Improving Wind Resource Assessments by filling the meso-gap between Numerical Weather Prediction models and Large Eddy Simulation (LES) on GPUs

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BACKGROUND

As wind energy produces a growing share of our energy, numerical modelling across all scales of atmospheric phenomena becomes increasingly crucial. We have developed a mesoscale-to-Large Eddy Simulation (LES) coupled weather model, resident on Graphics Processing Units (GPUs). This innovative model captures all microscale flow effects in the LES domain, while simultaneously modelling its mesoscale boundary conditions. Compared to an LES set-up with periodic boundaries, this development makes the model better equipped for complex sites like land-sea transitions and mountains, but also for offshore sites where large amounts of surrounding wind farm clusters are present.

OBJECTIVE

- Show development of a fast NWP-to-mesoscale-to-LES coupled weather model
- Illustrate the effects of meso-LES coupling
- Present validation results that show improvements in flow modelling in mean wind speed and turbulence
- Lift the veil on future developments

Methods

Model :

- Whiffle's operational Large Eddy Simulation (LES) model (Schalkwijk et al. 2015, Verzijlbergh 2021, Baas et al. 2023)

Strengths:

- GPU-resident: fast enough for year-long simulations of entire wind farms
- Resolution: <100m, resolves turbulence and turbines
- Mesoscale: resolves mesoscale flow phenomena and provides input for the LES

The latest development in LES for very large domains

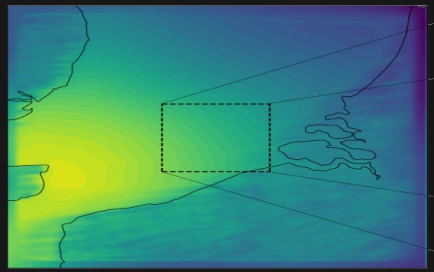

Figure 1: Snapshot of the wind field of the mesoscale domain, providing boundary conditions for the LES domain.

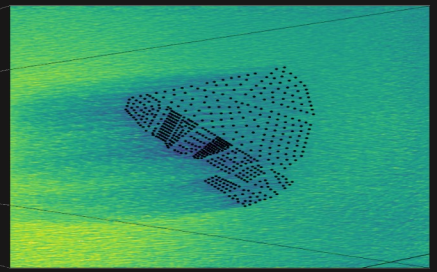

Figure 2: Snapshot of the 100m wind field around the Borssele clusters in the LES domain. Darker colours are lower wind speeds.

Improved capabilities

- Captures upstream flow phenomena of scales in between ERA5 and LES
- Shows better turbulence over the entire spectrum

Newest developments

- ERA5-Meso-LES cascade: running a concurrent mesoscale precursor simulation to generate enhanced boundary conditions for the LES
- Periodic LES replaced by open boundary conditions

Conclusions

- LES with mesoscale precursor simulation provides more accuracy over a range of scales
- First comparisons show improvements over most sites; further optimization of run settings necessary

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Improved atmospheric modelling capabilities

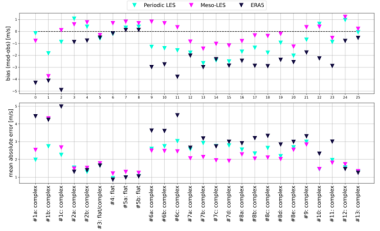

Figure 3: Validation of meso-LES compared to periodic LES and ERA5 against observations from 13 onshore sites (total of 26 met masts) across the world.

Close the turbulence spectral gap

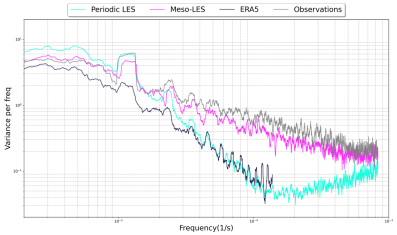

Figure 4: Comparison of periodic LES, meso-LES and ERA5 turbulence spectra with respect to observations from a met mast situated in complex terrain.

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