A study of nested simulations in PALM LES in application to the wind turbines

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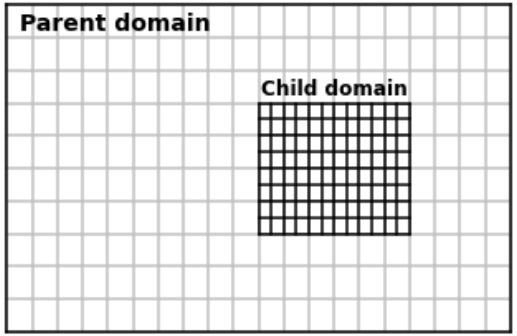
Nesting in large-eddy simulations

- Large-eddy simulations (LES) need a grid resolution good enough to resolve relevant turbulence scales.

	10 m, parent	5 m, parent	5 m, child
Size, km	7.68 x 3.84 x 1.6	7.68 x 3.84 x 1.6	3.84 x 1.28 x 0.5
Size, grid points	768 x 384 x 160	1536 x 768 x 320	768 x 256 x 96
# of grid points	4.7e7	3.8e8	1.9e7

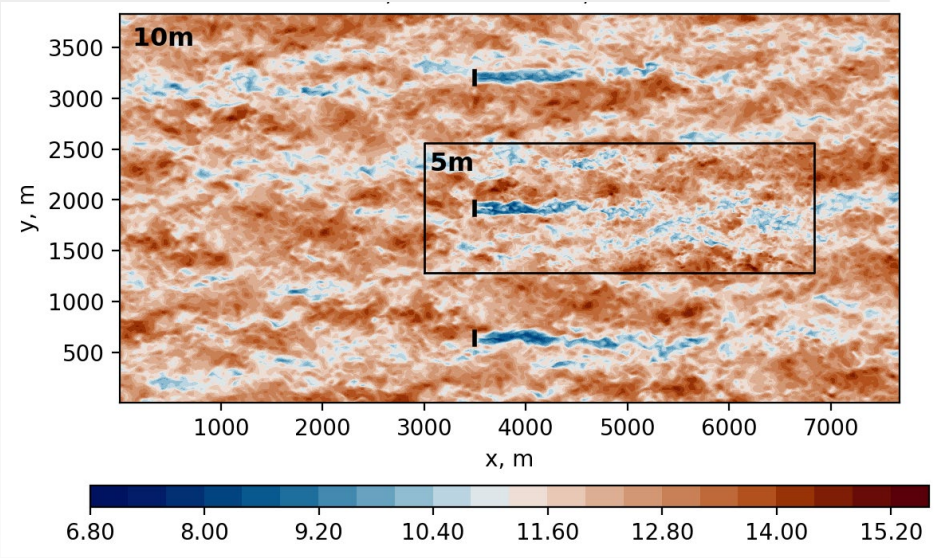


- The number of grid points can be reduced with nesting – local refinement of **the coarse parent domain** with **a child domain**.
- **Nesting modes**:
  - **Two-way**: parent and child domains affect each other.
  - **One-way**: parent domain does not get feedback from child domain.
- The nesting effects are studied for PALM LES [1][2], but not in the connection with wind turbines.

PALM LES setup

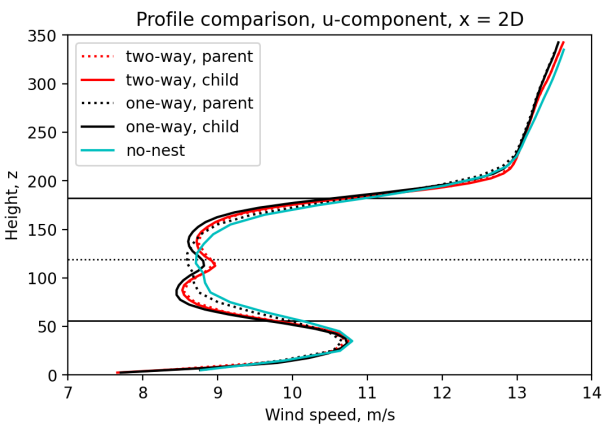
- Parent domain: Δ = 10 m
- Child domain: Δ = 5 m
- Three NREL 5 MW wind turbines
- No wake-wake/turbine interaction.
- Free flow: U_0 = 12.5 m/s, true neutral.

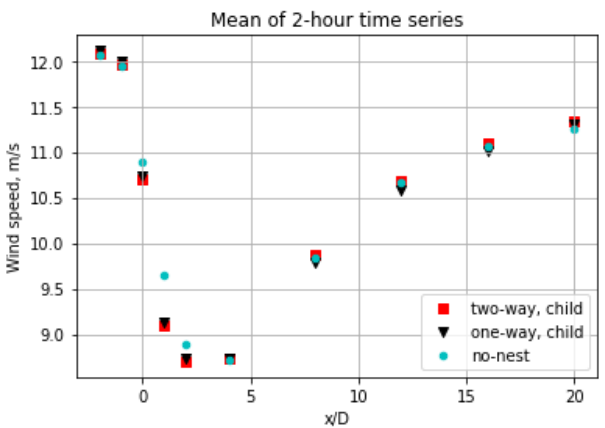
- **Simulations**:
  - No nested domain (coarse, 10m).
  - One-way nesting.
  - Two-way nesting.
  - 3 hours simulated, 2 hours of data at 5Hz

