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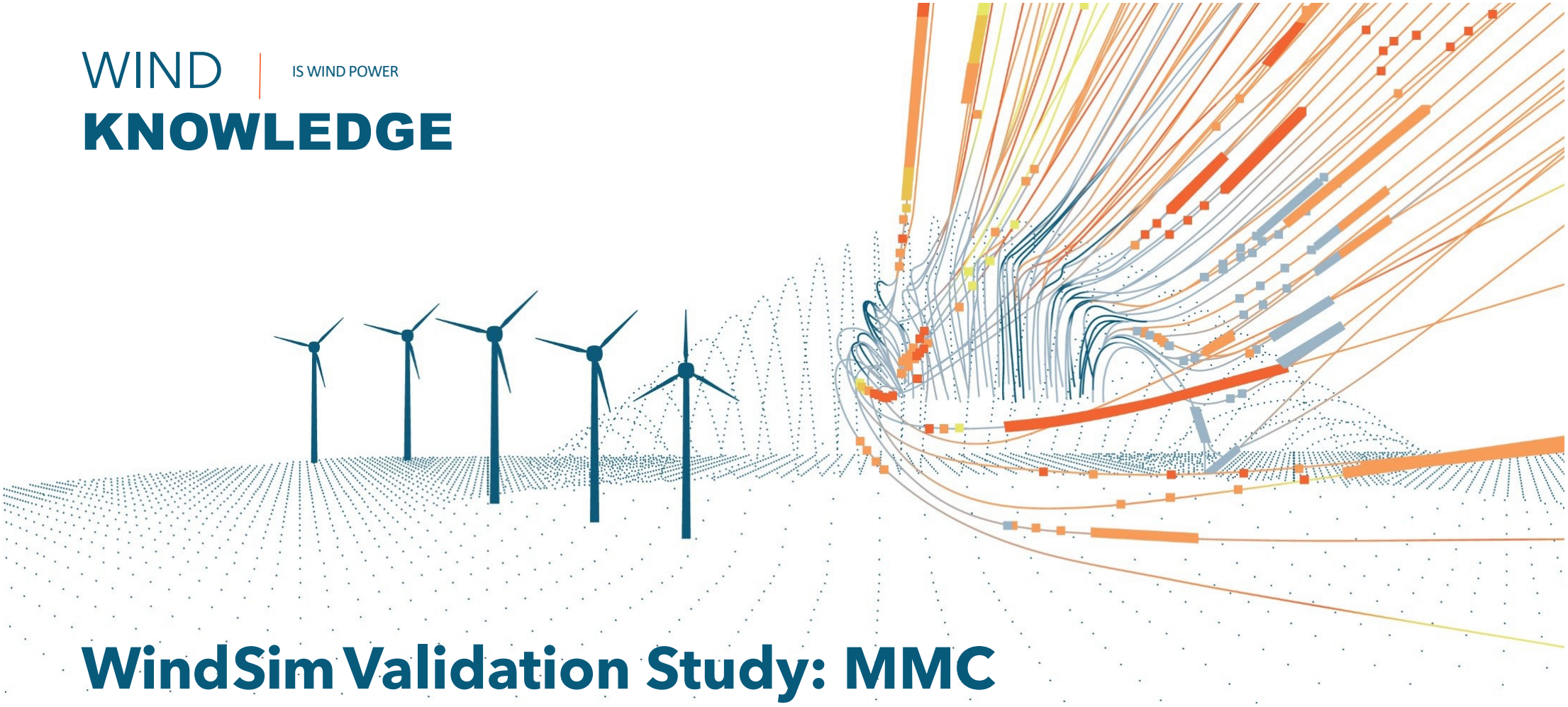

