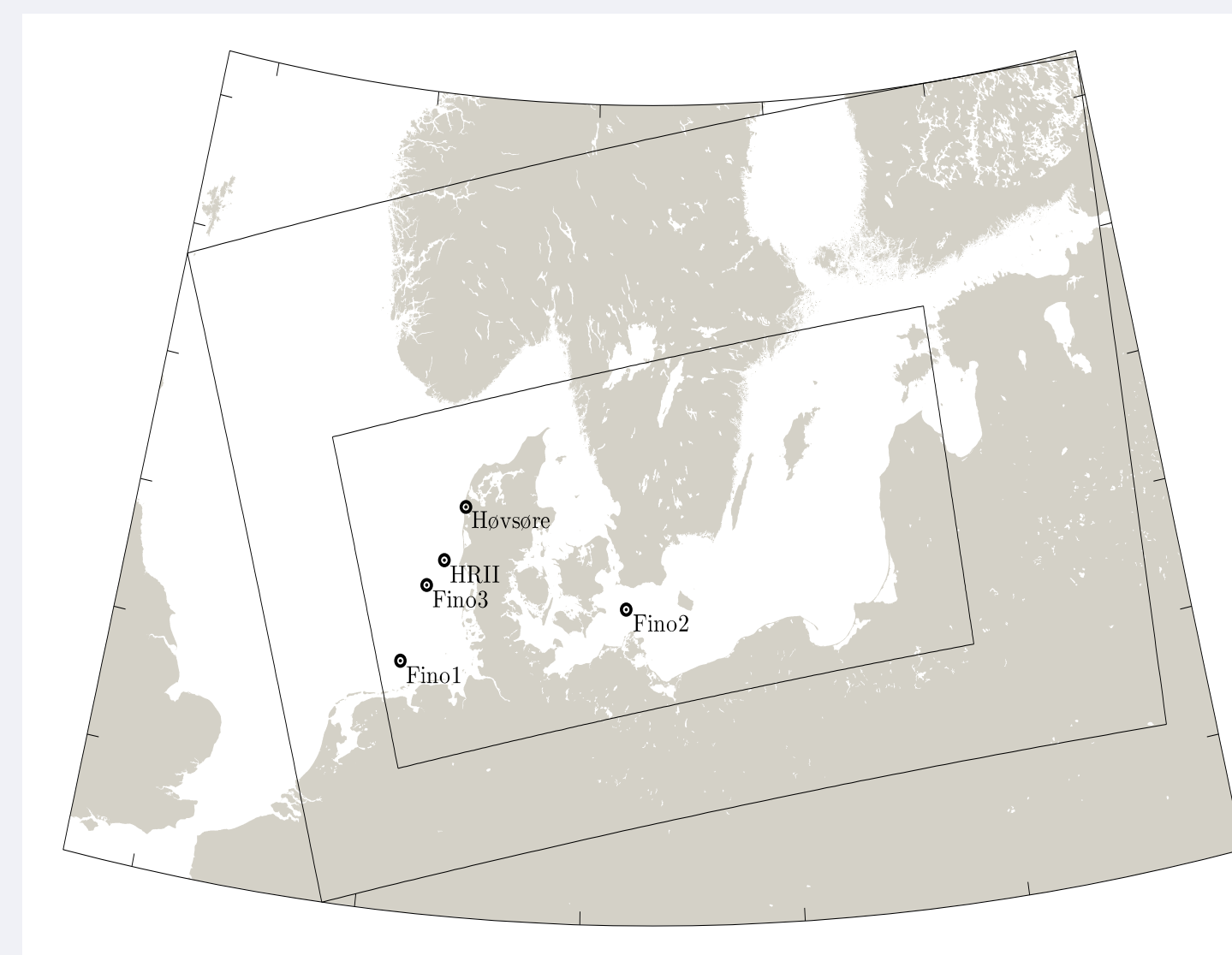


Figure 2. Model set up for the south Baltic simulation.

Results

East North Sea Wind Atlas.

