Implementation of Wake Deflection in the Simple Actuator Disk for Large Eddy Simulation

Hai Bui, Mostafa Bakhoday-Paskyabi
Geophysical Institute, University of Bergen, and Bergen Offshore Wind Centre

Introduction

Wake deflection occurs when the turbine is yawed at an angle from the facing wind. This effect can be harnessed to maximize the total wind production of a wind farm.

The Simple Actuator Disk for Large Eddy Simulation (SADLES) has been implemented in the Weather Research and Forecast (WRF) (Bui et al. 2023).

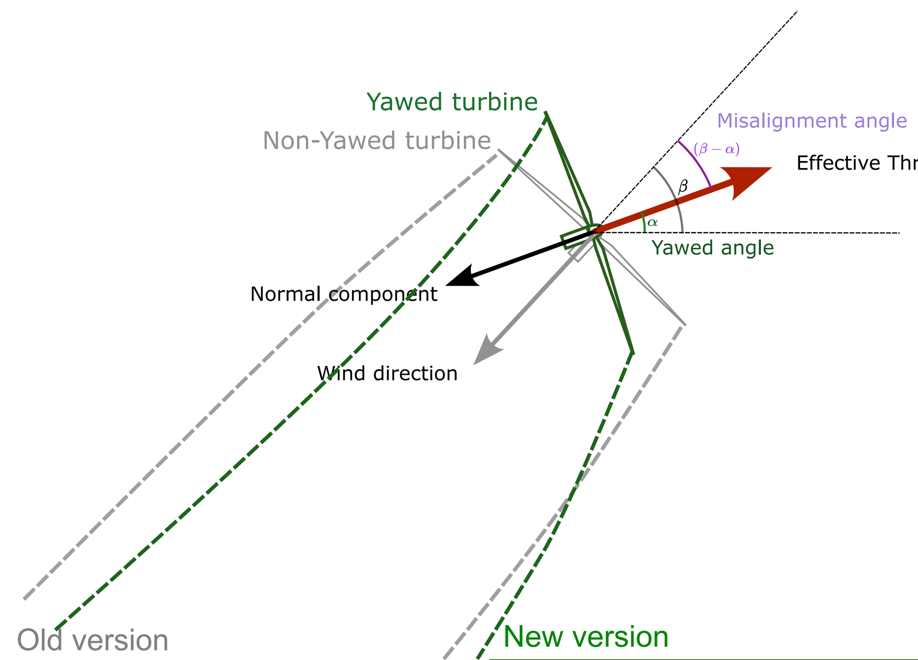
The WRF-SADLES system can explicitly simulate turbine wakes for multiple wind farms using realistic downscaled flow conditions.

However, in the current version of WRF-SADLES, the turbine is always assumed to be facing the headwind, making it incapable of simulating wake deflection.

This poster presents an additional update to WRF-SADLES by incorporating the capability of wake deflection.

The system can be used to verify or construct analytical wake models for real-time wind farm control.

Methodology



Old version

$$\left.\frac{\partial U}{\partial t}\right|_T = -\frac{1}{2(1-a)^2}\mu_d C_T |\mathbf{V}| u F_A$$

$$\left.\frac{\partial V}{\partial t}\right|_T = -\frac{1}{2(1-a)^2}\mu_d C_T |\mathbf{V}| v F_A$$

New version

$$\left.\frac{\partial U}{\partial t}\right|_T = \frac{1}{2(1-a)^2}\mu_d C_T |\mathbf{V}|^2 \cos^2(\beta-\alpha)\cos(\alpha) F_A$$

$$\left.\frac{\partial V}{\partial t}\right|_T = \frac{1}{2(1-a)^2}\mu_d C_T |\mathbf{V}|^2 \cos^2(\beta-\alpha)\sin(\alpha) F_A$$

where the Axial Induction factor

$$a = \frac{1}{2}(1-\sqrt{1-C_T(|\mathbf{V}|)})$$

where the and the Area factor

$$F_A = \delta A/(\Delta x \Delta y \Delta z)$$

Figure 1. Schemeatic and the new fomula for WRF-SADLES with wake delfection

Idealized simulations

Model: WRF-ARW Version 4.3.1
Weak convective: surface turbulence heat flux=0.02 K s^{-1}
Spin-up time 15h (D01 only)
Simulation time 1h simulation with 1-m output frequency
Two 5-MW Turbines, D=116 m, hub=90 m.

