Technical University of Denmark

A quasi 3D computation of merging wakes using a boundary layer equation model approach

Aagaard Madsen , Helge; Larsen, Gunner Chr.; Troldborg, Niels; Larsen, Torben J.

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Aagaard Madsen, H., Larsen, G. C., Troldborg, N., & Larsen, T. J. (2011). A quasi 3D computation of merging wakes using a boundary layer equation model approach. Poster session presented at EWEA Annual Event 2011, Brussels, Belgium.

178

A quasi 3D computation of merging wakes using a boundary layer equation model approach

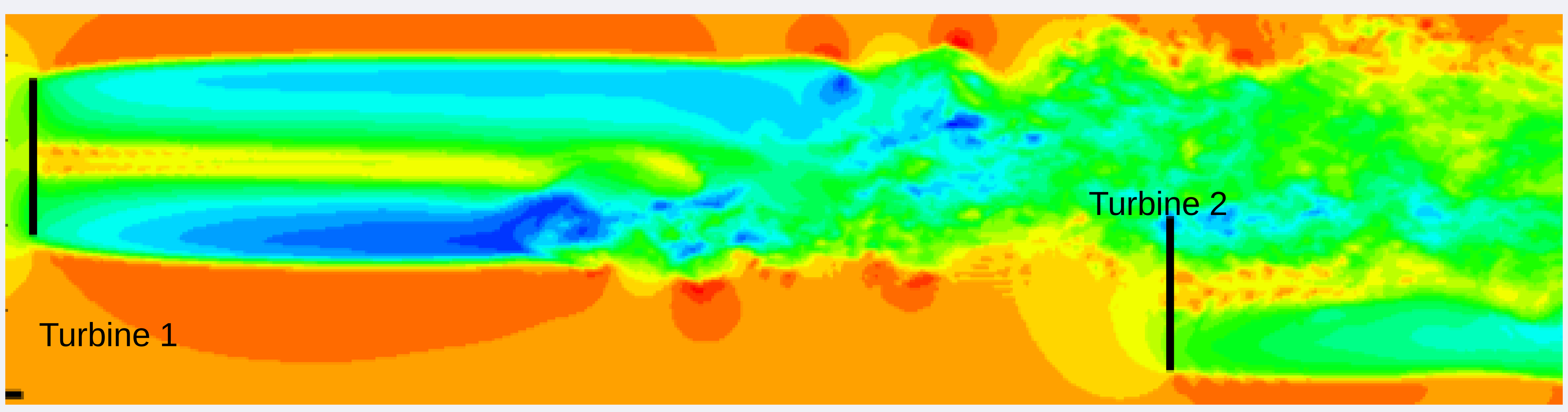
Helge Aagaard Madsen, Gunner C. Larsen, Niels Troldborg, Torben J. Larsen
Risø National Laboratory for Sustainable Energy, Technical University of Denmark (DK)