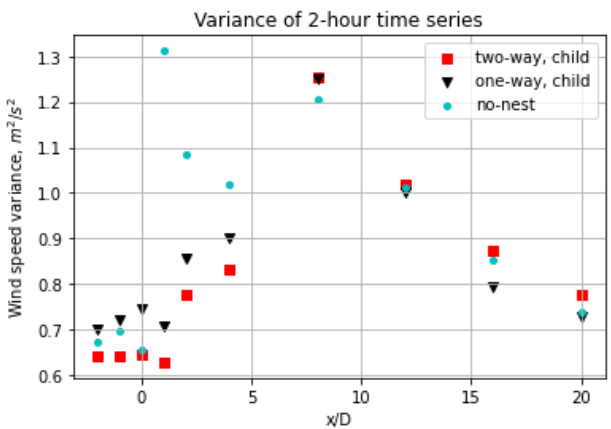


Results: Comparison

- The average profiles have strong disagreement in the near wake:
  - **two-way run** and **child domain of one-way run** agree rather well.
  - coarse domains of **no-nest** and **one-way run** do not capture the double peak at 1-2D.
- The **wind speed time series** are taken for the middle wind turbine along rotor axis.
- Wind speed **mean** and **variance** have discrepancy within 4D distance from the wind turbine – probably caused by highly tubulent near wake.

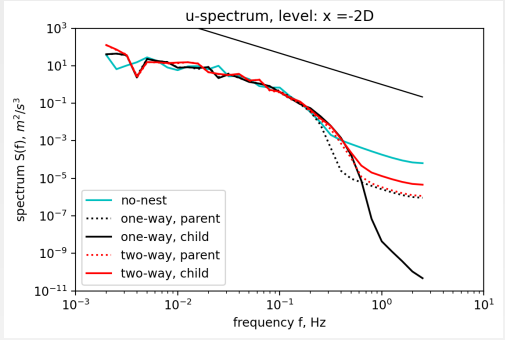


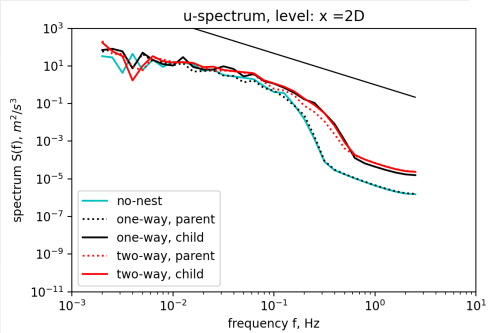


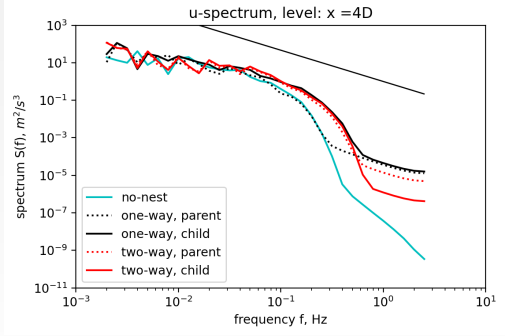


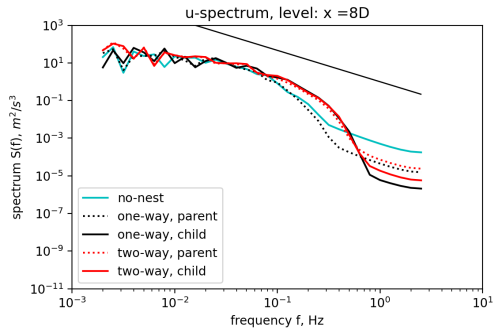
Results: Spectra

- Good agreement in front of wind turbine.
- More difference in the wake area.
- **Two-way nesting** spectra coincide well for both domains due to mutual influence.
- No-nest case follows one-way parent (coarser) domain.
- Inertial subrange is wider for **fine grid** and **two-way** nesting.









Conclusions

- CPU time required to simulate 3 hours at 512 cores

No nest, coarse	One-way nest	Two-way nest
14 847 s	29 185 s	30 519 s

- Use of the nested domain increases CPU time by 100%.
- ~5% gain for one-way nesting compared to two-way (low complexity simulation).
- The effect of grid resolution is most pronounced in the near wake.
- Child domains in the **one-way** and **two-way** nesting runs produce similar results.
- **One-way run parent domain** follows the behaviour of **no-nest** run rather closely.
- Strong discrepancy between the runs in the near wake ($x/D < 4$).
  - Need to be studied with higher resolution + comparison to experimental data.

References

1. Hellsten, A. *et al.* (2020) ‘A Nested Multi-Scale System Implemented in the Large-Eddy Simulation Model PALM model system 6 . 0’, (September), pp. 1–45.

2. Resler, J. *et al.* (2020) ‘Validation of the PALM model system 6.0 in real urban environment; case study of Prague-Dejvice, Czech Republic’, *Geoscientific Model Development Discussions*, pp. 1–57. doi: 10.5194/gmd-2020-175.

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