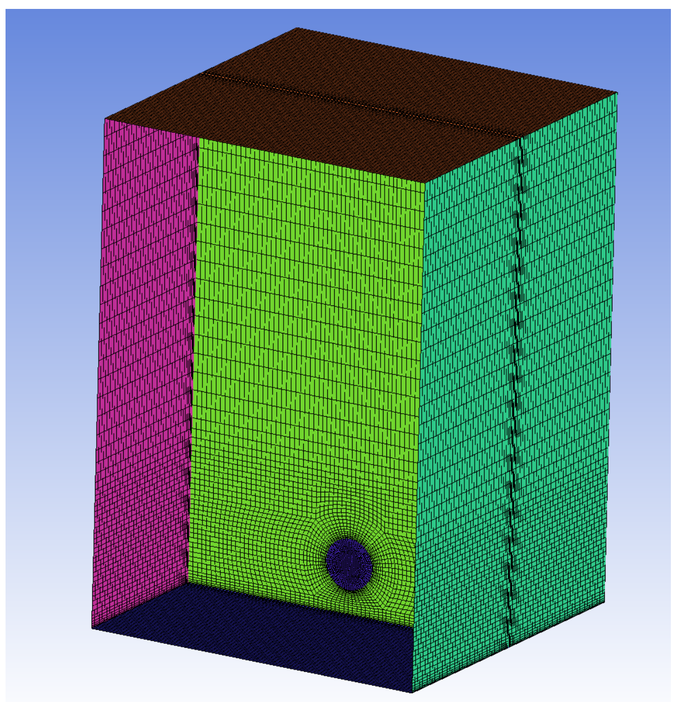
Exploring the optimal efficiency of large offshore wind farms using LES

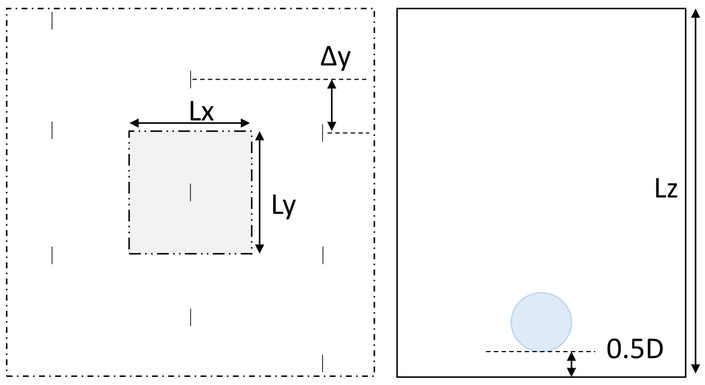
What to study

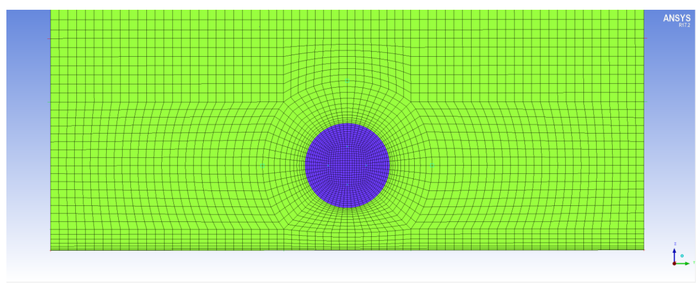
- Optimal efficiency of turbine arrays
- Interaction between farm scale and turbine scale
- Innovative turbine design and layout for large offshore wind farms

How to study

- Exclusive CFD simulations
- Actuator disc and line models
- Comparison with latest theorectical models

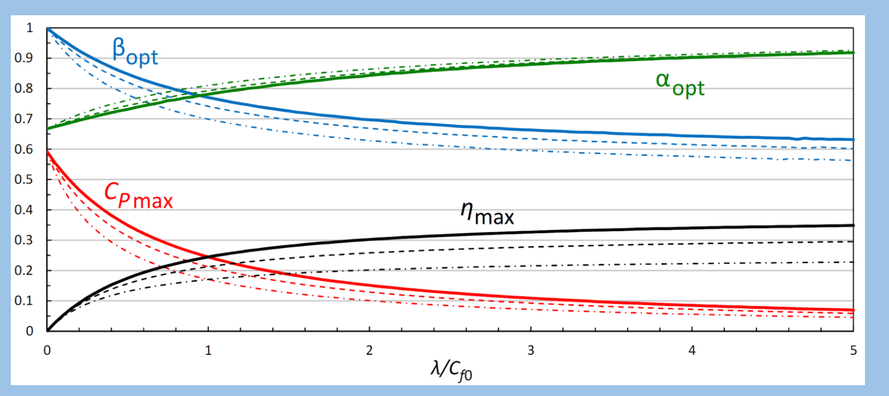






Top: 3D mesh section view, middle left: staggered layout, middle right: simulation domain, bottom: 3D mesh section view

