Meso-microscale coupling for wind resource assessment using averaged atmospheric conditions

PO.122

Pablo Durán[1,2], **Cathérine Meißner[1]**, Gibson Kersting[3]

[1]WindSim AS, Fjordgaten 15, N-3125 Tønsberg , Norway

[2]Norwegian University of Life Sciences, 1433 Ås, Norway

[3]E.ON Climate & Renewables, United States

Introduction

In the coming years, mesoscale reanalysis data sets will be freely available with a horizontal resolution of less than 5 km. Such reanalysis data can reproduce complex local wind circulations like thermal winds and low-level jets, offering an opportunity to improve wind resource assessment by using this information.

One way is to use more realistic initial and boundary conditions for computational fluid dynamics (CFD) models based on mesoscale data instead of just using simple analytical profiles which is the standard today.

Meso-microscale direct coupling with averaged conditions

For Reynolds-Averaged Navier-Stokes CFD modelling, boundary conditions are normally imposed as analytical logarithmic wind profiles. Those are theoretical profiles, which often deviate from the observed wind profile in the area.

More realistic boundary conditions can be obtained by using data calculated by Numerical Weather Prediction (NWP) models (Fig. 1).

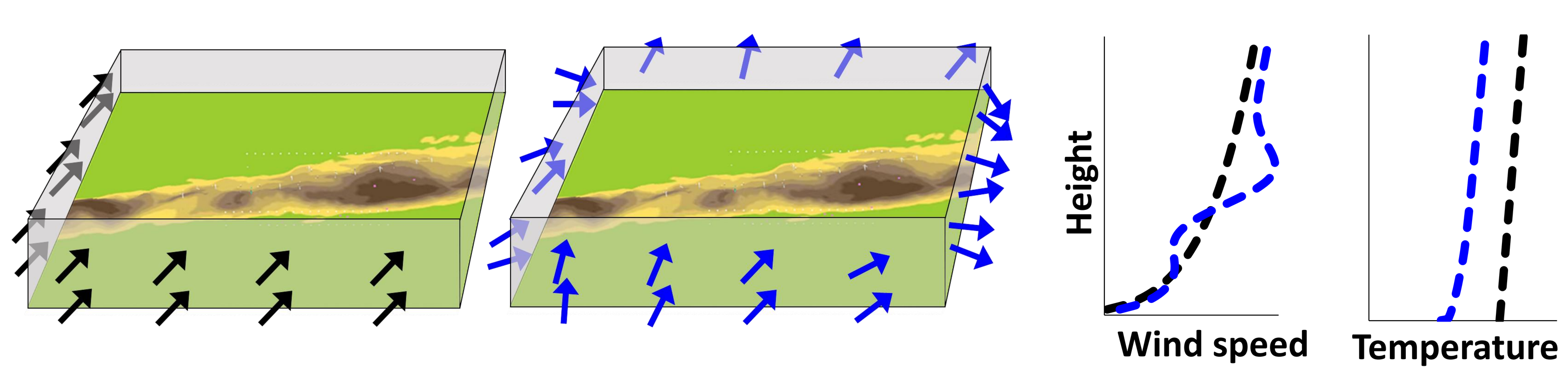


Figure 1: Boundary conditions for the default (black) and coupled (blue) WindSim simulations

Boundary conditions are derived from hourly Weather Research Forecasting (WRF) output for one year by averaging each time-step according to its wind direction (Fig. 2).

