Coupled Mann-Large Eddy Simulation of a Wind turbine to Understand the Wake Meandering

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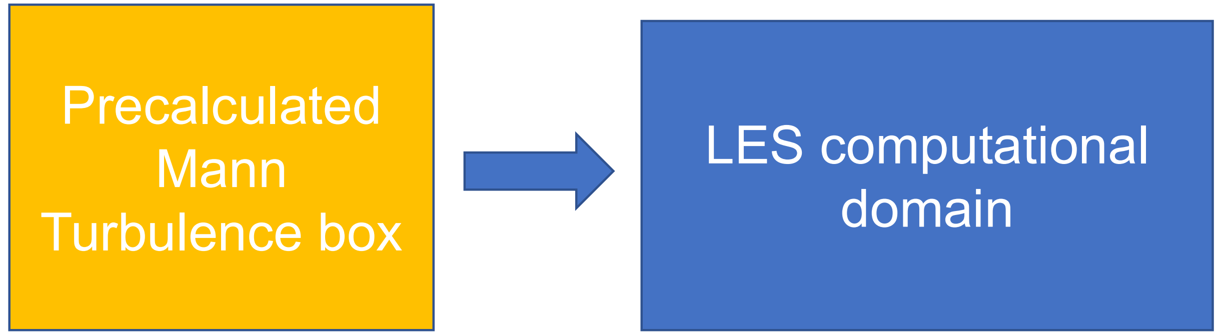
Methodology

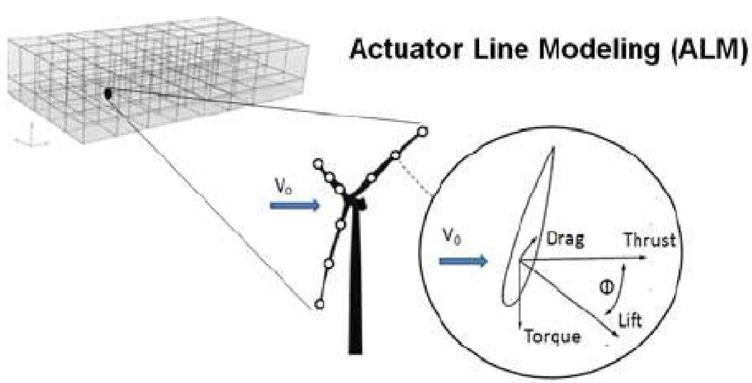
- Generate turbulence boxes using Mann turbulence generator
- Turbulence velocity components of each slice of Mann turbulence box will be given as input to the LES domain
- Performed coupled Mann-Large Eddy Simulations (Mann-LES) are performed.



Precalculated box

Wind turbine modelling (ALM)

- The turbines are modelled as a sink term in momentum equation, and this is described by following generalized N-S equation.
- $\frac{\partial \rho \bar{u}_i}{\partial t} + \frac{\partial \rho \, \bar{u}_i \bar{u}_j}{\partial x_j} = -\frac{\partial \bar{p}_i}{\partial x_i} + \frac{\partial \tau_i}{\partial x_j} + S$
- The turbine source term is based on BEM approach



schematic of the actuator line model for blade. The lift and drag forces calculated using the blade element method are distributed over the actuator lines of a blade[1].

