A Numerical Investigation of the Geometric Characteristics of Floating Offshore Wind Turbines Wake under Axial and Yawed Rotor Conditions

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Motivation

- Floating wind turbines experience considerable motion induced by sea waves
- The unsteady component of the rotor aerodynamic thrust is known to reach a substantial proportion of the time-averaged thrust (Shen *et al*, 2018, Tran *et al*, 2018)

➢ ***Wave evolution may different considerably than that of fixed rotors***

Research Objective

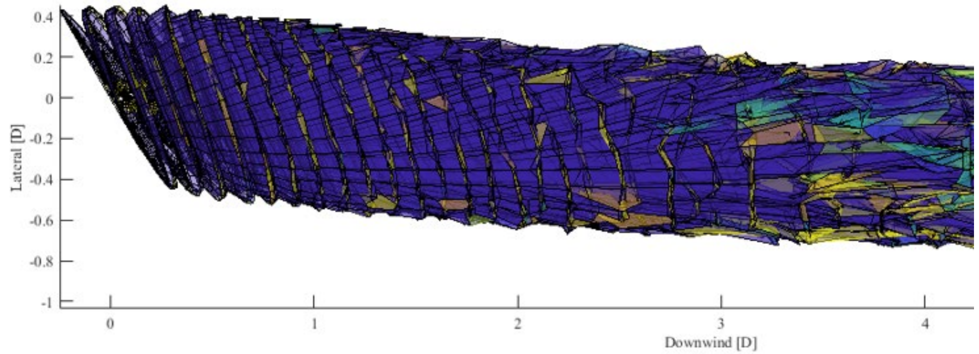
- Using numerical modelling to compare the geometric characteristics of FOWT wakes with those of fixed wind turbines under axial and yawed conditions

➢ ***Focus is on wake boundary and centerline for the first 4D downstream***

Code Used

❑ Free-wake Vortex Method (FWM)

→**WInDS** (UMASS, *Sebastian et al, 2012*)



Approach

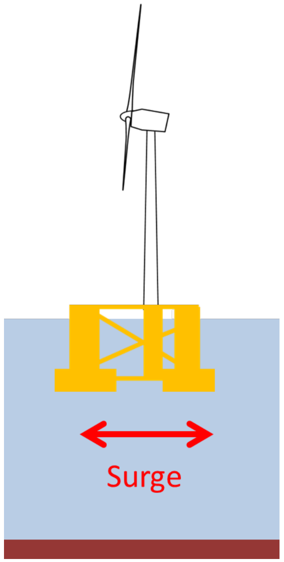
Modelled Wind Turbine

- NREL 5 MW wind turbine
- Rotor diameter 126 m
- Rigid blades and tower

Operating Conditions

- Regular wave conditions (Sinusoidal surge prescribed)
- Windspeed fixed at rated value of 11.4m/s
- Rotor tip speed ratio fixed at $\lambda = 7$ (for optimal CP)
- Rotor yaw angles $\Psi = 0$, 15, 30 and 45 deg
- 4 Yaw settings x 4 Sea States = **16 simulations**

Sea State	H_w (m)	T_w (s)	A_s (m)	V_s (m/s)
S0 (fixed)	0	0	0	0
S1 (Mild)	3.66	9.5	0.75	0.5
S2 (Very Stormy)	6.4	11.65	1.85	1.0
S3 (Extreme)	9.14	13.6	3.31	1.53



$$X = A \sin(2\pi f)$$

↓

Free-wake vortex model

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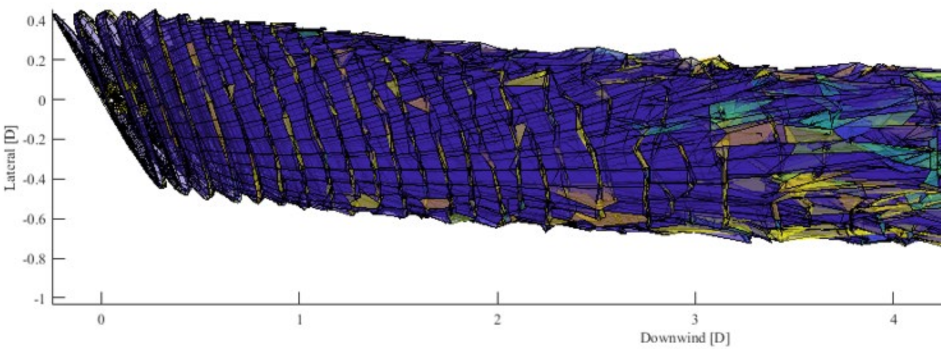
Python post-processing code

