Analysis of Wind Spectra and Coherence in Neutral Stability at Sea Based on Two LES Codes

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14.01.2021

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OBJECTIVE

To compare the performance of SOWFA and PALM in reproducing flow characteristics in a neutral boundary layer (NBL), with the focus on the wind spectra and coherence.

Motivation

- LES becomes useful tool in wind industry.
- Better understanding of models, less uncertainties.
- Spectra and coherence reveal the energy distribution and spatial structure of multi-scale turbulence.
- Accurate wind field reconstruction is necessary for load analysis of wind turbines with large rotor size.

Case Information

Lx = 2560m Ly = 2560m Lz = 960m

nx = 256 ny = 256 nz = 96

Cyclic boundary condition

Wind speed: 8.0m/s at height of 90m

Roughness length = 0.001

Stability condition: Neutral

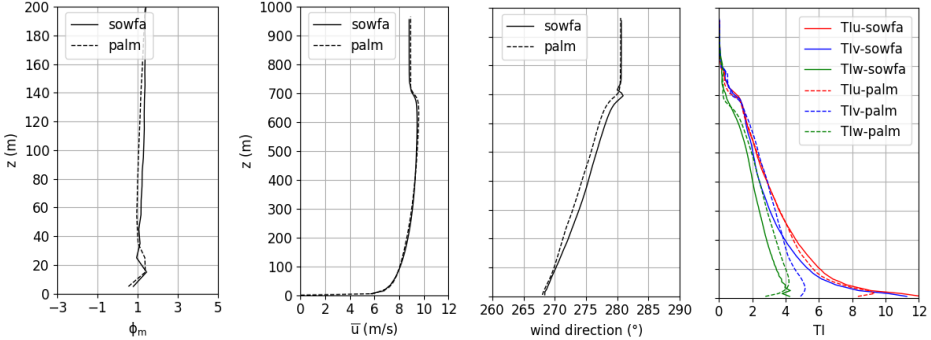
Simulation time: 40h + 2400s (10Hz)

RESULTS - Profiles

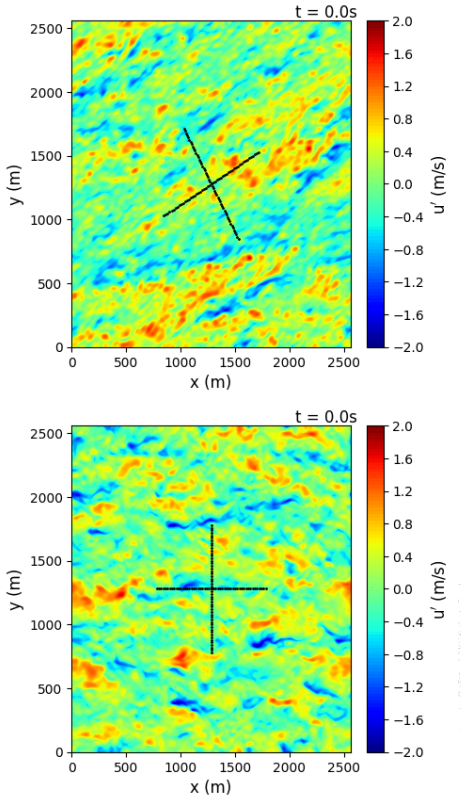
- Results of wind shear and veer from two codes have good agreement.
- A change of wind direction of 3~4 degrees across the height of a rotor.
- the bottom and top of a turbine rotor could experience very different inflow fluctuations.

Wind speed and direction

Turbulence intensity



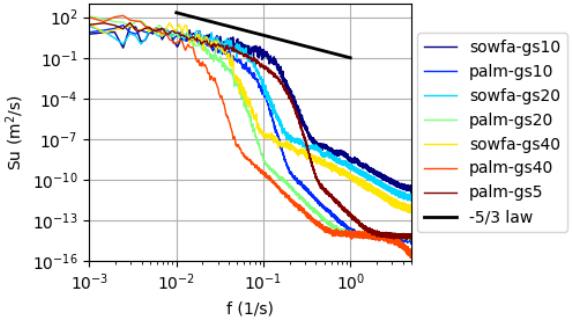
Turbulent streamwise velocity at height of 100m



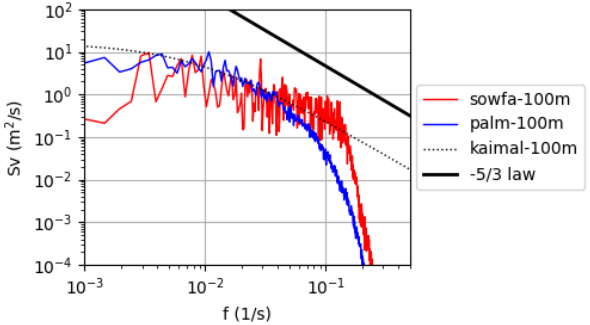
RESULTS – Spectra

- Mesh resolution directly determines the cut-off frequency. SOWFA and PALM need at least 10m and 5m grid sizes respectively to correctly capture wind turbulence.
- In low frequency region, wind spectra from PALM have larger value than SOWFA and closer to Kaimal spectra.
- spectra from SOWFA have obvious fluctuations while PALM provides very smooth results.