WindSim Validation Study: MMC

2025

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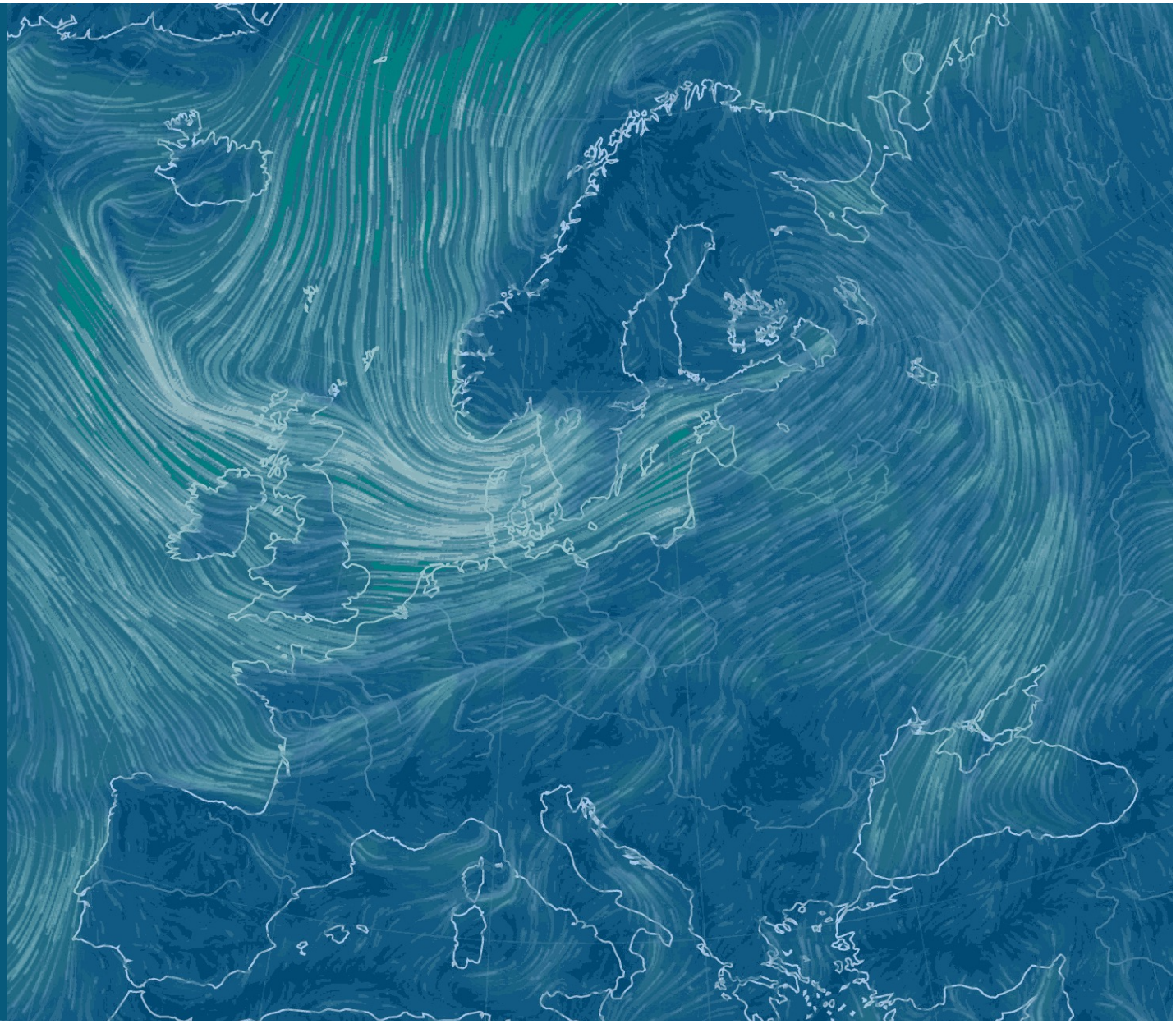
WindSim MMC: Enhanced Accuracy When Coupling CFD and Mesoscale

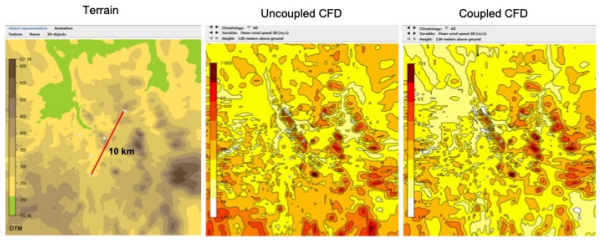


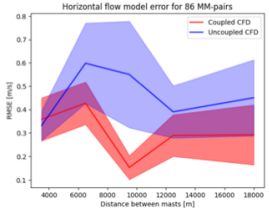
WindSim MMC | Enhanced Accuracy When Coupling CFD and Mesoscale

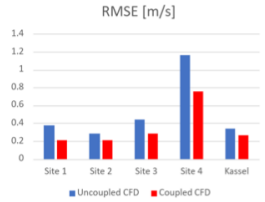
Objective:
- Demonstrate the improved accuracy of WindSim's wind resource assessment by coupling mesoscale models with CFD simulations through spatial-mean scaling.