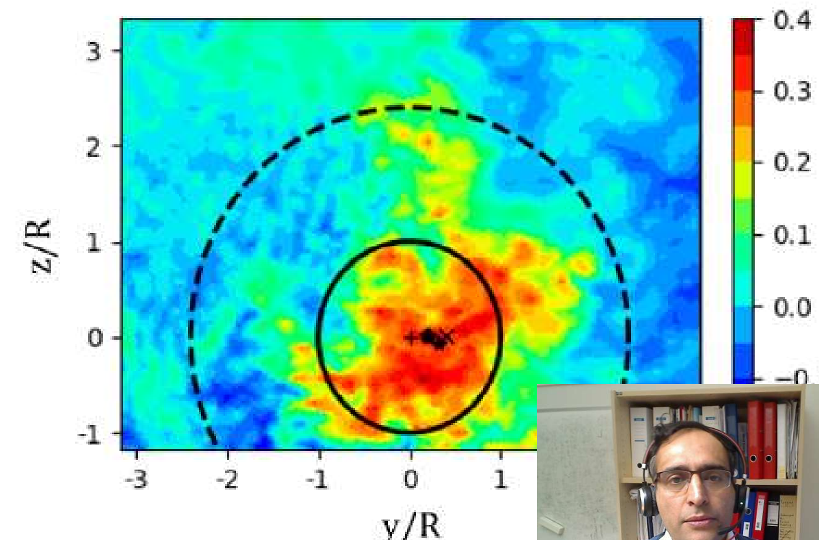
[1]Jha et al., Turbulence Transport Phenomena in the Wakes of Wind Turbines

wake centre detection

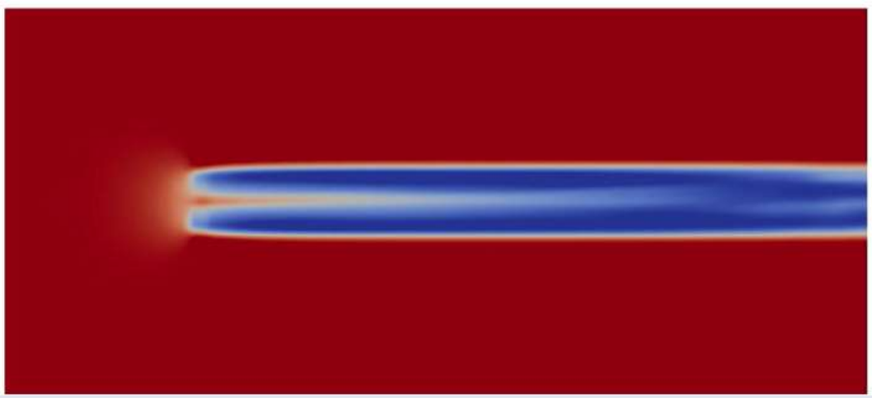
- The gravity centre of the velocity deficit field;

$$y_C = \frac{\int y(1 - \frac{U}{U_0})dA}{\int (1 - \frac{U}{U_0})dA}, \qquad z_C = \frac{\int z(1 - \frac{U}{U_0})dA}{\int (1 - \frac{U}{U_0})dA}.$$

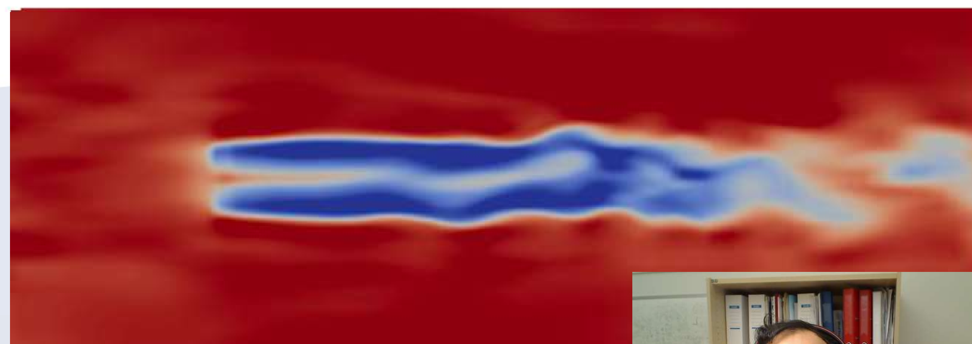
- The point of maximum velocity deficit.



