RESOURCE & TECH

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whiffle
Precision weather forecasting

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

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)
- Strength
  GPU-resident: fast enough for year-long simulations and operational forecasting of entire wind farms
  Sub 100m resolution LES domain: resolves turbines and turbulence
  Order 2km resolution meso domain: resolves mesoscale flow phenomena and provides input for LES domain

RESULTS

The latest development in our LES model – simulating very large domains

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

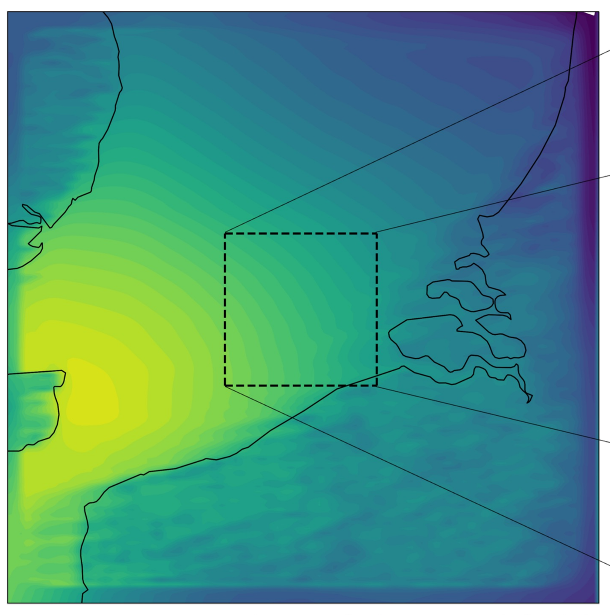


Figure 1: Snapshot of the wind field of the meso domain, providing boundary conditions for the LES domain.

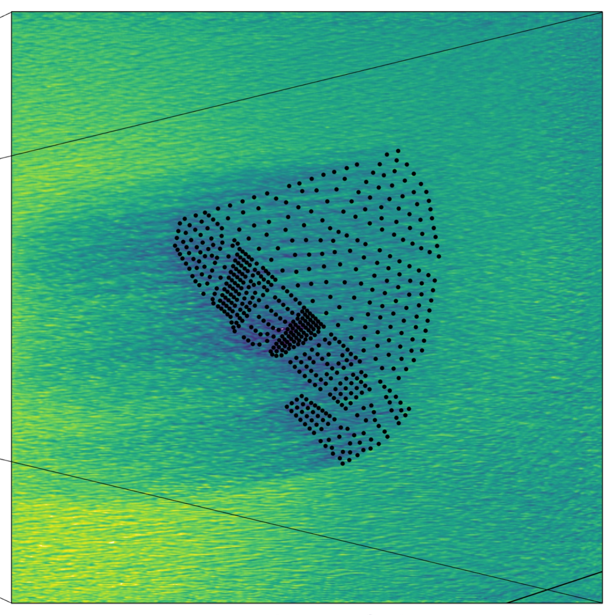


Figure 2: Snapshot of the 100m wind field around the Borssele clusters in the LES domain. Darker colours are lower wind speeds.