Snapshot:
- Project: Kassel Site & Four European Sites
- Comparison: Coupled CFD vs. Uncoupled CFD
- Location: Germany & Four Other European Sites
- Data Sources: NEWA Mesoscale Data and Lidar/Metmast Measurements
- Analysis Period: Various validation periods across multiple sites
- Error Reduction: Coupled model reduced errors by 20–50% across five European sites.

Key Validation Results:
- Coupling CFD with mesoscale data (NEWA) improved prediction accuracy by up to 50% at larger spatial scales (greater than 6 km).
- Horizontal cross-prediction errors at the Kassel site decreased by 20–50% when using the coupled model compared to uncoupled CFD.
- Performance at smaller spatial scales remains similar between coupled and uncoupled CFD models.







Value Proposition:
- Enhanced Accuracy: Coupling mesoscale and CFD models results in higher accuracy at larger scales, benefiting sites with complex terrain.
- Validated with Public Data: Coupling method uses publicly available mesoscale data, offering broad applicability.
- Proven in Real-World Conditions: Validation across multiple European sites demonstrates the method's effectiveness in varying environments.

Summary:
- WindSim's spatial-mean scaling approach for mesoscale-microscale coupling significantly improves wind resource assessment accuracy at larger spatial scales.
- Access the full study here: "Coupling Mesoscale and CFD Models Through Spatial-Mean Scaling"
- Contact us for a personalized demo or case study to see how WindSim can enhance your wind resource assessments.

WindSim MMC | Enhanced Accuracy When Coupling CFD and Mesoscale

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

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WindSim AS, Tønsberg, Norway

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):

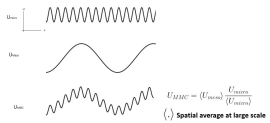
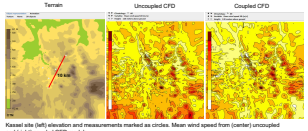


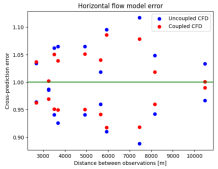
Illustration of the mean-scaling approach we propose for mesoscale-microscale coupling.

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.

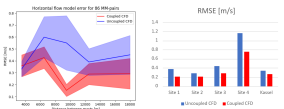


Horizontal cross-prediction errors for (blue) uncoupled and (red) coupled CFD models at Kassel.

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.

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Bechmann, A. (2015). How to use CFD for long-term energy assessments. SoundVisual production (digital)

Duran, P., Meißner, C., & Casso, P. (2020). A new meso-microscale coupled modelling framework for wind resource assessment: A validation study. *Renewable energy*, 160, 536-554.

Kühn, P., Basse, A., Cellas, D., Chen, Y., Dörfler, R., Freier, J., ... & Peuscher, L. (2018). NEWA Forested Hill Experiment Kassel.

