Evaluation of planetary boundary layer schemes and meteorological reanalyses in meso-scale simulations above the North Sea

Hauke Wurps, Gerald Steinfeld

ForWind - Center for Wind Energy Research, Carl von Ossietzky Universität Oldenburg

Introduction

- An accurate and reliable estimation of turbulence, shear and veer is necessary for the prediction of wind energy production and loads on wind turbines.
- The upper tip height of offshore wind turbines is around 150 m which exceeds the height of currently existing measurement masts (e.g. FINO1: 103 m).
- Mesoscale simulations can be a convenient tool to gain information on the wind conditions in this part of the atmosphere.

Methods & Data

We use the meso scale model **WRF** (Weather Reasearch and Forecasting model) for the simulation of the atmospheric conditions by the means of dynamical downscaling. As initial and boundary conditions three different reanalyses are compared:

- **CFSR** (NCEP)
- **ERA-Interim** (ECMWF)
- **MERRA** (GMAO)

As boundary layer parameterization five different PBL-schemes were used: **ACM2, MYJ, MYNN, QNSE, YSU**. To validate the simulations they are compared to measurements of the metmast **FINO1**.

Setup

The resolution of the coarsest domain is **22.5 km**, that of the inner one is **2.5 km**. For each combination of PBL-scheme and input data a simulation of the whole year 2007 was performed.

Figure 1 : Area of the WRF simulation showing all three domains

Results

The input data influences mean windspeed, the PBL-scheme influences the shape:

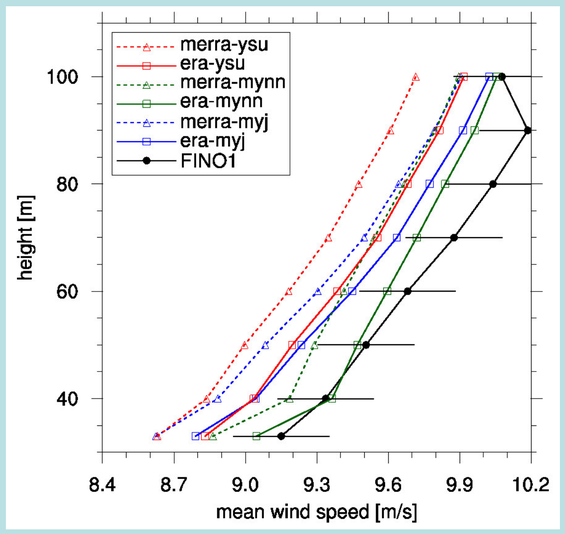

Figure 2 : Mean wind profiles 2007

Contact: hauke.wurps@forwind.de

WRF vs FINO1

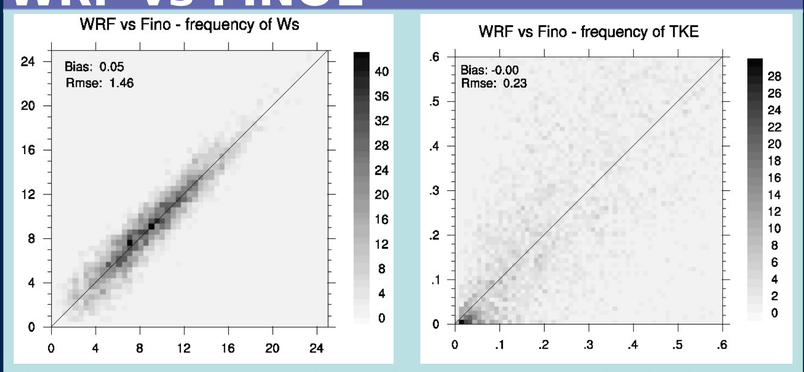

Figure 3 : Frequencies of occurence of wind speed and turbulent kinetic energy, WRF vs. Fino1, PBL-scheme: MYNN, input data: ERA-Interim. Bin size 0.5 (left) and 0.01 (right).

Apparently the computation of windspeed is far more accurate than the computation of the turbulent kinetic energy (TKE).

Bias [m/s]	ERA	MERRA	CFSR
ACM2	-0.17	-0.45	-0.31
MYJ	-0.01	-0.18	-0.08
MYNN	0.05	-0.18	-0.11
QNSE	0.05	-0.14	-0.10
YSU	0.00	-0.26	-0.18

RMSE [m/s]	ERA	MERRA	CFSR
ACM2	1.51	1.63	1.60
MYJ	1.49	1.57	1.53
MYNN	1.46	1.62	1.55
QNSE	1.52	1.66	1.61
YSU	1.53	1.65	1.61

Table 1: Bias (left) and RMSE (right) of the wind speed compared to a sonic anemometer at 80 m.

Stabilities

To better understand the performance of PBL-schemes in different weather conditions the data was filtered by atmospheric stability using the Monin Obukhov length.