Flow Field (NREL 5MW at 8m/s, TI=6%)

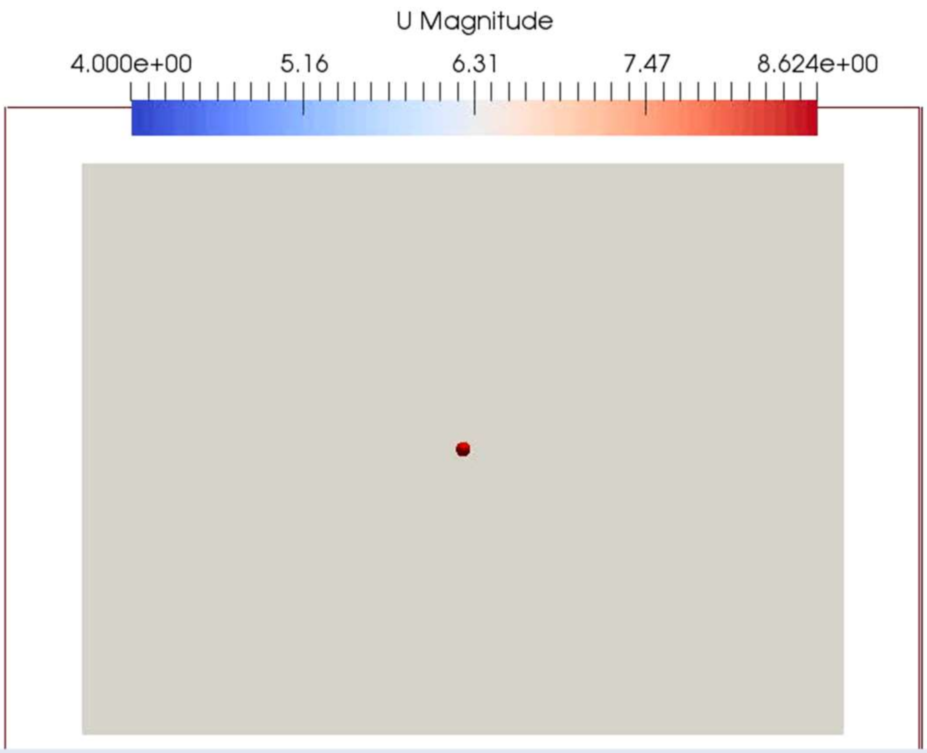


Without coupling

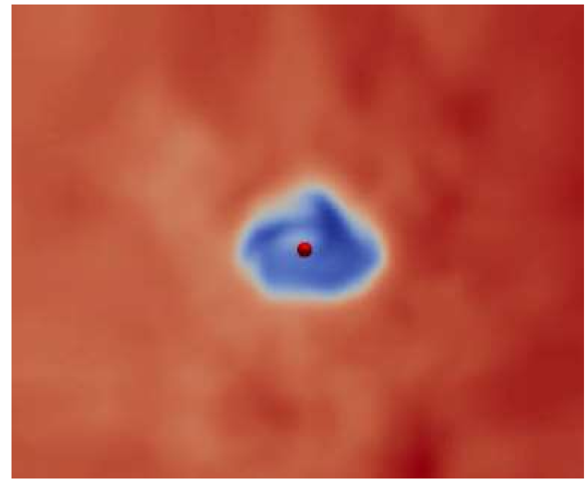


With coupling

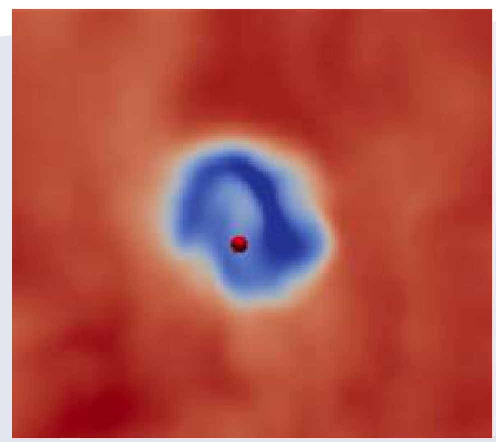
Flow field with coupled turbulence box



X/D= 5.5

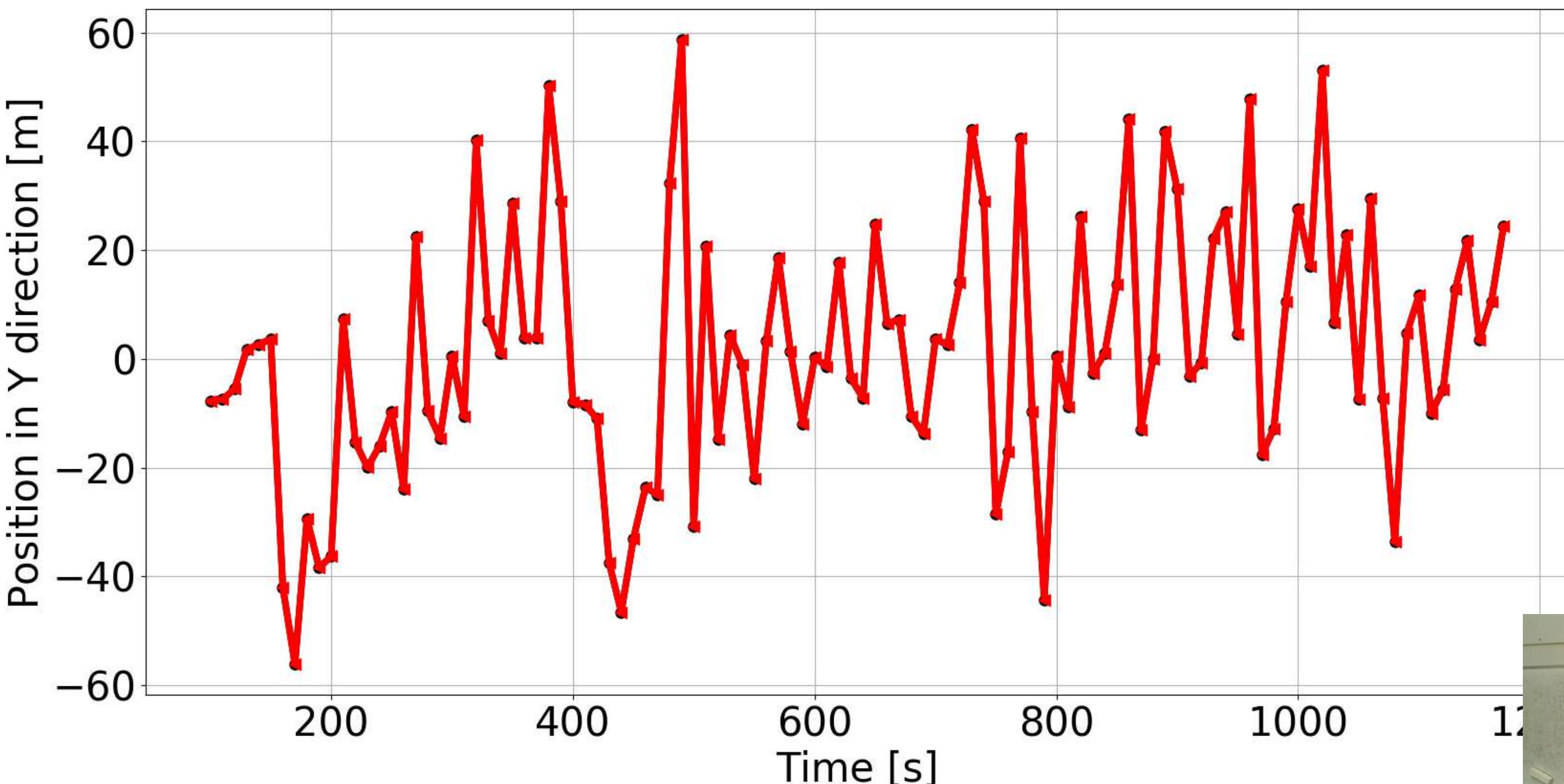


