

CFD-Based Wake Steering Models for Floating Wind Turbines: Bridging High-Fidelity and Engineering Tools

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Floating offshore wind farms are emerging as a key technology for harnessing wind energy in deep waters. Unlike fixed-bottom turbines, floating platforms experience significant motions, such as tilt and pitch, which strongly influence wake dynamics and turbine performance. Accurate prediction of these wake effects is crucial for optimizing wind farm design, control strategies, and energy yield. However, conventional engineering wake models do not account for wake deflection resulting from wind turbine motion (tilt and yaw), creating a gap between high-fidelity simulations and practical design tools. This work addresses this challenge by developing analytical wake-steering models (wake deflection model) tailored for floating wind applications, thereby bridging the gap between advanced CFD insights and efficient engineering models.

Introduction and Methodology

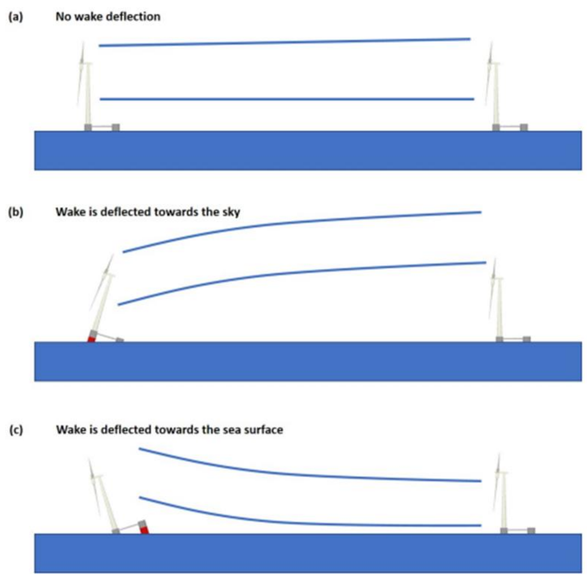
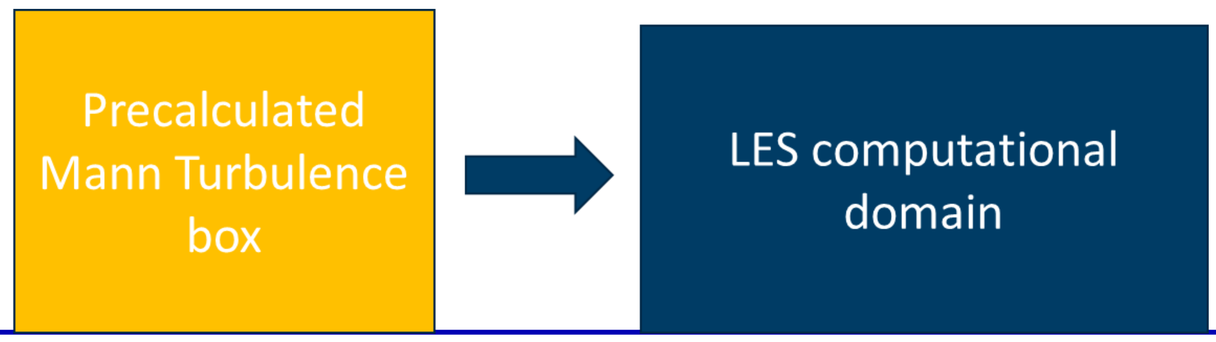


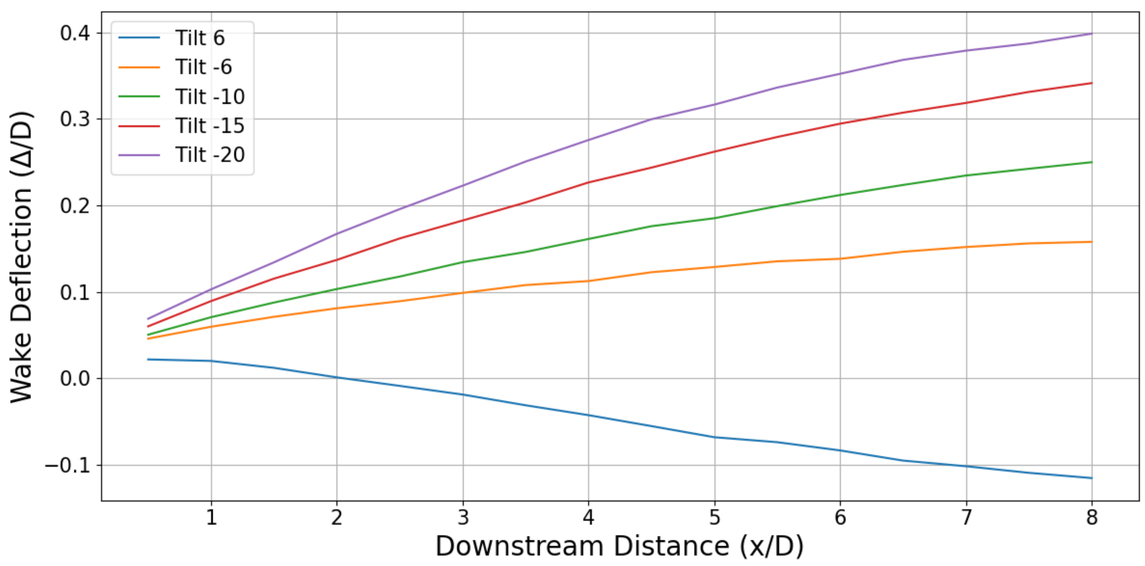
Image is taken from: https://wes.copernicus.org/articles/7/1641/2022/