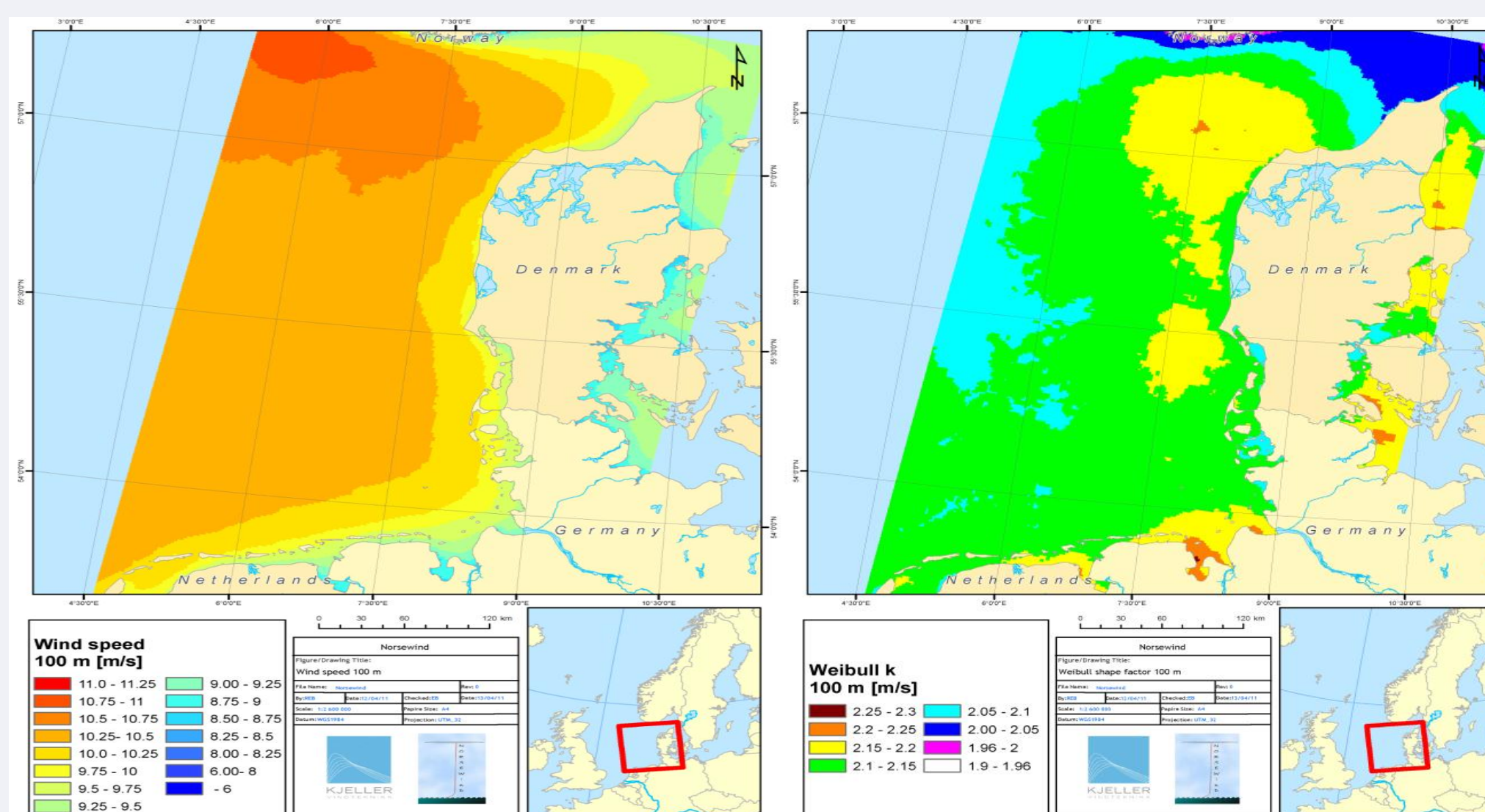


Figure 3. Annual average wind speed (left) and Weibull k (right) for the period 01.05.2006-30.04.2007.