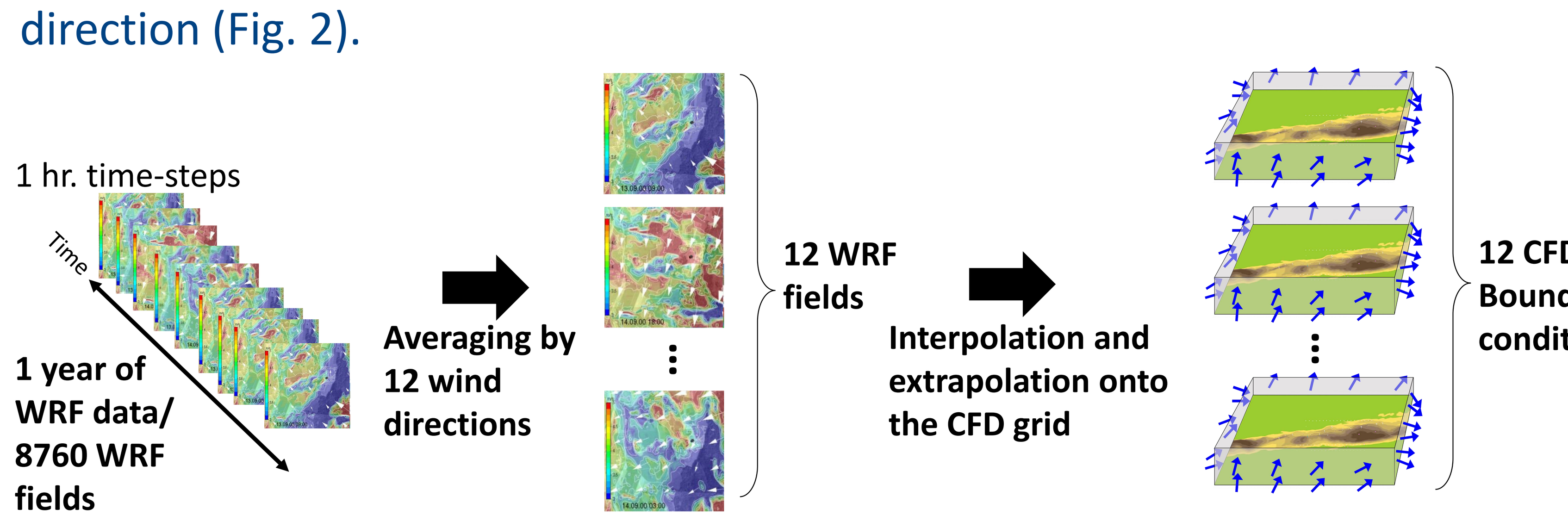


Figure 2: Proposed meso-microscale coupling methodology

Validation site and simulation set-up

Validation Site: 13 km wide, 21 km long, 6 met masts – all at least 100m high equipped with class I sensors. Dense forested areas with a lot of clearings. The detailed modelling of the site is described in Kersting et. al (2016).

Atmospheric stability conditions derived from the WRF data show a predominant very stable atmosphere for all directional sectors (Fig. 3), which is reflected in the averaged WRF fields.

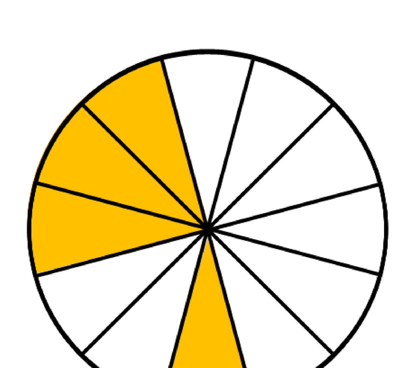
2 CFD simulations are compared:

CFD : Default CFD simulation

cCFD : Coupled CFD simulation

Measured main wind directions :