The study employs high-fidelity Computational Fluid Dynamics simulations using OpenFOAM to investigate wake dynamics under floating wind turbine conditions. The turbines are modelled using the Actuator Line Method (ALM), which represents blade-induced forces as momentum sink terms in the Navier–Stokes equations based on blade element theory.

To capture atmospheric turbulence, two approaches are used:

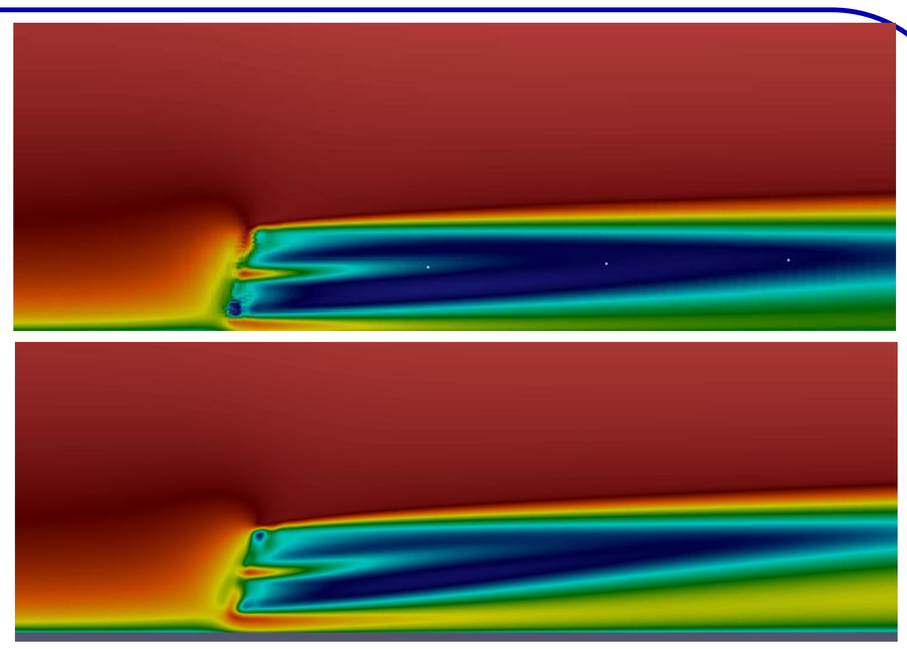
- ❑ RANS (k-ε model) for steady-state validation, with modified epsilon equations.
- ❑ LES: for resolving unsteady wake meandering and turbulence structures. For turbulence precalculated Mann model was used.





The plot shows the variation of wake centre deflection (Δ/D) with downstream distance (X/D) for different rotor tilt angles. Positive tilt angles (e.g., +6°) cause the wake to shift downward, while negative tilt angles (−6° to −20°) result in upward wake deflection.

CFD results



The plot shows a velocity contour plot (Ux) from a CFD simulation, representing the streamwise velocity distribution in the wake of a wind turbine under 6-degree (top) and 20-degree (bottom) tilt.

Analytical model development

The model predicts the normalized wake centre displacement as a function of downstream distance(x), tilt angle β, thrust coefficient (C_t), and turbulence intensity (TI).
It combines: an initial offset for near-wake skew ($\boldsymbol{Y_{d0}}$), a growth term that saturates downstream due to mixing. This is a model for the wake deflection ($\boldsymbol{\Delta(x)}$) due to shaft tilt

$$\frac{\boldsymbol{\Delta(x)}}{\boldsymbol{D}} = \boldsymbol{Y_{d0}} + \frac{\boldsymbol{a}\cdot\boldsymbol{(x/D)}}{\boldsymbol{1}+\boldsymbol{b}\cdot\boldsymbol{(x/D)}}$$