Main Outputs:

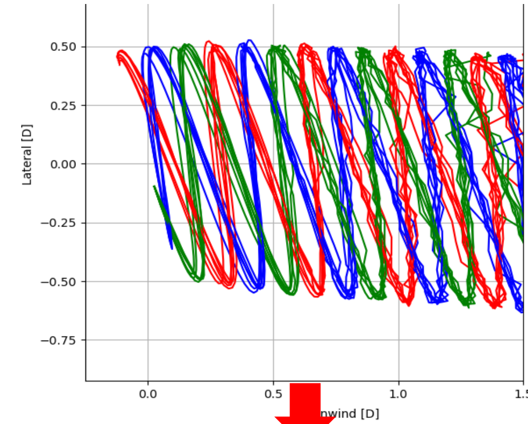
1. Curvilinear wake centerline
2. Wake skew angle

Approach: Postprocessing of free-wake geometry data

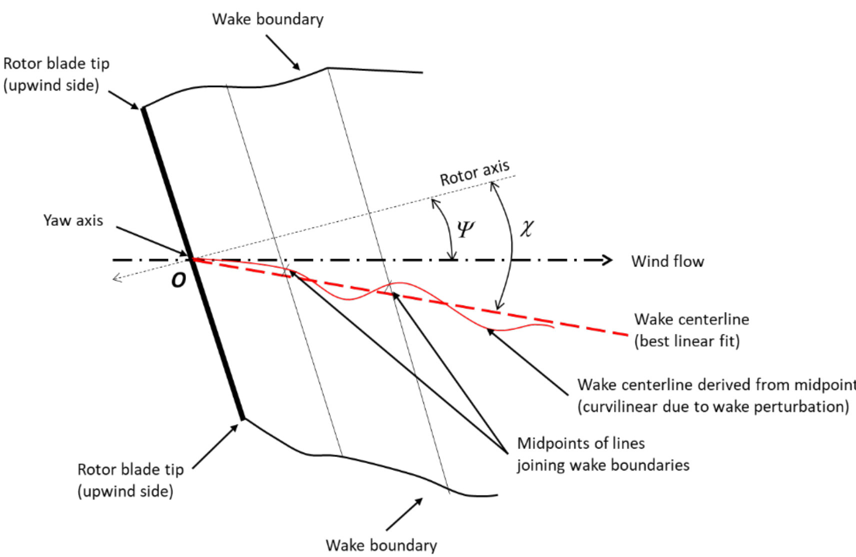
Step 1: **Generate free-wake using vortex model**



Step 2: **Derive wake boundary based on average position of the outer 6 helical trailing filaments**

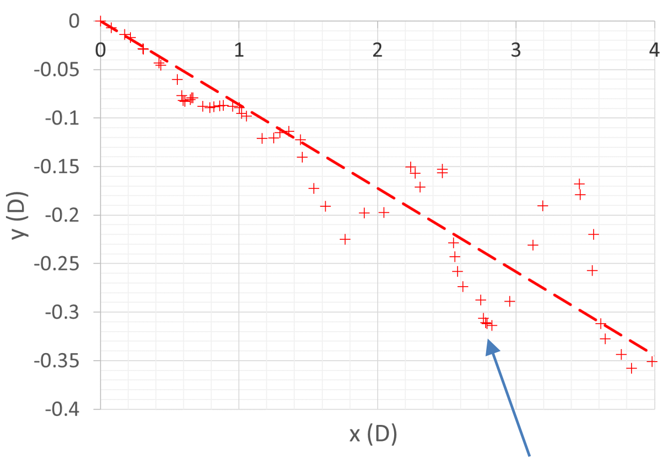


Step 3: **Determine centerline of wake at a position downstream by plotting horizontal straight line parallel to rotor plane**



