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# Coupling Mesoscale and Computational Fluid Dynamics Models Through Spatial-Mean Scaling

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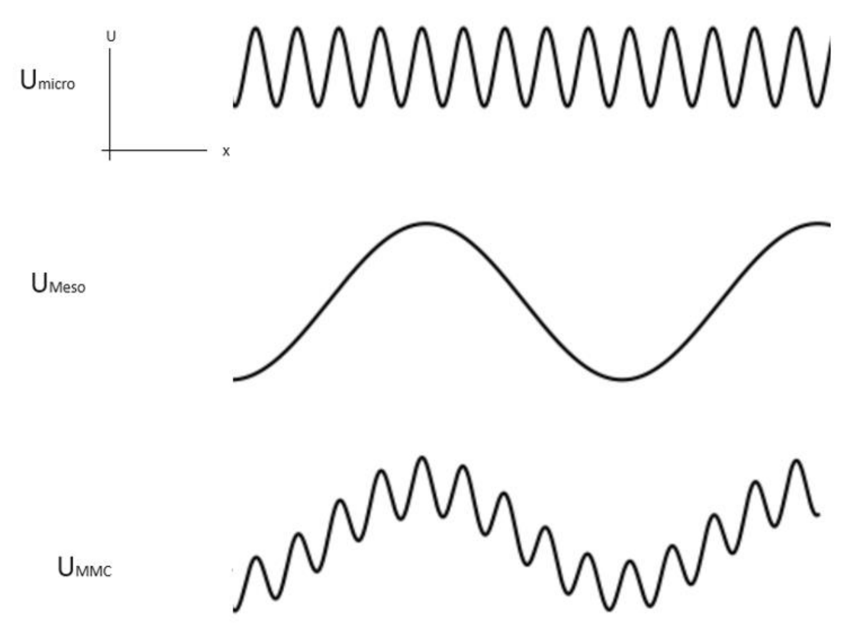
## Abstract

We present a method to couple mesoscale models with computational fluid dynamics (CFD) simulations by scaling (at large scales) the latter with the former. We used mesoscale data and observations from the New European Wind Atlas (NEWA) to evaluate the coupled model performance against the uncoupled CFD solutions. Comparison with measurements revealed that the coupling improves accuracy at large spatial scales that are resolved by the mesoscale model.

## Method

CFD microscale models have traditionally been used for flow modelling on sites with complex terrain. For such sites, the flow is to large degree dominated by the interaction of the boundary layer with the terrain, but many of these sites still contain non-negligible mesoscale effects that are not resolved by the physical equations used in the CFD models.

A substantial amount of work has been done by the community to come up with ways to couple the meso- and microscale models together (so called meso-micro coupling, MMC). In this study, we propose a simple scaling approach in which the CFD is used to model microscale variability from the mesoscale mean (similar to Bechmann 2015, also Duran et al., 2020):