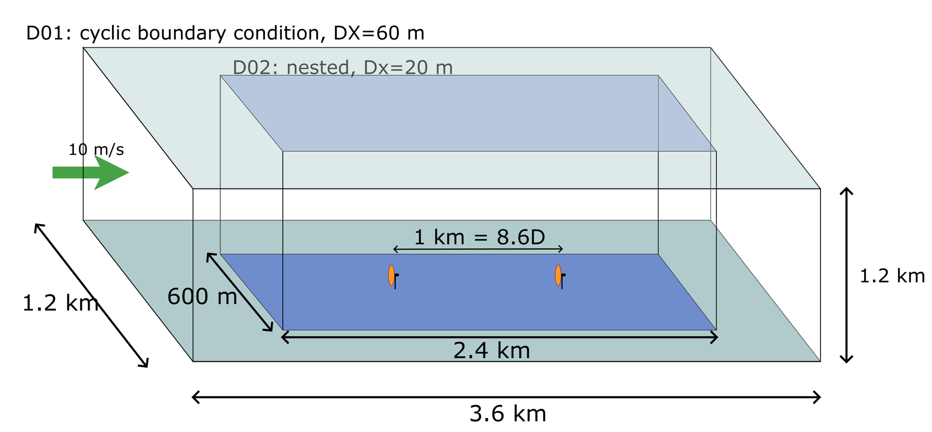


Figure 2. Schemeatic of the domains and turbine locations

Results

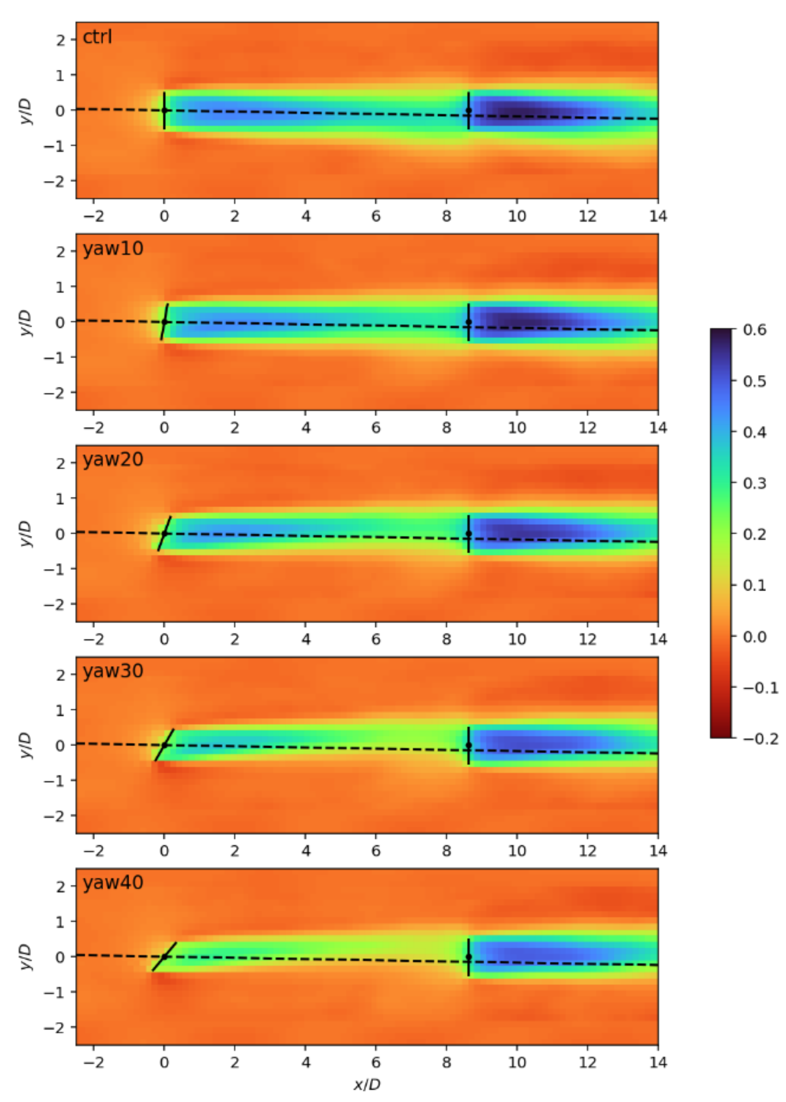


Figure 3: horizontal hub-height speed