Step 4: **Draw best line fit to represent wake axis.**

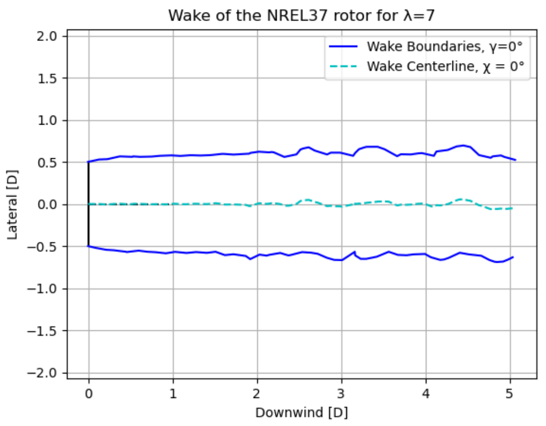
- *Standard Error taken as measure of wake perturbation*
- *Best line fit used to compute* χ



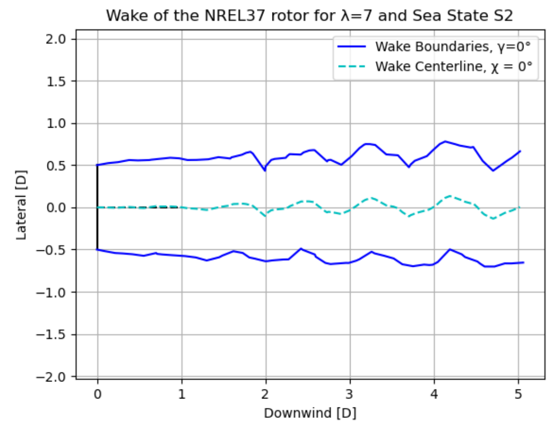
Each data point denotes wake centre line at give position downstream