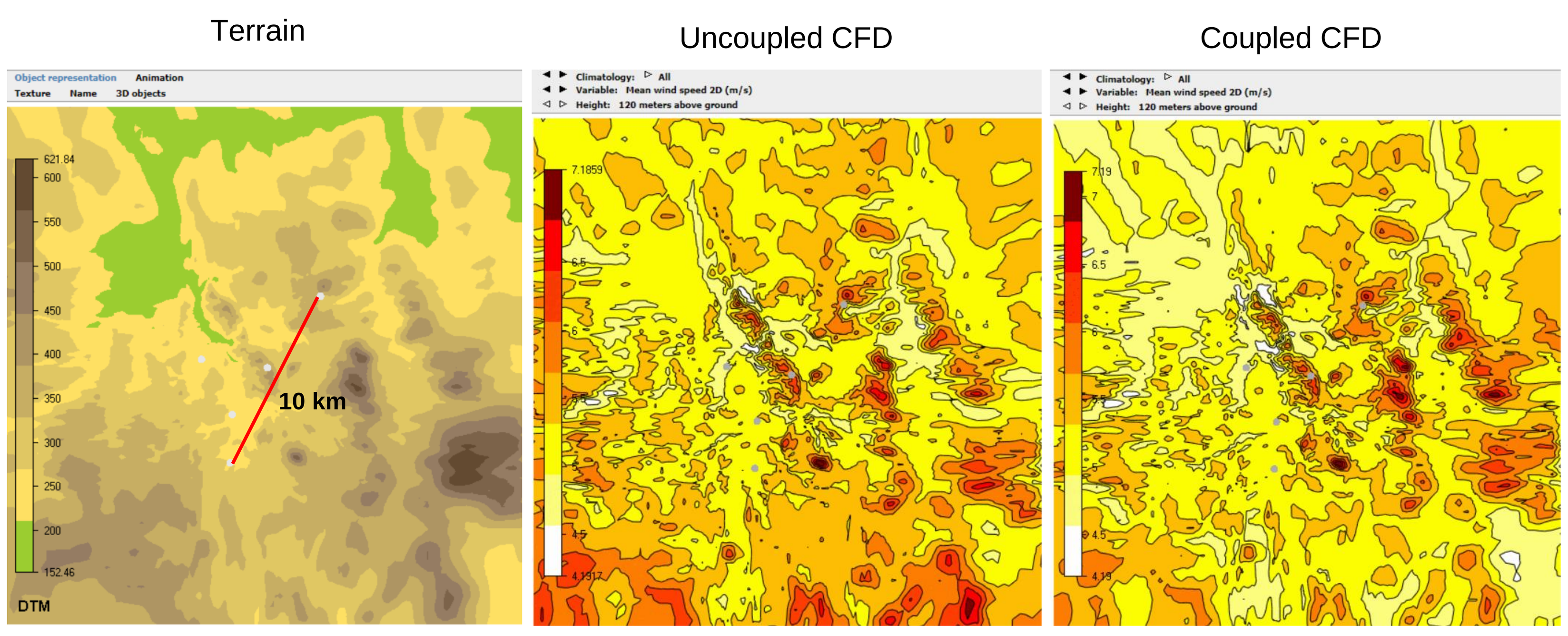

$$U_{MMC} = \langle U_{meso} \rangle \frac{U_{micro}}{\langle U_{micro} \rangle}$$

$\langle . \rangle$ **Spatial average at large scale**

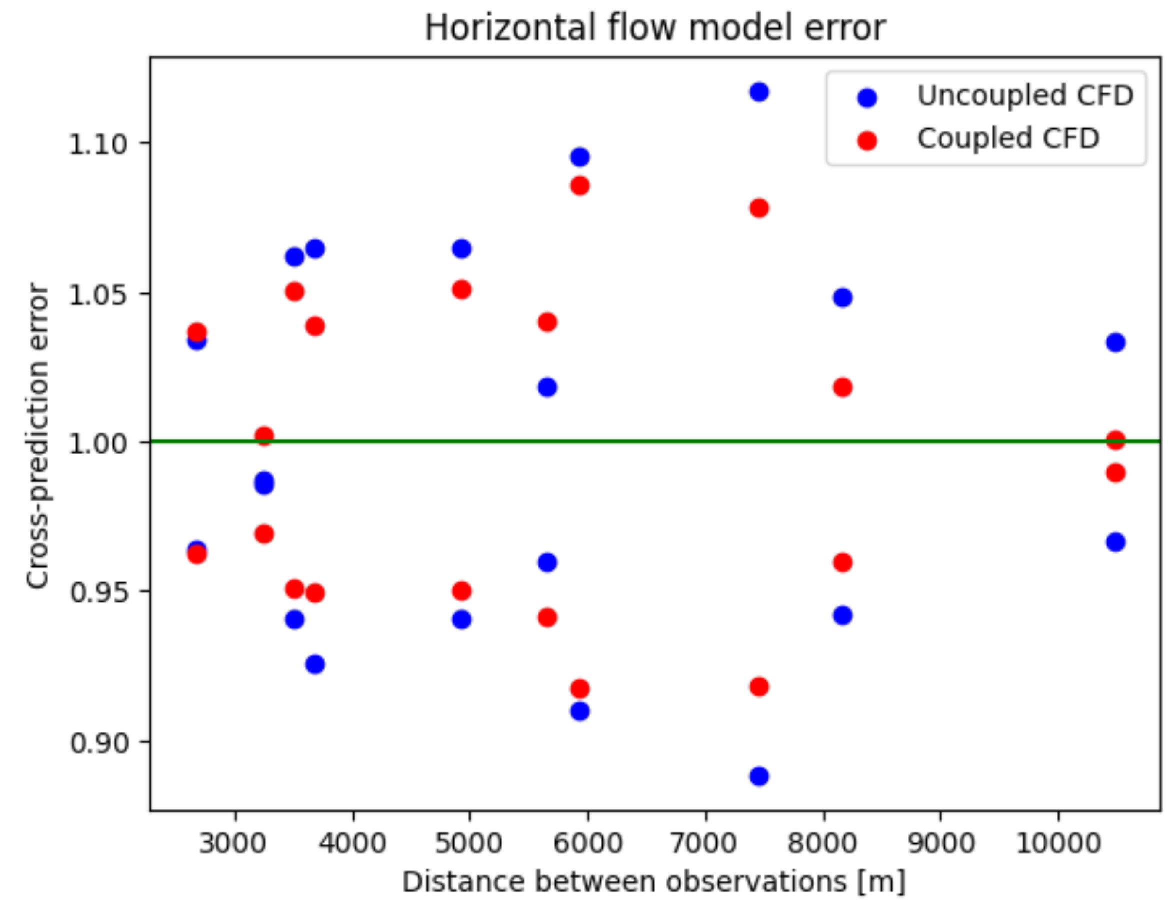
Illustration of the mean-scaling approach we propose for mesoscale-microscale coupling.