The annual average wind speed is highest in the northwestern part of the area with values up to 11 m/s (Figure 3). The lowest offshore wind speeds are found close to land on the eastern side of Denmark. The Weibull k factor peaks to the east of the wind speed maximum and close to the shorelines. Comparison with the FINO 1 platform data (Table 3) shows rather small deviations of the annual average wind speed. This has also been confirmed in earlier studies by Berge et al. (2009).

Table 3. Average wind speeds for the period 01.05.2006 - 30.04.2007 at Fino1. The data coverage is 96 % for both heights. Results with the new SST data assimilation system in WRF.

	Height of measurement (m)	Observed average (m/s)	WRF-average (m/s)	% deviation	Correlation
Fino 1	100	10.53	10.26	-2.7%	0.92
Fino 1	90	10.16	10.17	+0.1%	0.90

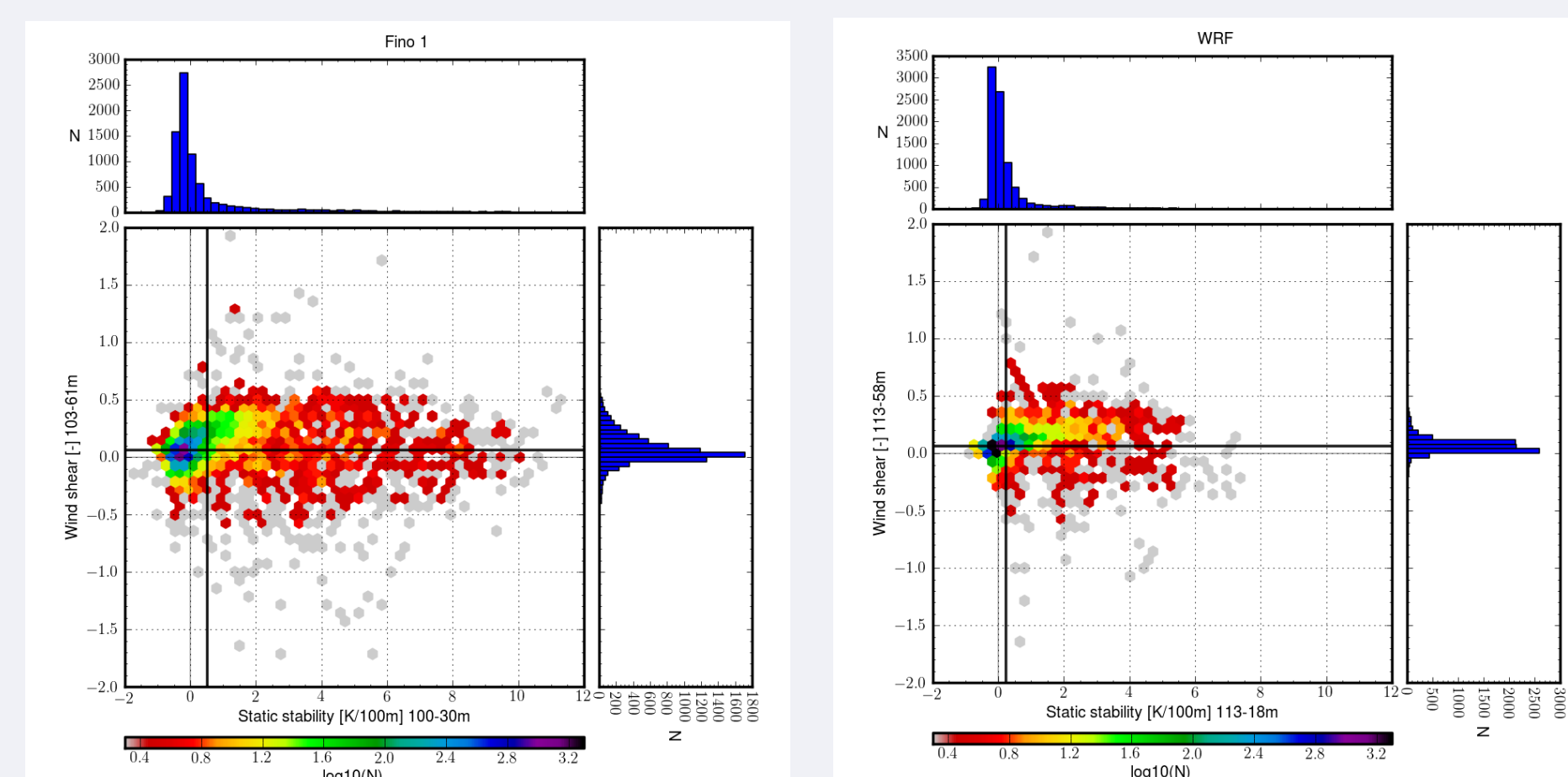


Figure 4. Distribution of wind shear against static stability from Fino 1 (left) and WRF (right). The measured windshear (left) are valid for the 103-61 m layer, while the modeled windshear (right) are valid for the 113-58 m layer. The peaks of the distributions are more intense around the origin, e.g. the dark colors indicate higher occurrence count than the lighter colors.

South Baltic Wind Atlas.

The wind speed profiles of the 6 different PBL schemes are presented for Fino1 and Fino2 in Figure 5. The observed wind profile at Fino2 may indicate difficulties with the measurements due to the very irregular shape of the profile. Note also the high wind speed values of the top sensor at 100 m at both measuring sites.

This may be due to over-speeding at the top sensor, while the other sensor are influenced by mast shadowing effects. Both the shape of the wind profiles, and the absolute wind speed level are very sensitive to the selected PBL-scheme.