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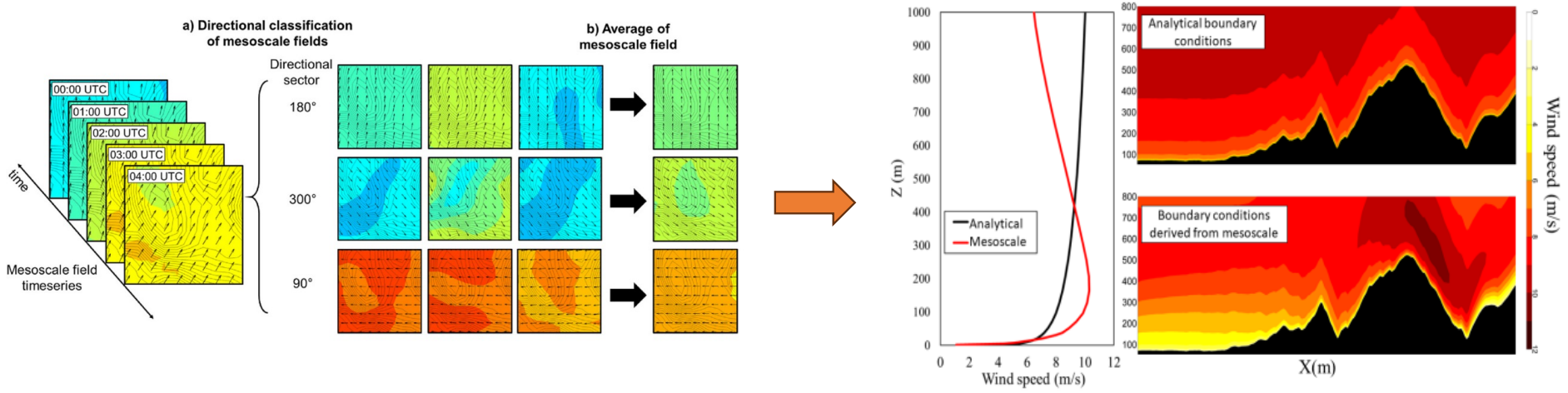
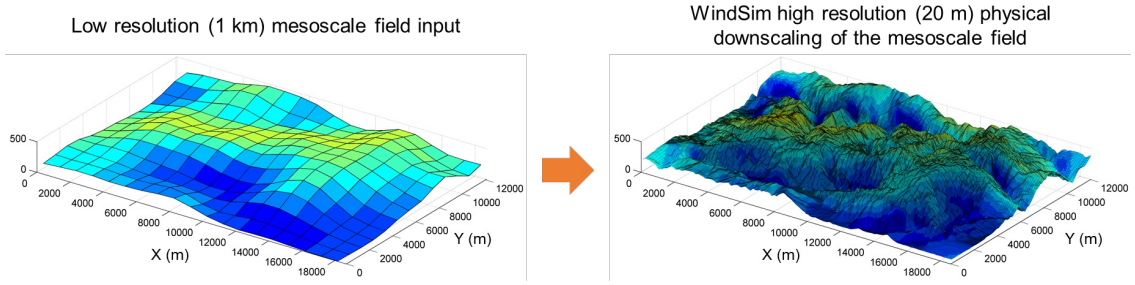
Meso-Micro coupling

- Sector-averaged mesoscale fields as boundary conditions
- Optional specification of atmospheric stability

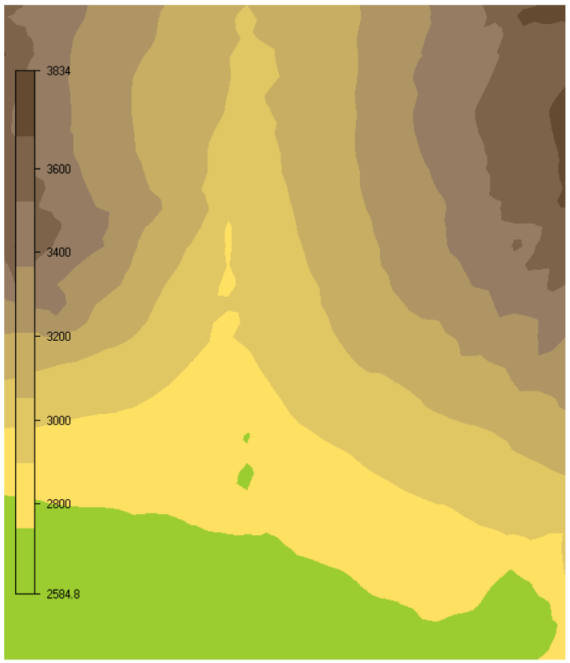




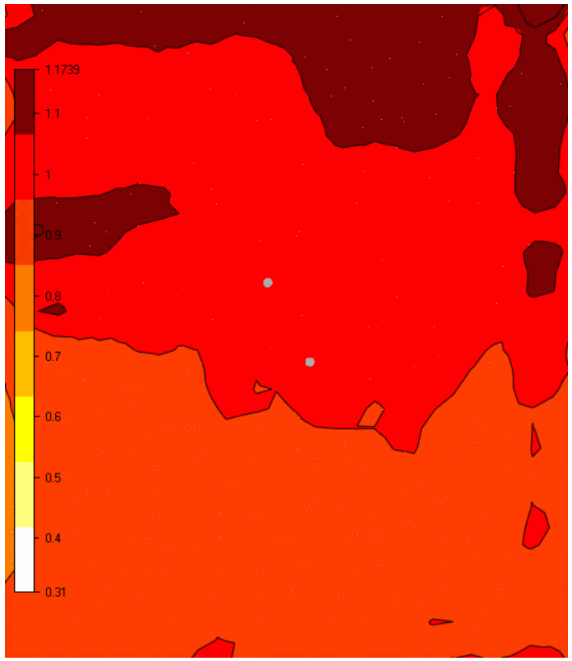
Meso-Micro coupling

- Sector-averaged mesoscale fields as boundary conditions
- Optional specification of atmospheric stability