## NEWA Kassel experiment

We used four lidars and one metmast at the NEWA Kassel site (Kühn et al., 2018) in Germany to validate the MMC procedure. We combined CFD simulations at 50-m resolution with NEWA mesoscale data and use the measurements to calculate the horizontal cross-prediction errors for the resulting flow model.




Kassel site (left) elevation and measurements marked as circles. Mean wind speed from (center) uncoupled and (right) coupled CFD models.

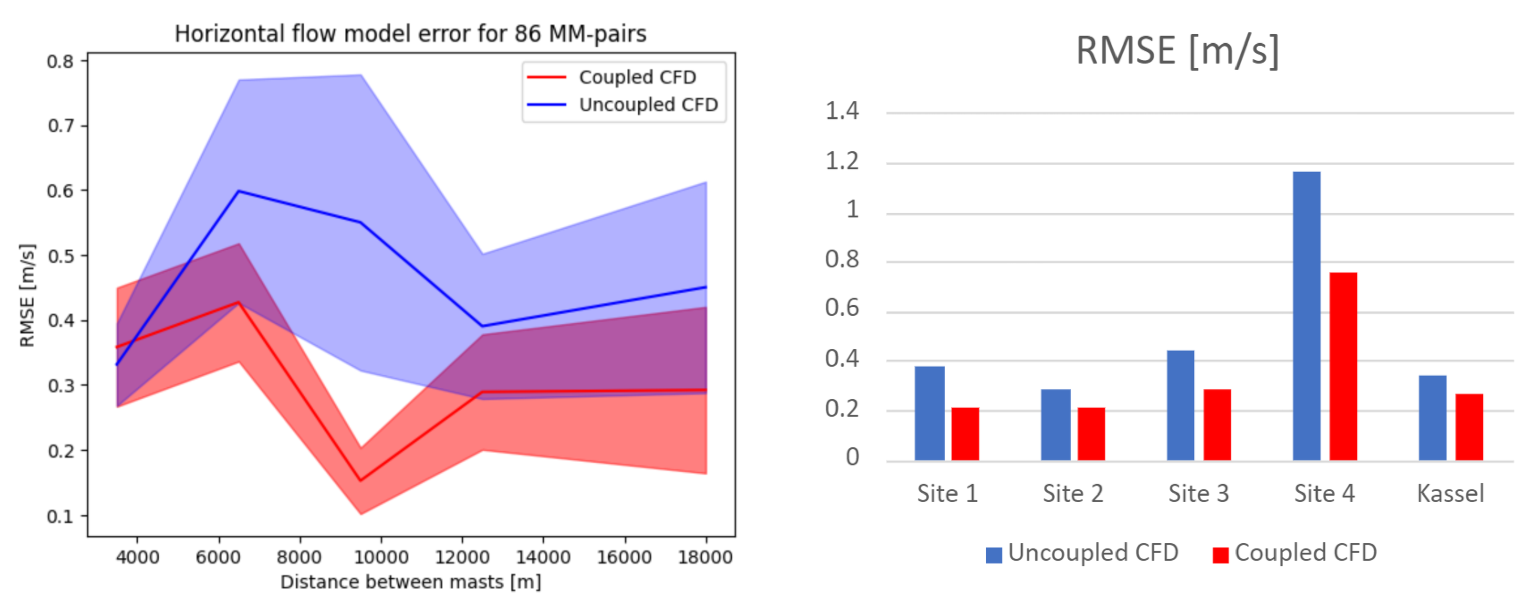



Horizontal cross-prediction errors for (blue) uncoupled and (red) coupled CFD models at Kassel.

Model performance is similar on short spatial scales (less than about 6 km or twice the NEWA grid spacing). On larger scales — well-resolved by the mesoscale data — the coupling procedure seems to improve cross-prediction results.

## Five European sites

We evaluated coupled NEWA-CFD model performance at four more European sites (a total of 86 mast pairs) to gather more representative statistics. Results broadly align with those obtained at Kassel, showing pronounced improvements in accuracy at the scales resolved by the mesoscale model. Evaluating the overall flow model accuracy at these five sites shows that mesoscale coupling tends to lead to an error reduction between 20 and 50 percent.




Comparison of (red) coupled and (blue) uncoupled flow model errors for five European sites: (left) horizontal cross-prediction error for 86 metmast pairs, and (right) overall errors per site.

## Conclusions

1. Mesoscale-microscale coupling can be done relatively easily through spatial-mean scaling.
2. The procedure, which can be used with publicly available data like NEWA, improves flow modelling accuracy at large scales.

**References**

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Durán, P., Meißner, C., & Casso, P. (2020). A new meso-microscale coupled modelling framework for wind resource assessment: A validation study. *Renewable energy*, *160*, 538-554.

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