deficit for different experiments

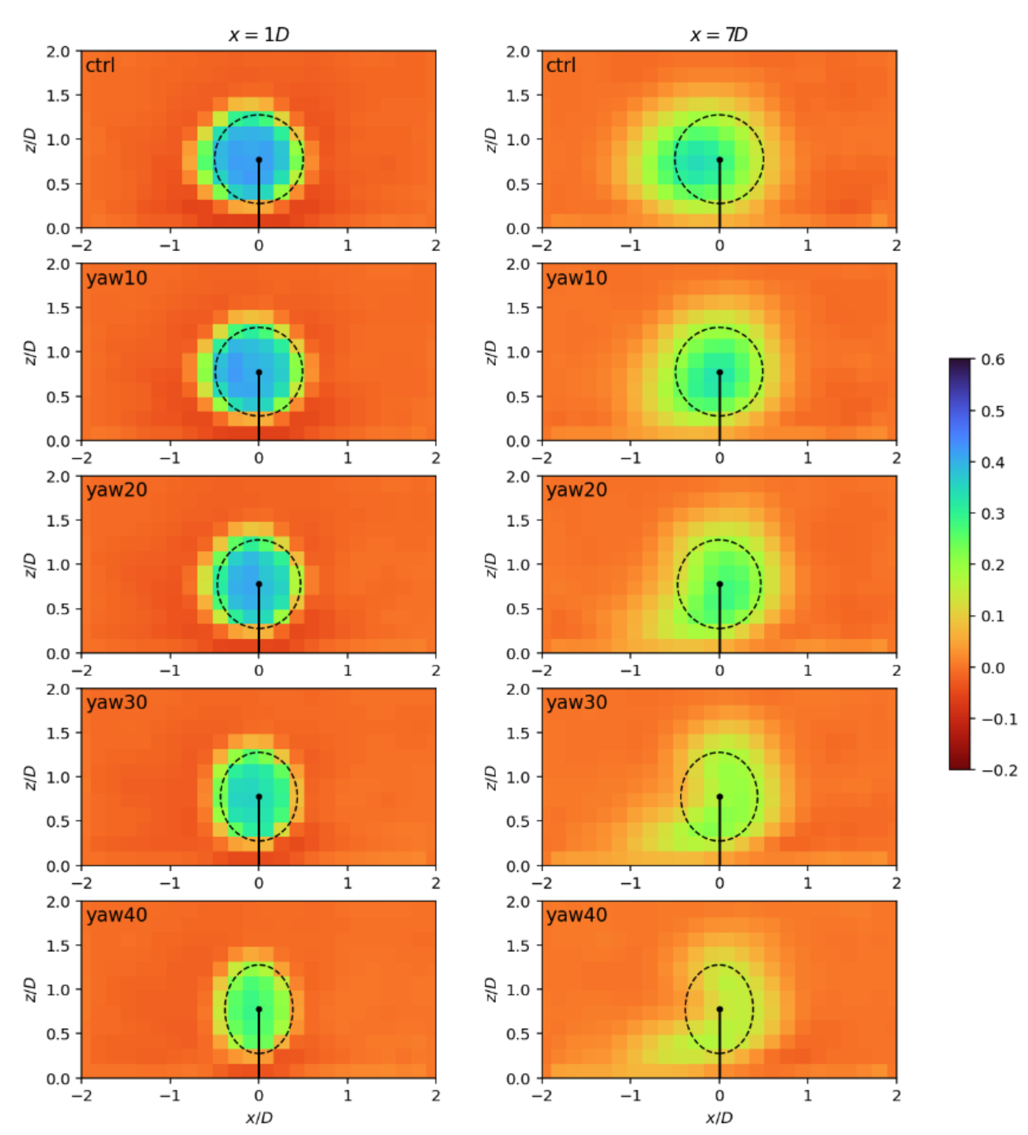


Figure 4: vertical cross-section of speed deficit for near wake (1D) and far wake (7D) behind the first turbine