Technical University of Denmark

Abstract

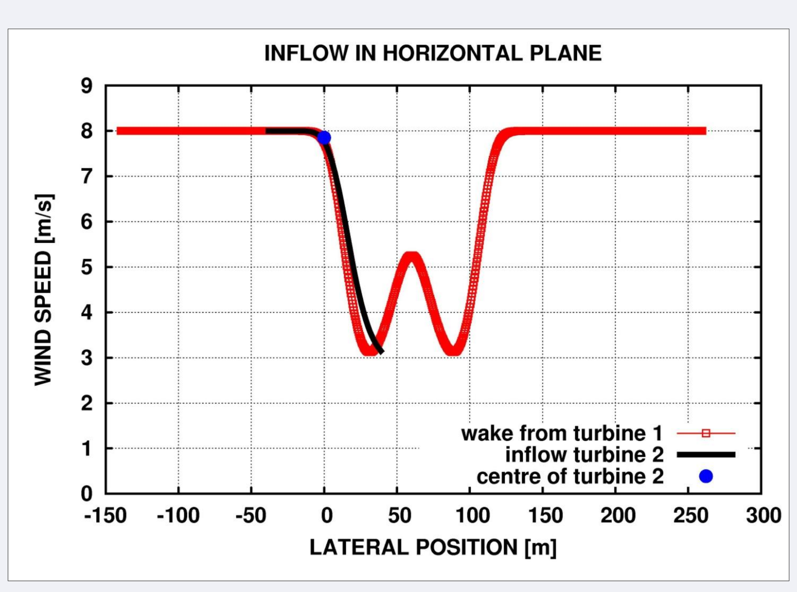
In the dynamic wake meandering (DWM) model [1] the meandering of the velocity deficit is the basic mechanism behind the increased loading in wake operation and likewise the main cause of the decrease in power. The computation of the deficit is thus a crucial part of the model. So far the velocity deficit has been computed using an axis-symmetric boundary layer equation (AS-BLE) model with the wake initial deficit derived from the blade element momentum (BEM) solution for the rotor induction. Within this framework it is possible to compute a single velocity deficit as well as merging deficits for a row of turbines when the wind is aligned with the row, however with meandering excluded. Model results for such cases have shown good correlation with measured row efficiency distributions. However, it is obviously important to extend the model complex to also handle arbitrary inflow directions to the row as well as interactions between different rows. The basic concept in the proposed approximate and fast model is to use a 2D BLE model in a horizontal plane and an AS-BLE model in a vertical plane for each deficit, where the initial deficit as in the present model is derived from the BEM model induction. Merging of the wakes is implicitly modeled with the 2D BLE model, where the computation can be extended over an arbitrary number of rows. For each deficit the 2D solution is locally coupled with the solution for the deficit in vertical direction computed with the axis-symmetric model. The coupling is done by enforcing a similar velocity from the two solutions at the centre of the released deficit using a coupling coefficient on the viscosity term in each of the two models.