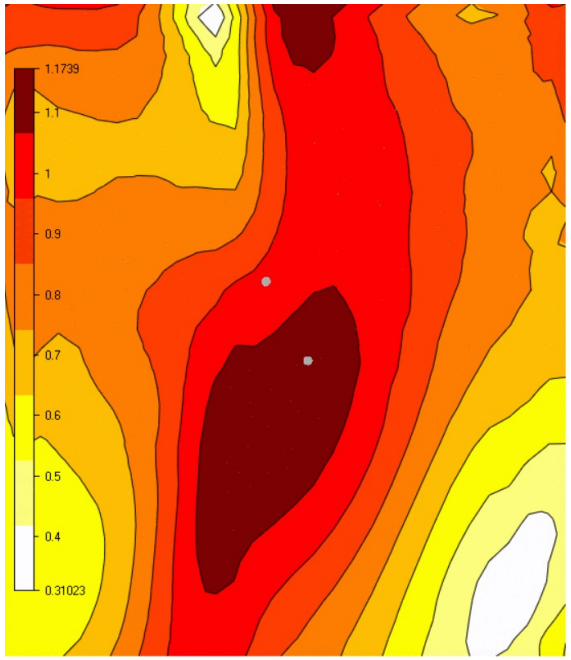
Site with strong meso effects



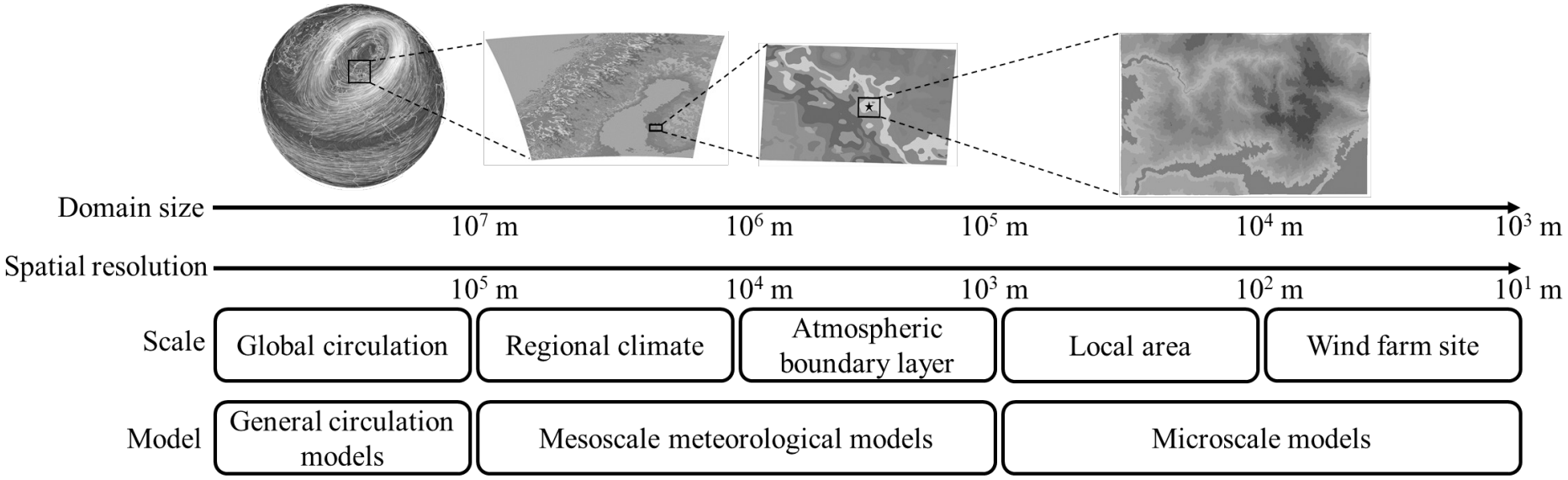
Standalone WindSim



WindSim with MMC



Meso-microscale coupling (MMC) definition



- Weather simulation and good representation of thermally driven flow

→ Good inclusion of orography

In the wind industry MMC methodologies use mesoscale data in combination with a microscale model