180°, 270°, 300°, 330°



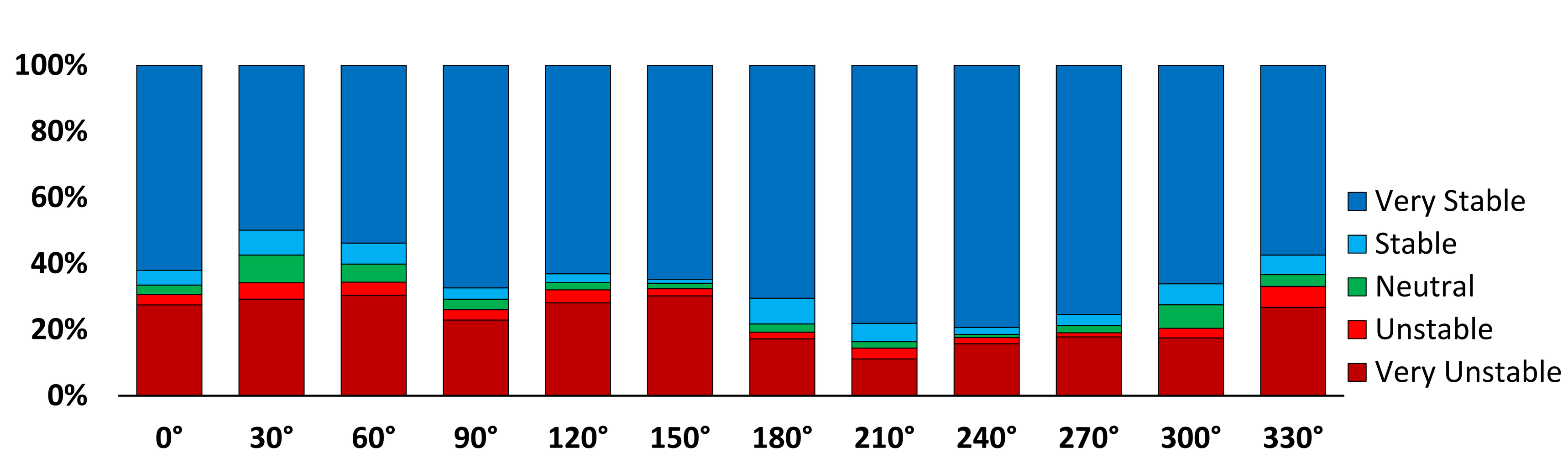


Figure 3: WRF data stability classification by wind direction sector

Results

In total, there are no large differences between the simulations when doing a cross-checking between the 6 met masts (Fig 4). Nevertheless, the coupled model (**cCFD**) has on average, **3,46% less prediction error** compared with the default model (**CFD**) for sectors 90, 210, 240, 270 and 300 (Table 1). For the main wind directions, **the error prediction decreased on average 1.01%**.

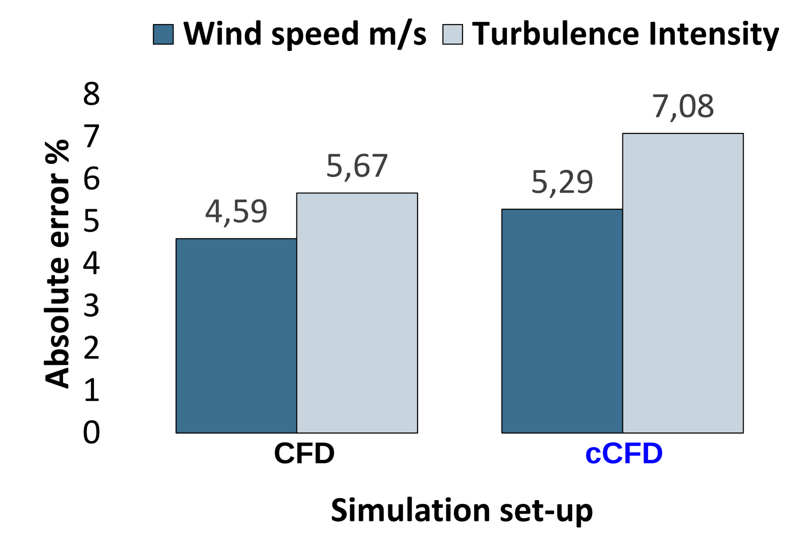


Figure 4: Cross-prediction error at 80 m

Simulation set-up	Absolute **wind speed** error by directional sector											
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
CFD	6,57	6,47	8,47	19,47	14,03	13,06	15,47	10,83	10,01	10,57	10,49	9,80
cCFD	8,02	7,17	8,19	13,87	20,13	15,12	16,25	8,77	6,68	7,90	7,36	9,78
CFD - cCFD	-1,45	-0,70	0,28	5,60	-6,11	-2,06	-0,78	2,05	3,33	2,66	3,13	0,02

Simulation set-up	Absolute **turbulence intensity** error by directional sector											
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
CFD	9,09	3,77	3,29	0,28	6,90	11,15	9,35	8,16	15,48	7,79	7,98	8,21
cCFD	10,76	3,92	3,12	0,04	4,91	11,55	8,05	8,87	17,74	9,76	16,57	8,89
CFD - cCFD	-1,68	-0,14	0,17	0,23	2,00	-0,39	1,30	-0,71	-2,26	-1,97	-8,58	-0,68

Table 1: Average absolute cross-checking prediction error at 80 m by directional sector. Values in %.

Differences between the simulations can be related to the different imposed boundary conditions. As expected, coupled and default simulations have similar results when their boundary conditions are similar, like in sector 180 (Fig. 5).