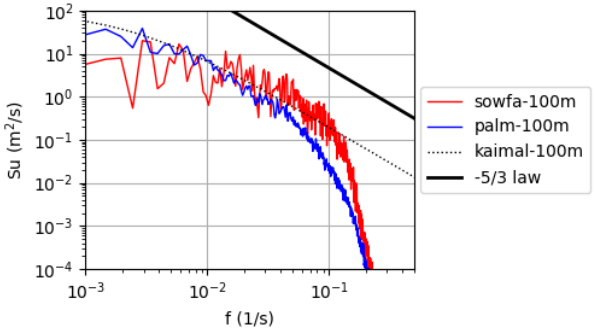
Sensitivity of grid size (H = 100m)



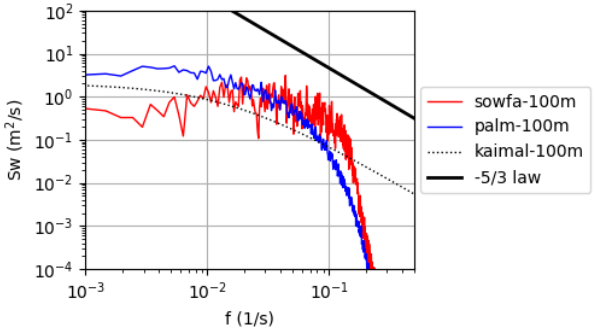
PSD of v at 100m height



PSD of u at 100m height



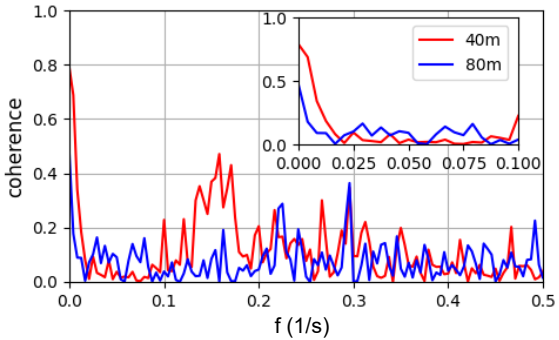
PSD of w at 100m height



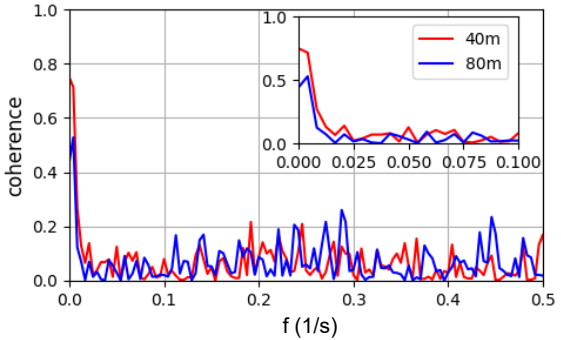
RESULTS – Coherence

- For both lateral and vertical separation of 80m, obvious coherence exists for frequency less than 0.02Hz. Coherent turbulence of such scale will have strong influences on rotor loads.
- SOWFA and PALM have very close coherence estimation for vertical separation, but SOWFA seems to have stronger coherence than PALM in lateral direction.

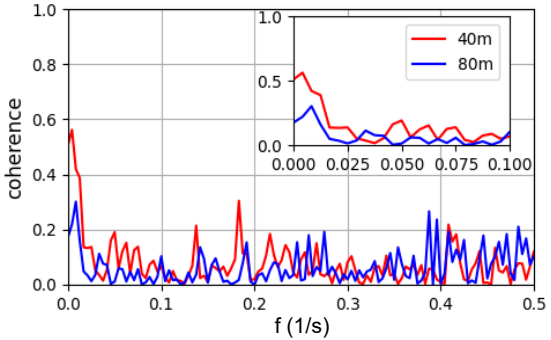
Lateral separation (SOWFA)



Vertical separation (SOWFA)



Lateral separation (PALM)



Vertical separation (PALM)