Coupling of induction and wake models for rapid estimates of wind farm blockage and wind farm velocity fields

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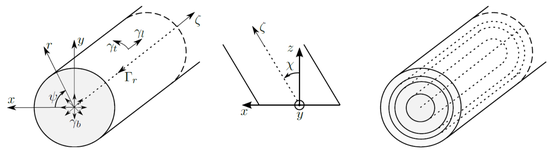
Abstract

Current wind energy prediction procedures neglect wind farm blockage effects, resulting in an overprediction of the farm production [1,2]. This poster presents an analytical and computationally inexpensive tool to assess wind farm blockage effects and wind farm velocity fields. An analytical induction model is coupled to the controls-oriented wake modeling tool FLORIS.

The induction model

- The induction zone is determined using a superposition of vortex cylinder models [3,4]

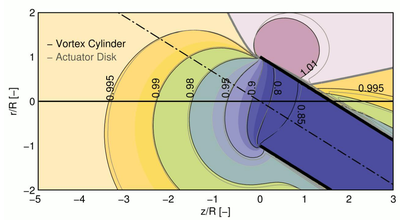


- The vorticity distribution is prescribed based on the thrust coefficient, and the velocity field obtained using the Biot-Savart law.

Induction velocity field ⟸ Vorticity field ⟸ Ct (r)

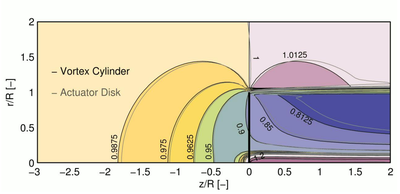
- Analytical and semi-analytical expressions are obtained for aligned and yawed flows, respectively. The model is compared below with Actuator Disk CFD [5]

Ct = 0.40, 30º yaw



- Swirl effects and ground effect may be included.

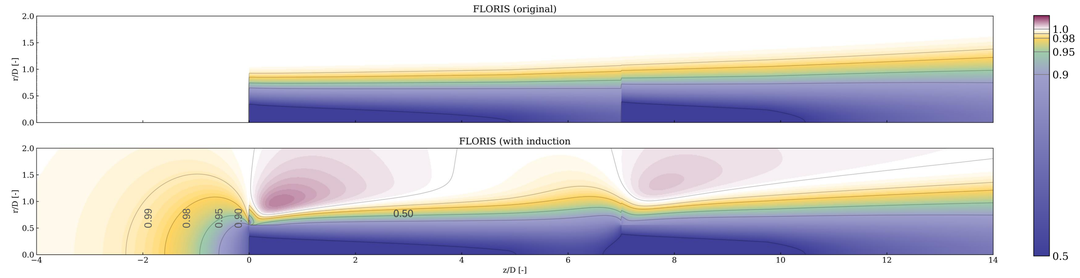
Ct = 0.4, λ = 2

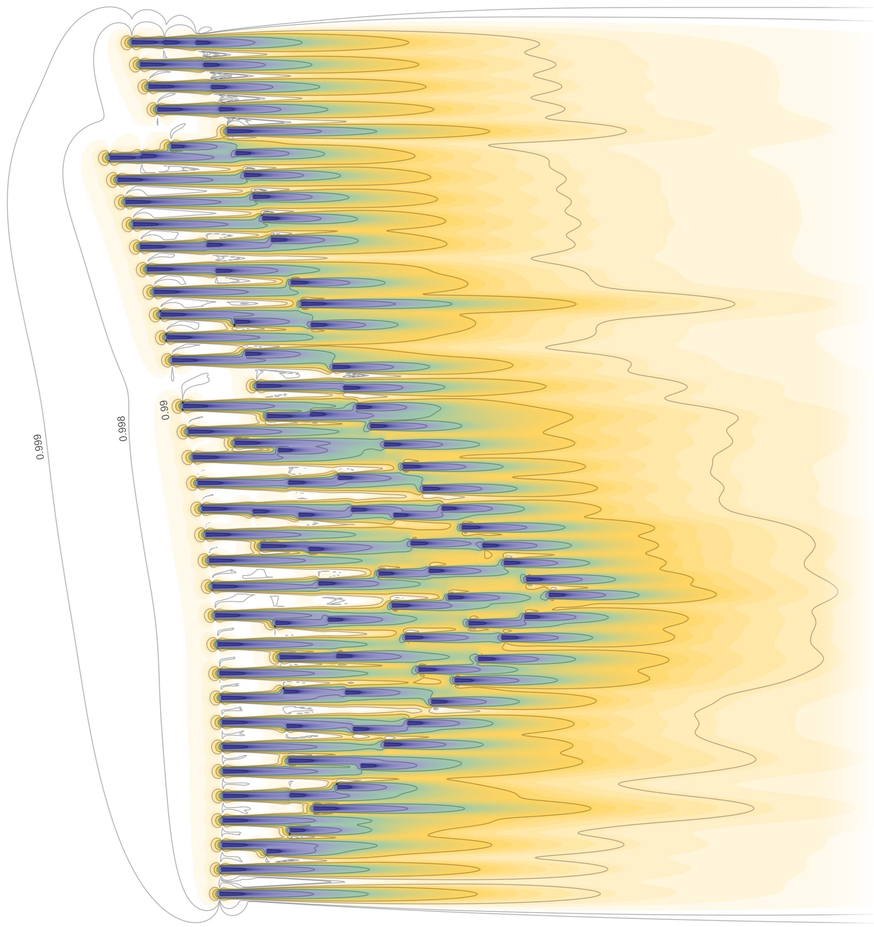


- The wake velocity provided by the model does no account for wake expansion or diffusion. The model is thus only used for the induction.

Coupling of the two models

The velocity field from the induction model is combined with the wake field. Iterations are required since both models depends on Ct and influence the velocity field. The main driver is FLORIS.





Wake models

- FLORIS [7] is a controls-oriented modeling tool which determines the steady-state wake characteristics in a wind farm
- The algorithm runs through the turbines from upstream to downstream to update the turbine operating conditions

V(r) ⟹ Ct (r) ⟹ Wake field

- Different engineering far wake model are implemented [7]:
  - Jensen
  - Jimenez
  - Gauss
  - Multi-zone
  - Curled wake
- The models account for wake expansion and diffusion
- Wakes can be combined in different ways

Future work

Future work will focus on the following points:

- Convergence of the method
- Options for merging wake with induction
- Approximations of the induction field
- Yawed inflow
- Comparison with higher fidelity models
- Comparison with measurements

References

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