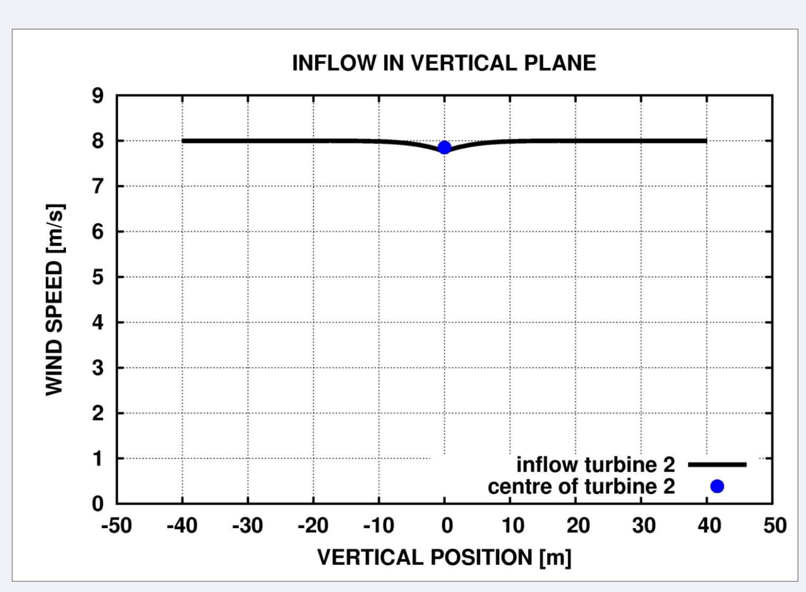
Test case



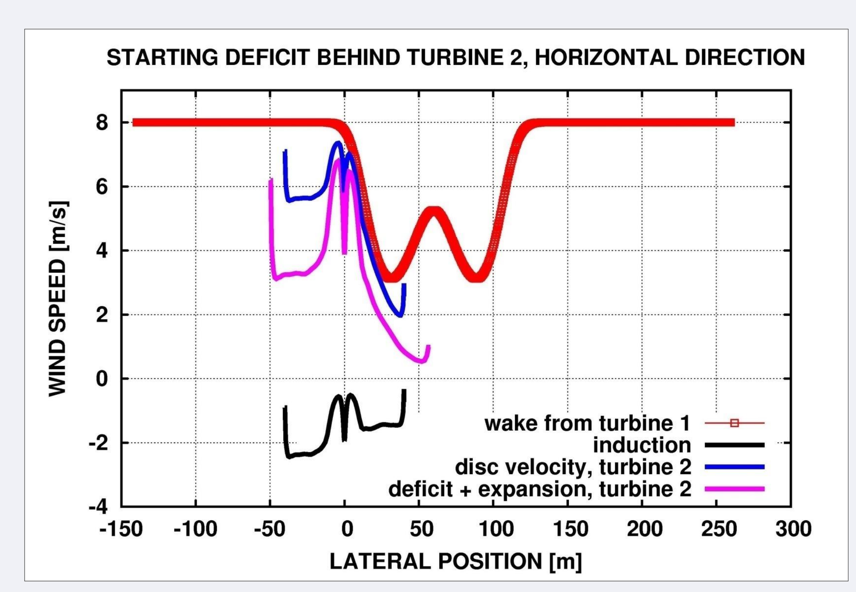
The test case is from the paper of Troldborg et al. [2], where a number of full and half wake cases at different ambient velocity conditions were simulated with an actuator line (ACL) model. For the present study, a test case with an axial separation of 6.6D and a lateral distance of 0.75D between the two turbines is used. Ambient mean wind speed 8 m/s and no ambient turbulence.

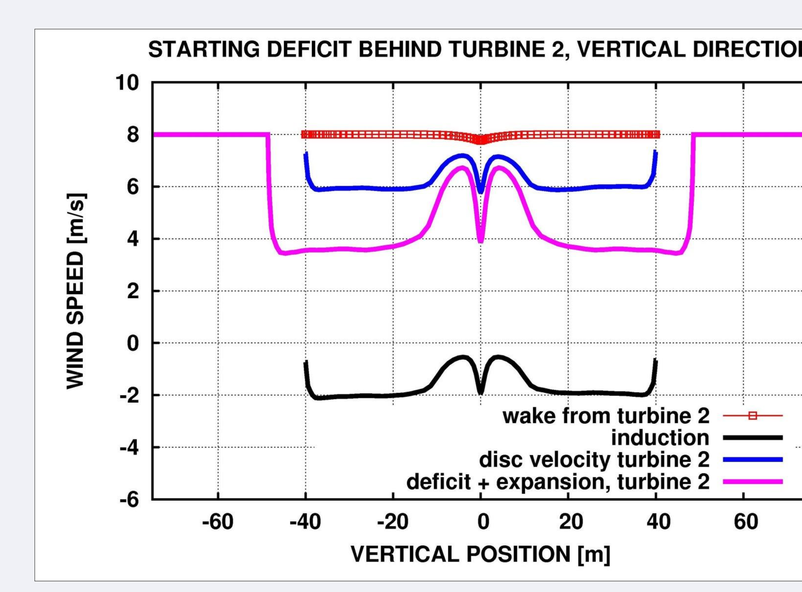
Coupled axis-symmetric/2D boundary layer equation (AS2D BLE) model