Two-scale-coupled momentum model (Nishino, 2016)



$C_p = \beta^3 \cdot 4\alpha^2(1-\alpha)$ and $\eta = \lambda \cdot \frac{1}{C_{f0}} \cdot C_p$

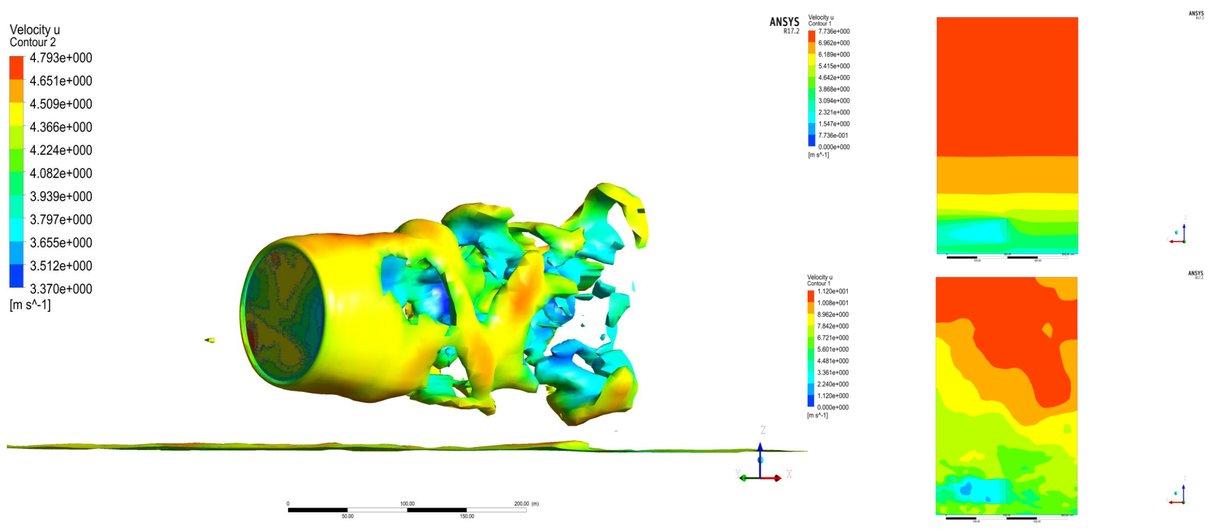
$\alpha = U_T/U_F$ (where U_T and U_F is the area-averaged wind speed across turbine swept area and volume-averaged wind speed across wind farm respectively), β is wind farm speed ratio (U_F/U_{F0}, U_{F0} is obtained before wind farm construction), η is normalised power density, C_{f0} is 'effective' friction coefficient, λ/C_{f0} is a farm parameter where λ is horizontal area allocated to a turbine over turbine swept area, and solid lines for γ = 2; dashed lines for γ = 1.5; dash-dot lines for γ = 1 ($\frac{\langle\tau_w\rangle}{\tau_{w0}} = \beta^\gamma$, where $\tau_{w(0)}$ is ground shear stress after (before) wind farm construction).

Current progress

- Considering both aligned and staggered turbine layout, with constant hub height (100m) and turbine diameter (D=100m)
- Simulation domain is 7Dx7Dx10D (WxDxH), with relatively fine mesh (460k cells)
- Actuator disc (simplified turbine representation) with periodic condition (as infinite large wind farm)
- Turbulence model testing, LES, DES and RANS (k-ω (SST) and k-ε)
- LES ground roughness integration

Next stage

- Detailed comparison of turbulence models
- Mesh and domain size sensitivity tests
- Convert to actuator line method
- Validation against fully-resolved rotor simulations



Left: swirl contour (LES), stream direction wind flow RANS (upper right) and LES (lower right)

Mr. Lun Ma, Academic Supervisors: Dr Takafumi Nishino and Dr Athanasios Kolios

Building 52, Cranfield University, Cranfield, MK43 0AL

l.ma@cranfield.ac.uk

www.cranfield.ac.uk