Improved capabilities

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

Has improved atmospheric modelling capabilities

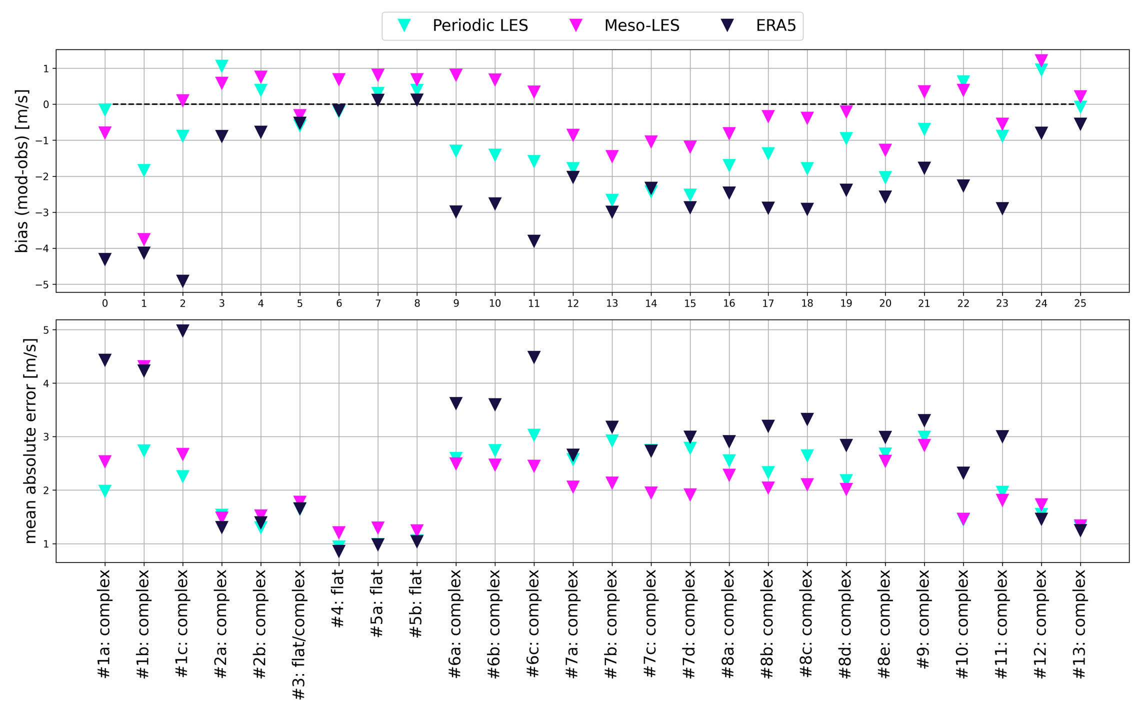
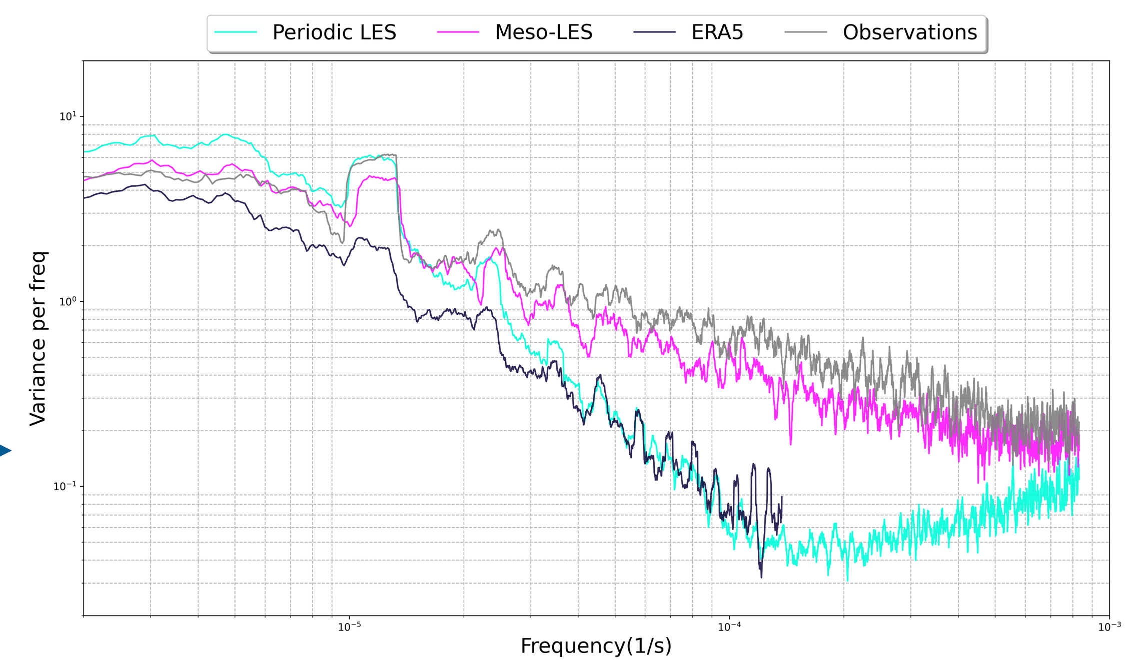


Figure 3: Validation of meso-LES compared to periodic LES and ERA5 against observations from 13 onshore sites (total of 26 met masts) across the world.

Closes 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.



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

FUTURE DEVELOPMENTS

Multi-GPU

- This year a beta version of country scale LES is released
- Uses multiple GPUs on standard cloud system

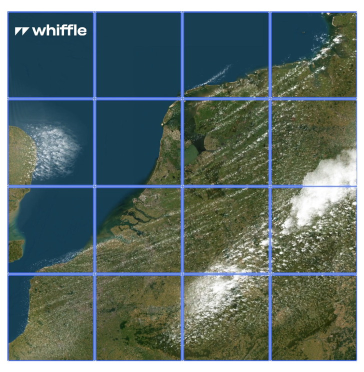


Figure 5: Cloud field of a 400x400km LES simulation on 100m resolution over the Netherlands and the North Sea. Each grid box represents an LES domain computed on one GPU.

ACKNOWLEDGEMENTS

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