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

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Abstract

A **coupling** method of mesoscale Numerical Weather Prediction (NWP) models with Computational Fluid Dynamic (CFD) models for **wind resource assessment applications** is presented.

The method is applied to one year of Weather Research Forecasting (WRF)[1] simulations at the Honkajoki wind farm in Finland and validated by Sonic Detection and Ranging (SODAR) measurements at the site.

The coupled simulations reproduce the wind speed profiles for the main wind directions better than the stand-alone simulations. A considerable difference in the horizontal wind speed patterns can be seen between the coupled and non-coupled approaches.

Coupling methodology

Average mesoscale wind fields per wind direction and/or atmospheric stability class are generated from the WRF simulations.

The fields are computed by **averaging** all WRF data with the **same main wind direction and atmospheric stability**.

The averaging procedure is conducted for 12 wind direction sectors, yielding a total of 12 WRF fields per stability class.

The resulting averaged WRF fields are then **interpolated onto the CFD grid as boundary and initial conditions** (Figure 1).

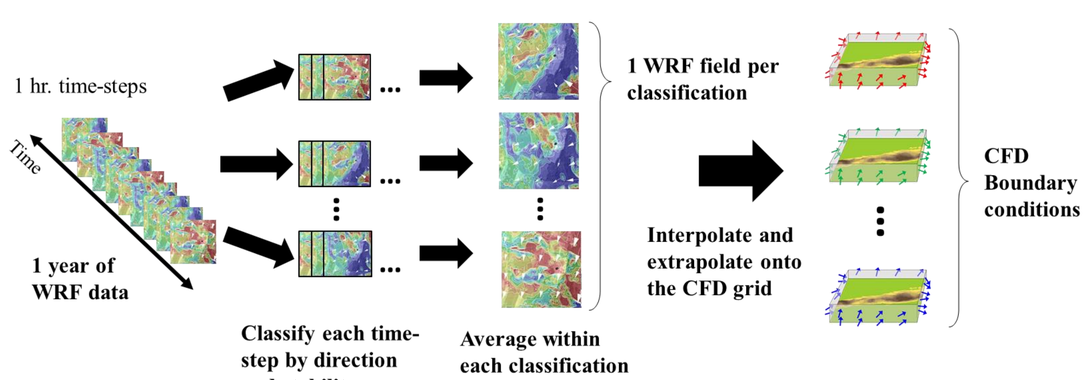

Figure 1: Diagram of the proposed coupling procedure between WRF and CFD model

Validation site: Honkajoki wind farm

The methodology is validated at the **Honkajoki Wind Farm**.

The terrain at the site is **flat** and mostly covered with **forest**.

The wind conditions have been monitored by a SODAR between February 2016 and April 2017.

Strong influence of **stable conditions** (Figure 2).

Main wind directions are 180, 210 and 240 degrees

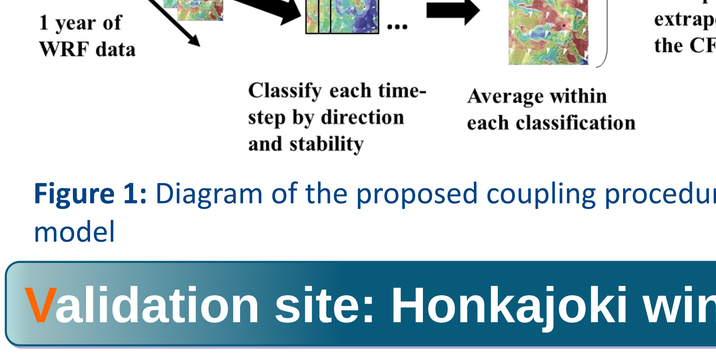

Figure 2: Wind rose (left) and measured mean vertical wind speed profile compared to a neutral profile (right)

Figure 3: Honkajoki wind farm and SODAR position (red dot)

Validation of the coupling methodology

The coupled simulations are compared to stand-alone simulations (Table 1).

Stand-alone simulations correspond to the standard in the industry and therefore they are labelled as “Default”.

Atmospheric stability	Simulation name
All stabilities	Default Coupled
Unstable	Default_U Coupled_U
Neutral	Default_N Coupled_N
Stable	Default_S Coupled_S