t = 500 s

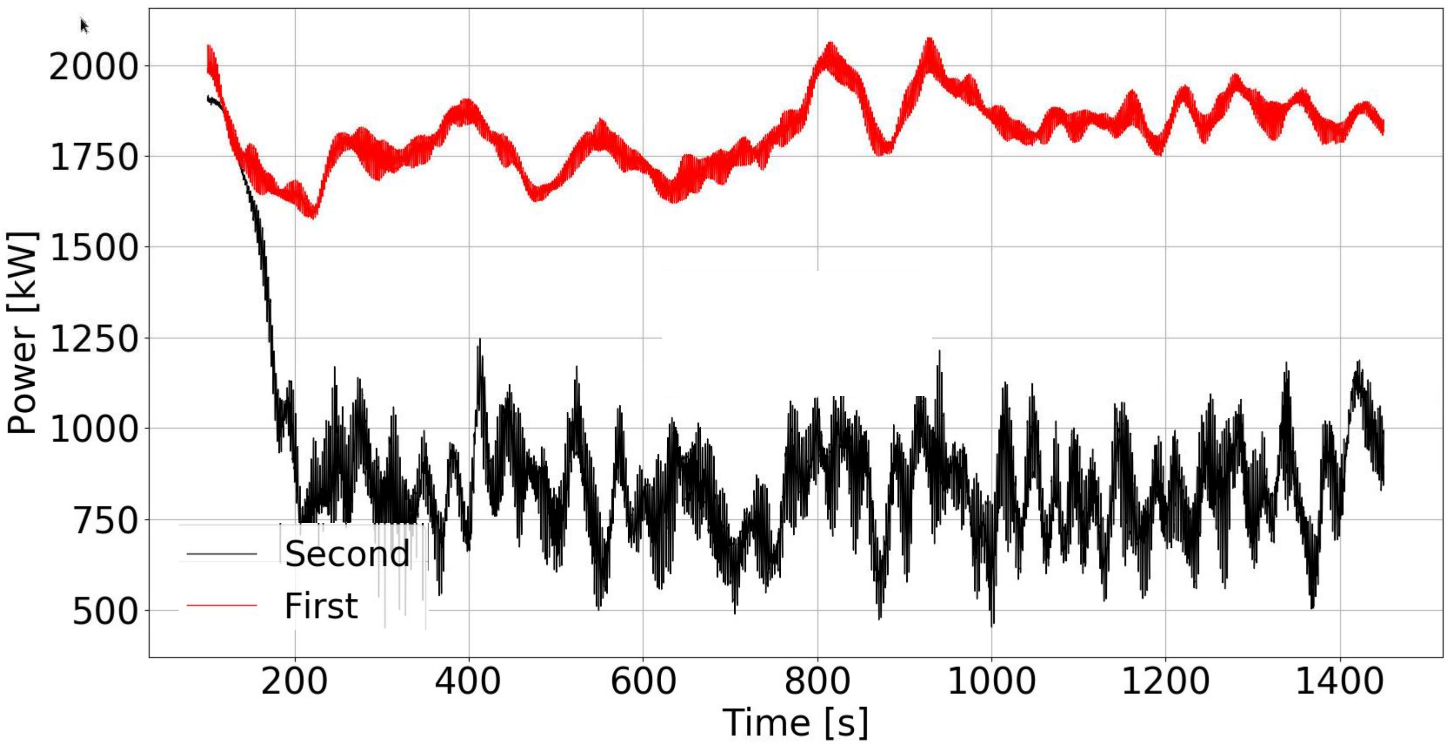


t= 800 s

Meandering in Y direction (X = 8D, TI = 6%, Mean wind speed = 8 m/s)



Power of first and second turbine (Two turbines in a row 8D apart) (Wind speed = 8m/s, TI = 6%)



Conclusion

- Two methods of wake center detection were tested and both gave same results
- The second turbine, which is in the wake of first turbine, gives larger variation in power due to the meandering.
- Validation of the approach is under progress

Acknowledgement

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