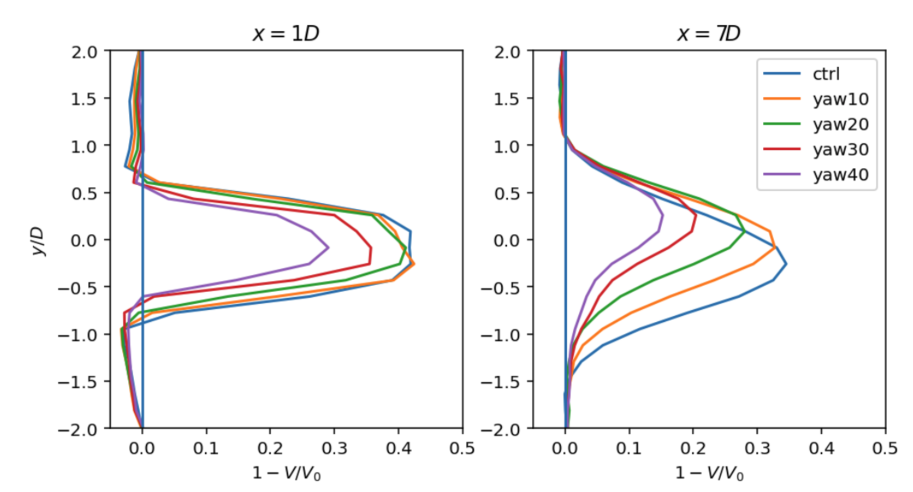


Figure 5: hub-height speed deficit at for near-wake and far wake

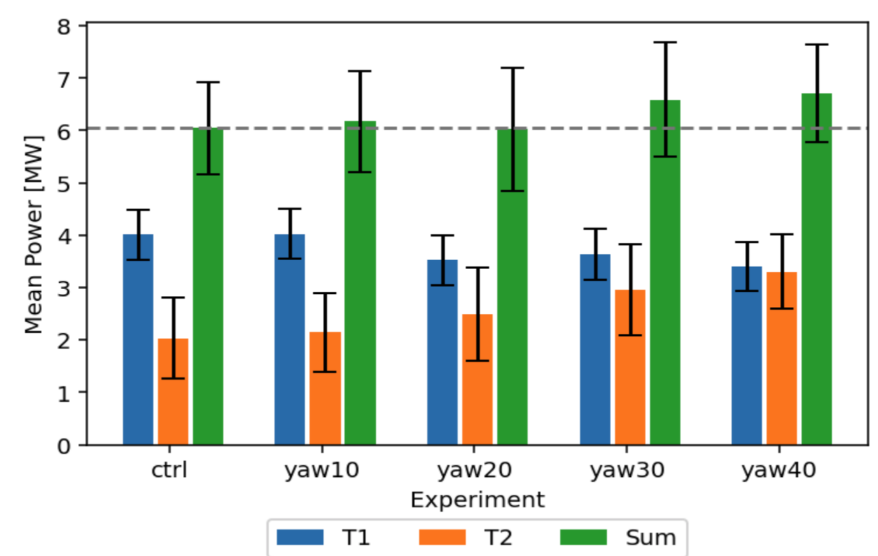


Figure 6: Average power production for each turbine and the total

Summary

- We have successfully implemented the latest version of WRF-SADLES, allowing for wake deflection when the incoming wind direction and yaw angle are not aligned.
- At larger misalignment angles, the near-wake deficit exhibits an elliptical shape, while the far wake transforms into a comma shape.
- The far-wake hub-height deficit transitions from a symmetric, Gaussian-like form to an asymmetric distribution with a longer tail to the south and a deflected maximum position to the north. This deflection, coupled with a weakened wake deficit, results in an increased power output for turbine number 2.
- Overall, the average total power sees a notable 10% increase for misalignment angles of 30° and 40°, while smaller misalignment angles show insignificant changes.

Reference

Bui, H., Bakhoday-Paskyabi, M., & Mohammadpour-Penchah, M. (2023). Implementation of a Simple Actuator Disc for Large Eddy Simulation (SADLES-V1. 0) in the Weather Research and Forecasting Model (V4. 3.1) for Wind Turbine Wake Simulation. EGUsphere, 2023, 1-24.

Contact

Hai Bui
Geophysical institute, University of Bergen
Email: hai.bui@uib.no

UNIVERSITY OF BERGEN

The work was supported by the CONWIND project (Research on smart operation control technologies for offshore wind farms), ENERGIX program, Grant number 304229.