Table 1: Coupled and Default simulations carried out

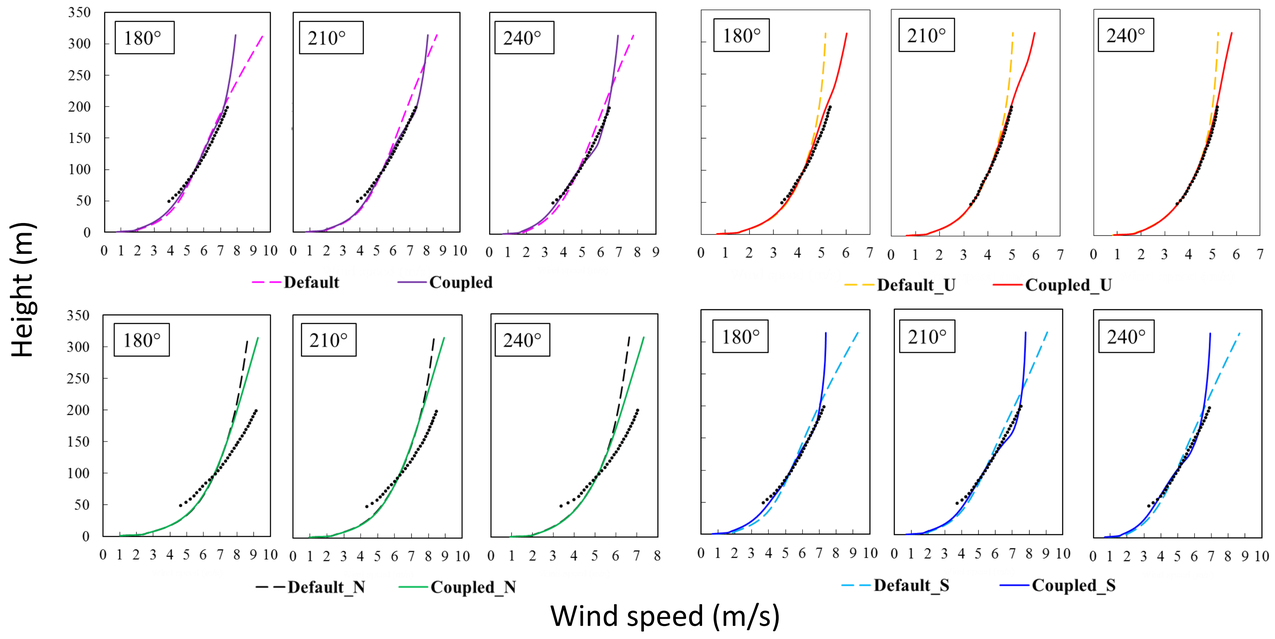

Figure 4: Simulated (lines) and measured (black dots) vertical profiles of horizontal wind speed. Color scheme is explained in table 1

Overall the coupled simulated profiles show a more realistic wind shear above 150 m:

- **When all stabilities are considered**, all main wind directions show an improvement
- In the **unstable cases,** the default simulations are already quite good but the coupled improve even more
- For **neutral simulations**, there is a slight improvement. But observations show a more stable profile than the simulated ones
- **Stable coupled** profiles simulate better the stratification present in stable conditions[2], which notably improves the estimation of the profiles around 150 m

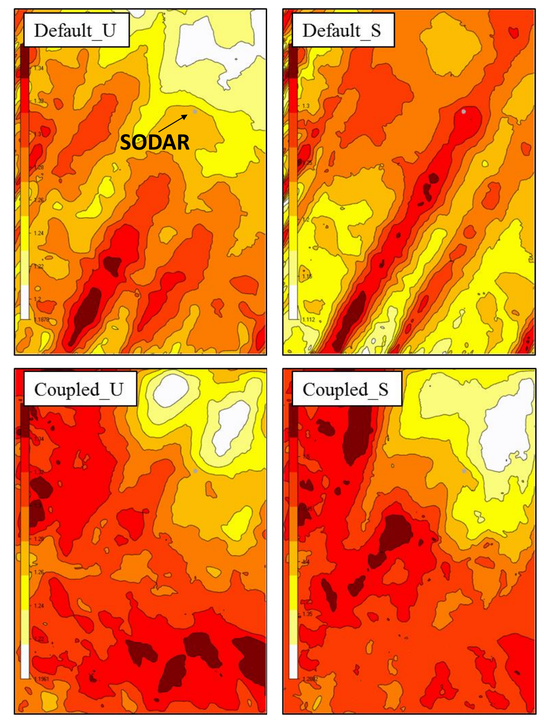

Figure 5: Simulated wind speed patterns for directional sector 210

The **horizontal patterns are very different** between the coupled and default simulations (Figure 5). For coupled simulations they vary with atmospheric stability.

Conclusions

1) The proposed **coupling methodology improves simulations results** by initializing the CFD with average atmospheric conditions per stability class

2) The coupled profiles have **more realistic shear above 150 m**, which is very important for wind resource assessment since wind turbine rotors reach those heights nowadays

3) The proposed methodology avoids the problem of choosing CFD modelling parameters and thereby **reduces subjective decisions of consultants**

References

1. Skamarock, W. C. et al. (2008) ‘A Description of the Advanced Research WRF Version 3’, *Technical Report*
2. Stull, R. B. (1988) An Introduction to Boundary Layer Meteorology

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