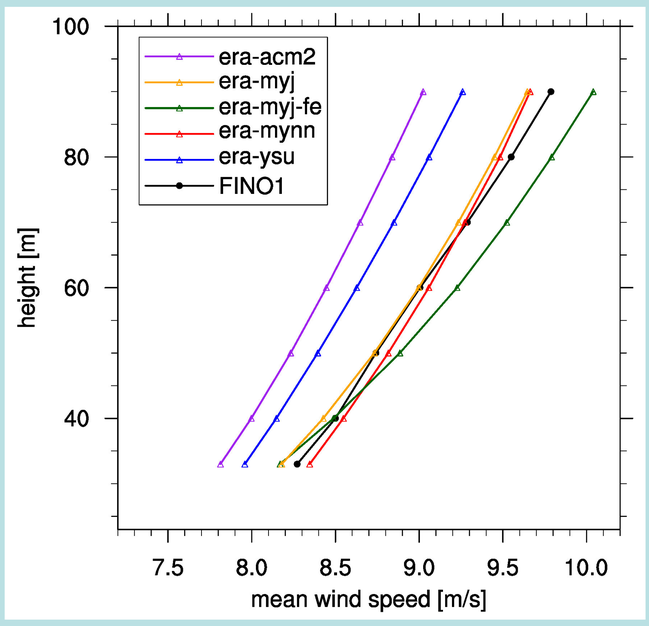

Figure 4 : Mean wind profiles for stable conditions

Five different PBL-schemes are compared to measurements at FINO1. Four of them are included by default in the WRF model whereas the MYJ-FE scheme is an MYJ scheme with changed closure constants following Foreman and Emeis (2012).

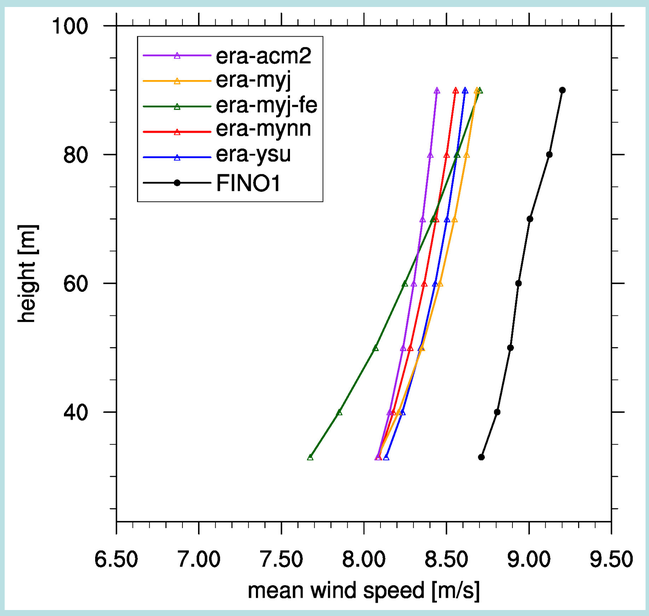

Figure 5 : Mean wind profiles for unstable conditions

Turbulence

A comparison of the turbulence intensity of the MYJ scheme and MYJ-FE with FINO1 shows an improvement for stable conditions.

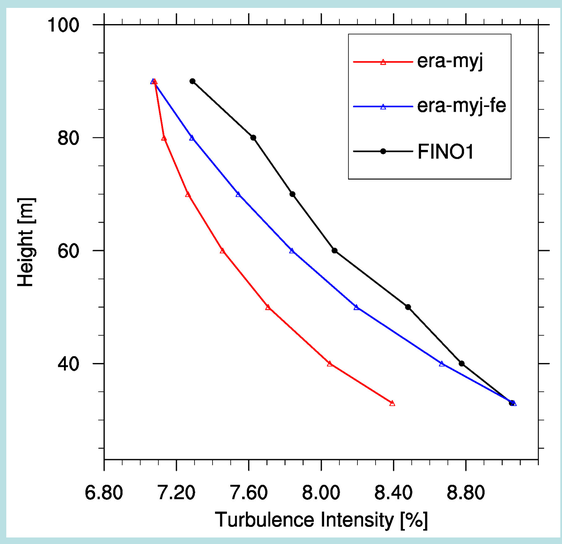

Figure 6 : Turbulence intensity for stably stratified atmosphere

However for unstable conditions the turbulence intensity is overestimated by the adapted scheme.

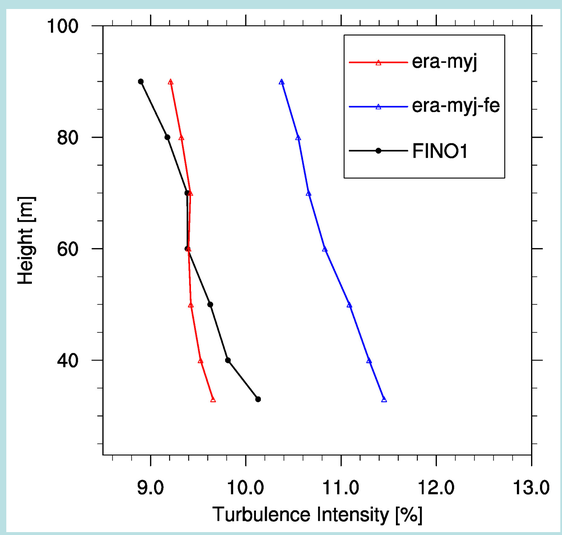

Figure 7 : Turbulence intensity for unstably stratified atmosphere

Conclusion

- The ERA-Interim Reanalysis performed best in the comparison to FINO1
- The computation of TKE in WRF can be improved by changes to closure constants.
- The performance of the PBL-schemes strongly depends on atmospheric stability.

Literature

- W. C. Skamarock, J. B. Klemp, "A time-split nonhydrostatic atmospheric model for weather research and forecasting applications." Journal of Computational Physics 227.7 (2008): 3465-3485.
- Foreman, Richard J., and Stefan Emeis. "A Method for increasing the turbulent kinetic energy in the Mellor–Yamada–Janjić boundary-layer parametrization." Boundary-layer meteorology 145.2 (2012): 329-349.

Acknowledgement

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