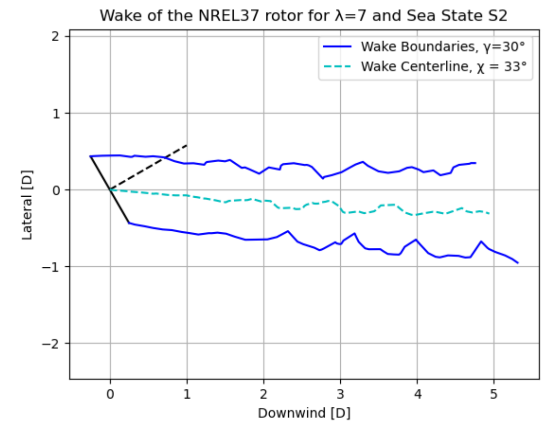
Results

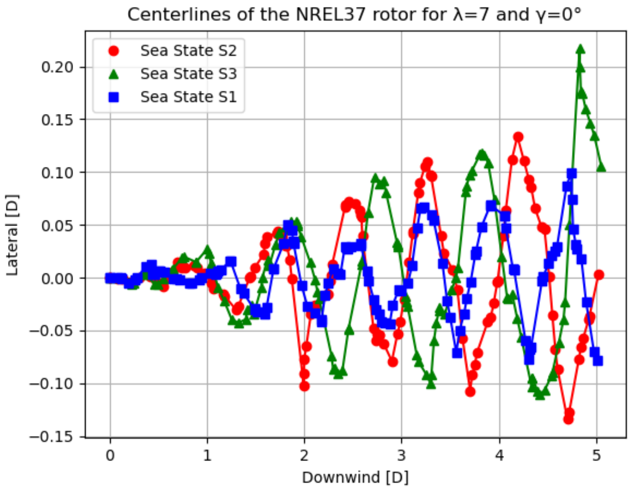
Fixed Rotor

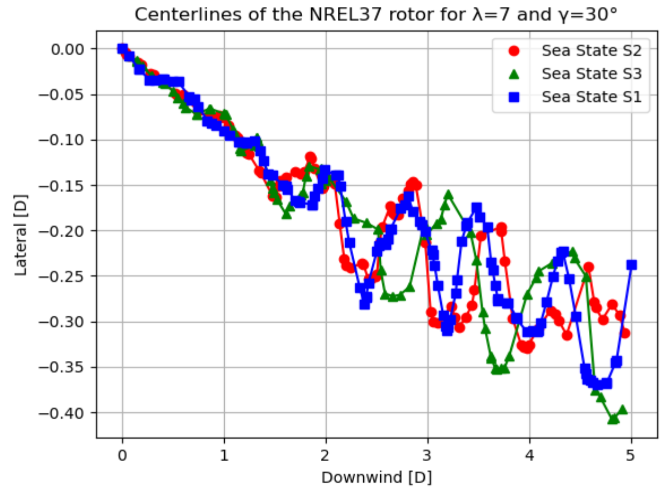


Floating Rotor



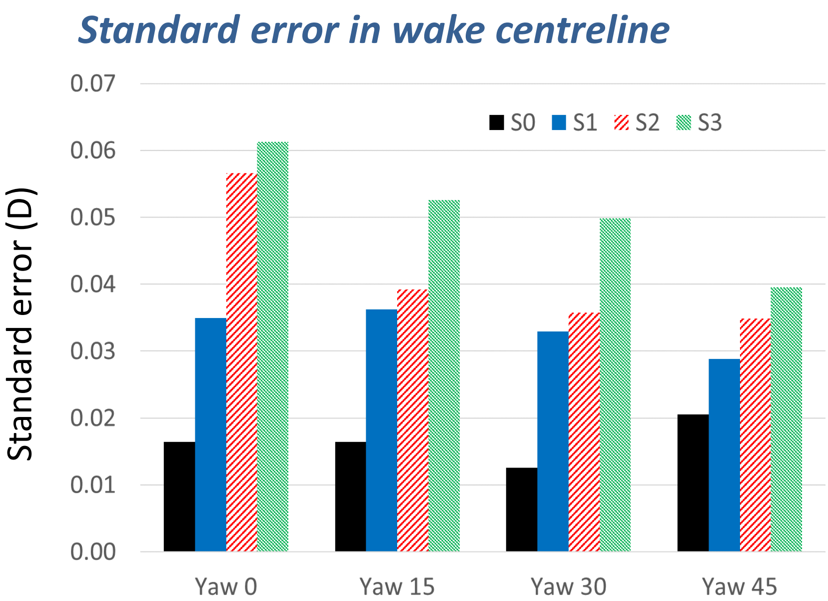


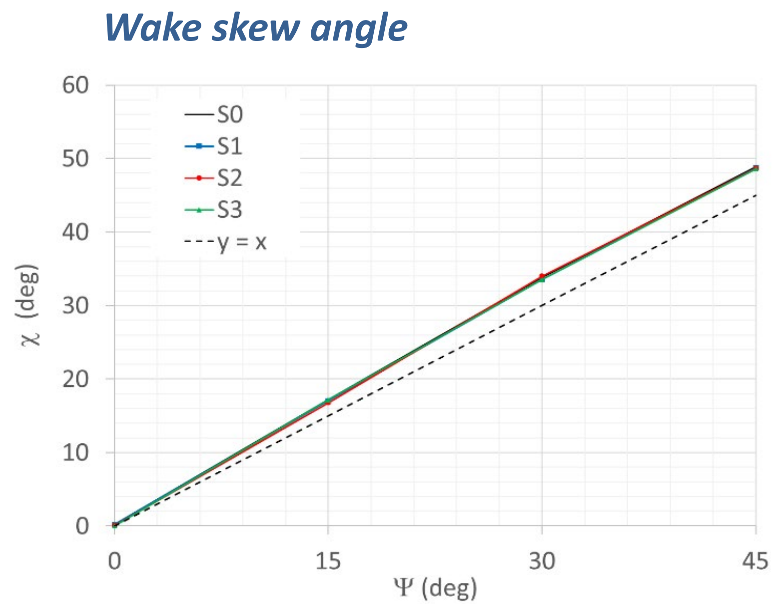




- Floating rotors encounter wake perturbation at earlier stage than fixed rotors
- Perturbation induced by wake vortex-to-vortex interaction which effects tip vortex stability. Such phenomena have been studied in depth for fixed rotors (e.g. Lignarolo et al, 2016 TUDelft) but not for floating rotors

Results





- Platform surge motion has a considerable influence on level of perturbation experienced by wake.
- During rough sea states leading to large surge motion, increasing the rotor yaw angle reduces the perturbation of the wake centreline. This is observed from the results for the wake centreline standard error for sea state S3
- The estimated wake skew angle derived from the best linear fit in the near wake is found to be quasi independent of the sea state. This is due to the fact that the time-average thrust coefficient does not change with sea state