Growth rate a**:**

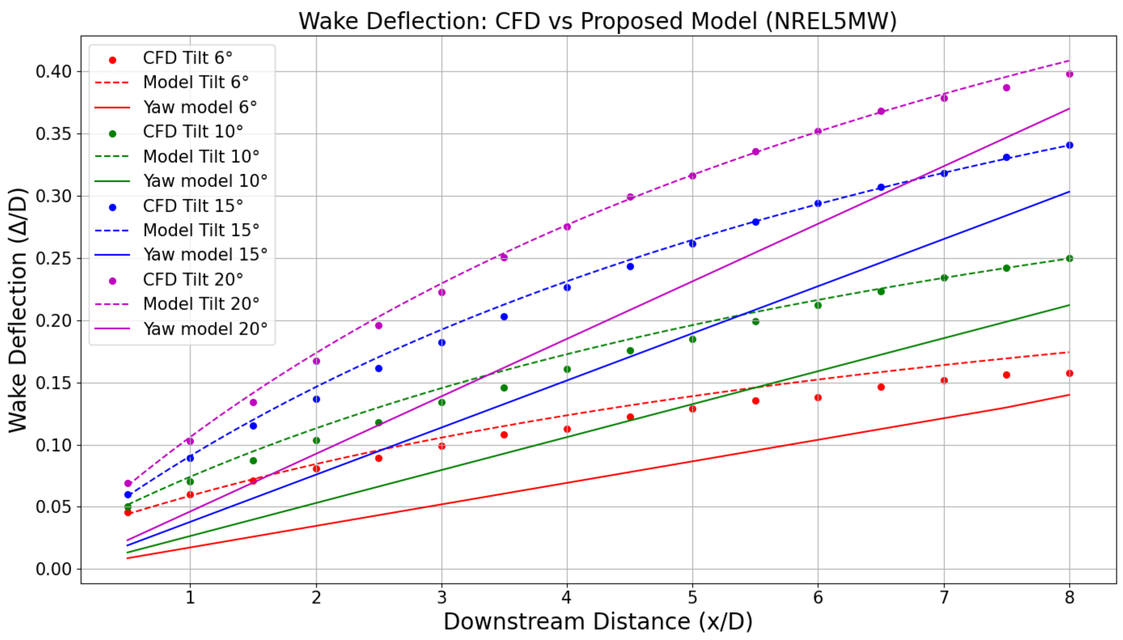
$$a = \theta_0 = \left(0.6 \cdot \frac{\beta_{rad}}{\cos\beta_{rad}}\right) \cdot \left(1 - \sqrt{1 - C_T \cos\beta_{rad}}\right)$$

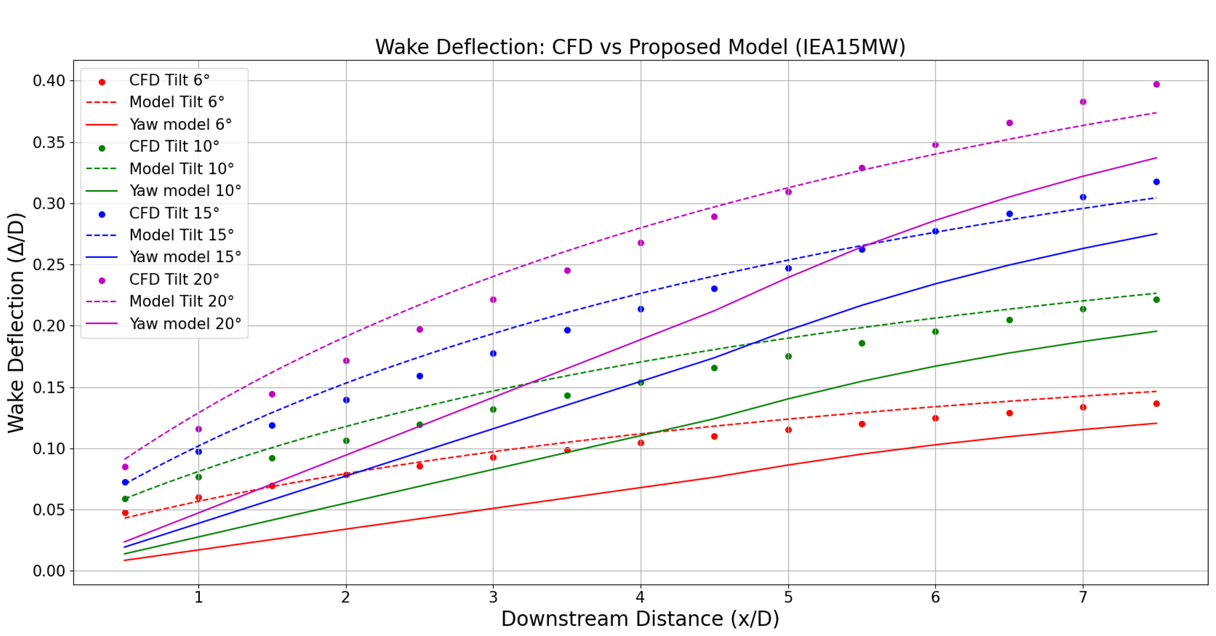
Mixing coefficient b**:**

$$b = 0.23 \cdot C_T^{-0.25} \cdot TI^{0.17}$$

Initial offset $\boldsymbol{Y_{d0}} = f\theta_0$ (where f is fitting parameter)

Results





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Disclaimer: Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or The European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the CINEA can be held responsible for them.

References for yaw model:

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