Improvements were obtained in the coupled simulation for sector 240 and 270 when the inlet profiles were different but wind speed increases with height. For sector 240 it is clear that the WRF wind speed profile is reflecting the influence of stable atmospheric conditions.

Decreasing wind speed with height in the WRF data like in sector 120 leads to an increased prediction error in the CFD simulations.

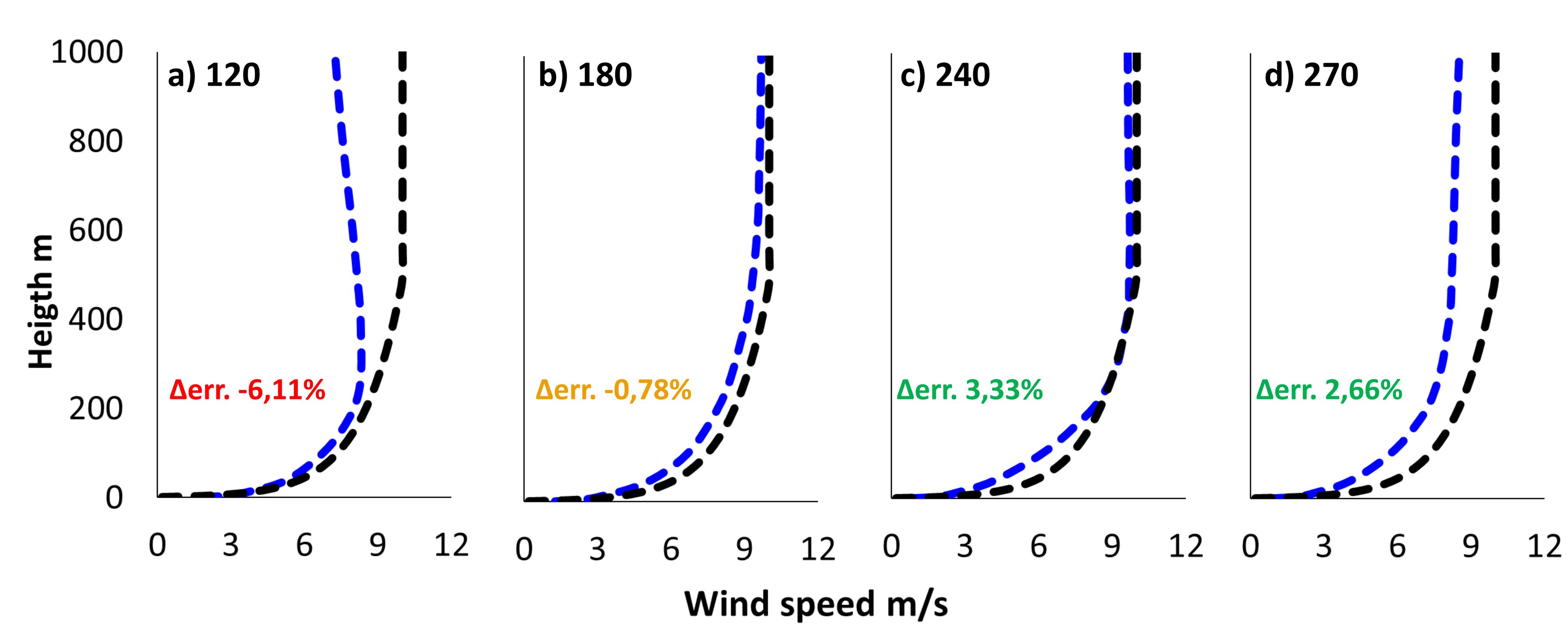


Figure 5: Inlet profiles for sectors a) 120, b) 180, c) 240 and d) 270.
Δerr. = $err._{CFD}$ - $err._{cCFD}$

Conclusions

(i) Changing the boundary conditions has an impact on the modelled wind field, even for big domains.

(ii) The proposed meso-microscale coupling produces more realistic wind profiles at the boundaries of the CFD domain.

(iii) Using inlet profiles based on averaged WRF model output has the potential of improving of the wind resource assessment

References

G. Kersting, C. Meissner, M. Mana. Validation of CFD based forest modeling for large forested areas with many measurement masts. Poster presentation, WindEurope Summit, Hamburg, 2016.