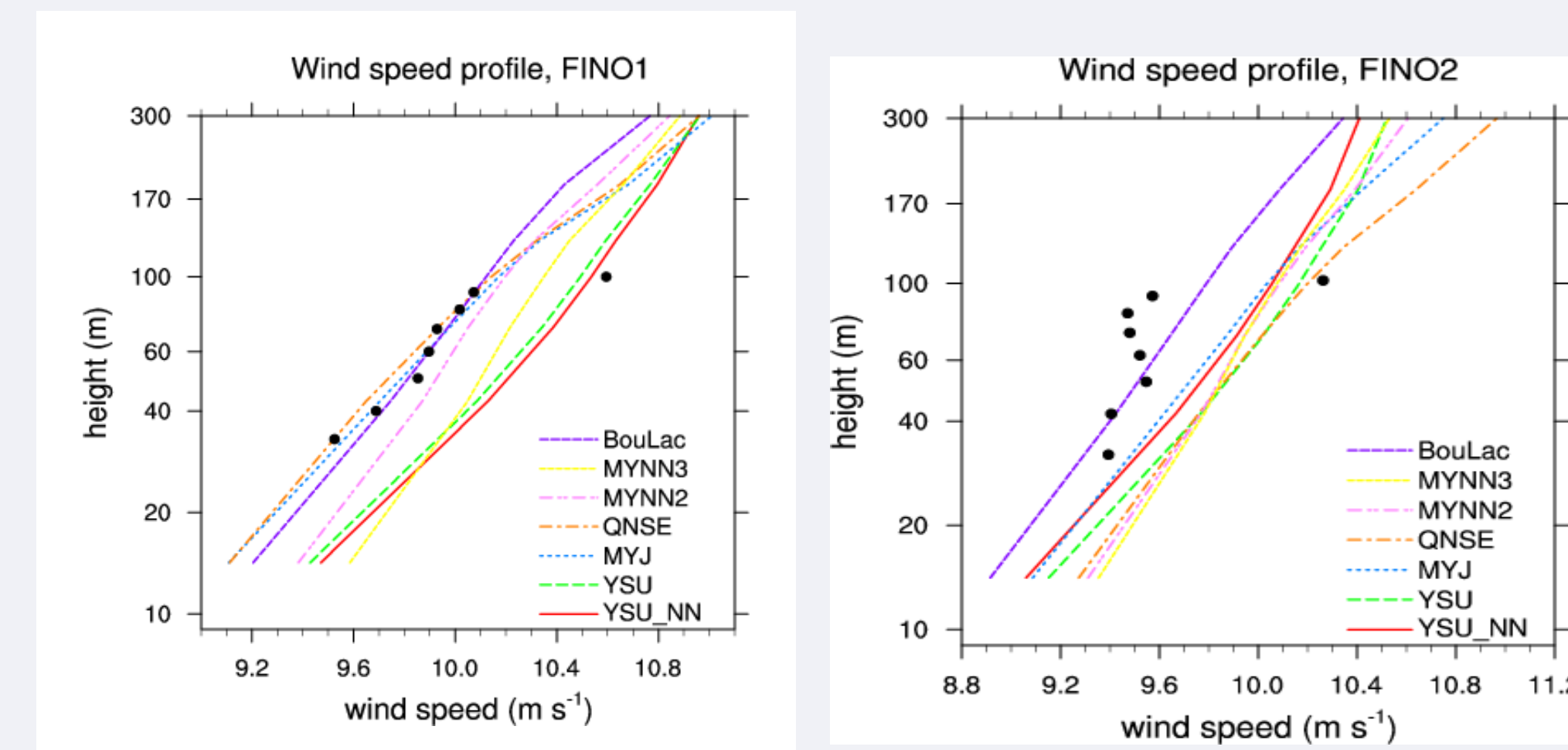


Figure 5. Wind speed profiles for the 6 different PBL parameterization schemes. The dots are the observed values

Mean column wind speed

Scheme	Høvsøre BIAS	Fino1 BIAS	Fino2 BIAS	Høvsøre RMSE	Fino1 RMSE	Fino2 RMSE
YSU	0.11	0.38	0.47	3.32	3.01	3.48
MYJ	-0.28	0.01	0.32	3.01	3.15	3.13
QNSE	-0.39	-0.03	0.47	3.40	3.37	3.95
MYNN2	-0.15	0.13	0.42	3.23	3.18	3.51
MYNN3	-0.10	0.30	0.43	2.89	3.19	3.71
BouLac	0.17	0.02	0.11	3.84	2.96	2.87

90 or 100-meter wind speed

Scheme	Høvsøre BIAS	Fino1 BIAS	Fino2 BIAS	Høvsøre RMSE	Fino1 RMSE	Fino2 RMSE
YSU	-0.22	0.38	0.59	0.67	0.46	0.60
MYJ	-0.24	0.05	0.45	0.65	0.49	0.55
QNSE	-0.17	0.01	0.62	0.72	0.51	0.68
MYNN2	-0.12	0.08	0.50	0.70	0.48	0.59
MYNN3	-0.10	0.24	0.50	0.63	0.48	0.62
BouLac	-0.35	0.01	0.22	0.76	0.44	0.49

Table 3. Bias and RMSE error at Høvsøre, Fino1 and Fino2 for the 6 different PBL parameterization schemes. Runs are for October 2009.

Table 3 shows that it is difficult to distinguish the quality of the different schemes. If we consider the mean column wind speed, the MYNN3 scheme performs better at Høvsøre, but the BouLac scheme performs best at Fino1 and Fino2. Similar results are found for the tall wind speed at (100 m at Høvsøre; 90 m at Fino1 and Fino2). Therefore, other metrics such as wind shear and wind speed variability should be used in conjunction with the statistics used here. The spread among PBL schemes is, as expected, lowest for the two ocean sites. Differences between the model-derived wind speeds and the observations are of the order of 0.5 m/s at Fino1 and Fino2, but much larger (~1.5 m/s) at Høvsøre. When considering the "slope" and "shape" of the wind profile YSU performs best at Fino1, MYJ at Fino2 and MYNN3 at Høvsøre.

Conclusions

Validations show that annual average wind speeds and wind-roses at hub-height (100m) are well represented by the model. But the vertical wind profile, wind shear parameters and static stability are less accurate. It is recommended to apply other techniques (measurements, PBL-theory etc.) to more accurately derive these quantities offshore.

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