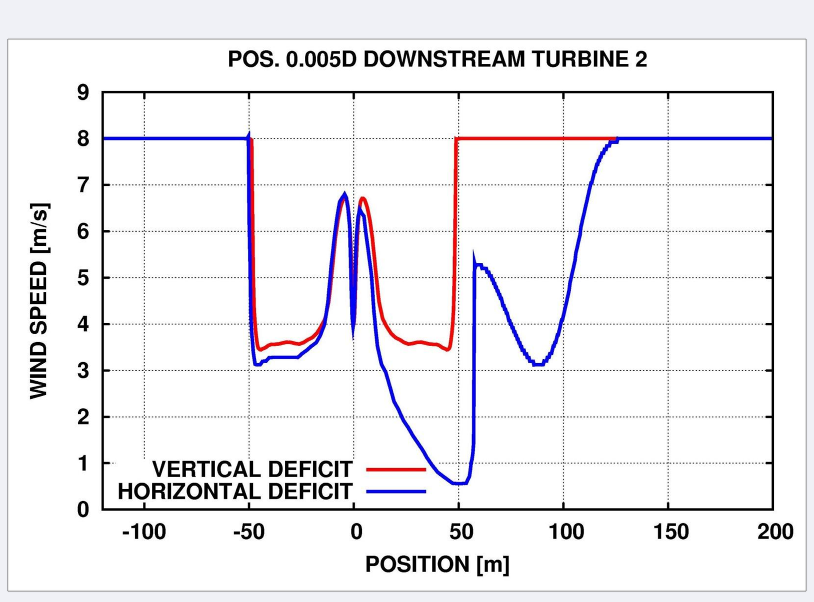


The wake deficit from turbine 1 is computed at the position of turbine 2 and used as inflow velocity profile.

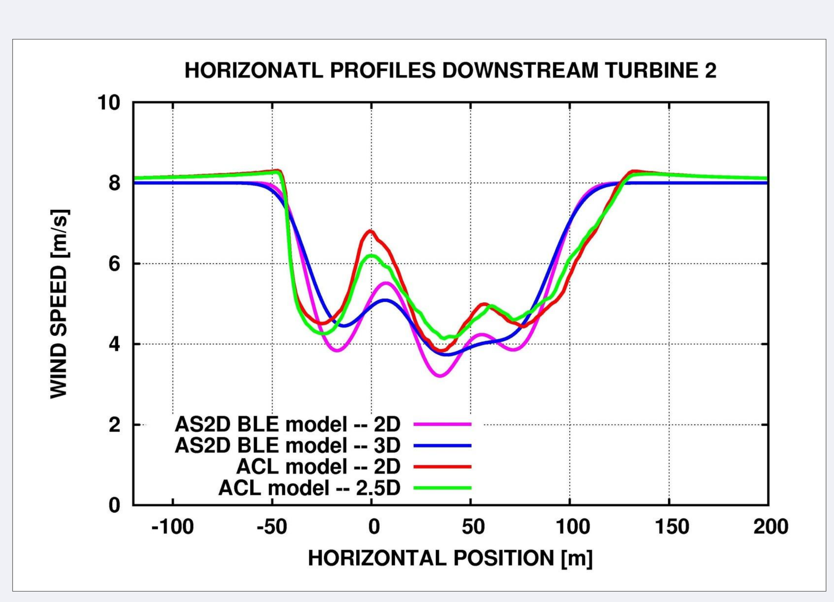




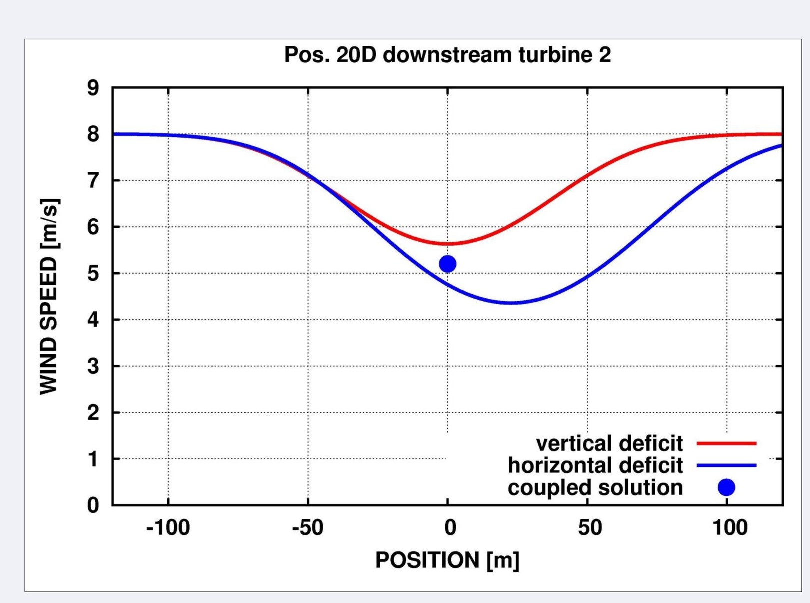
The wake deficit immediately behind turbine 2 is computed using the BEM induction and expanded assuming full deceleration to (1-2a).

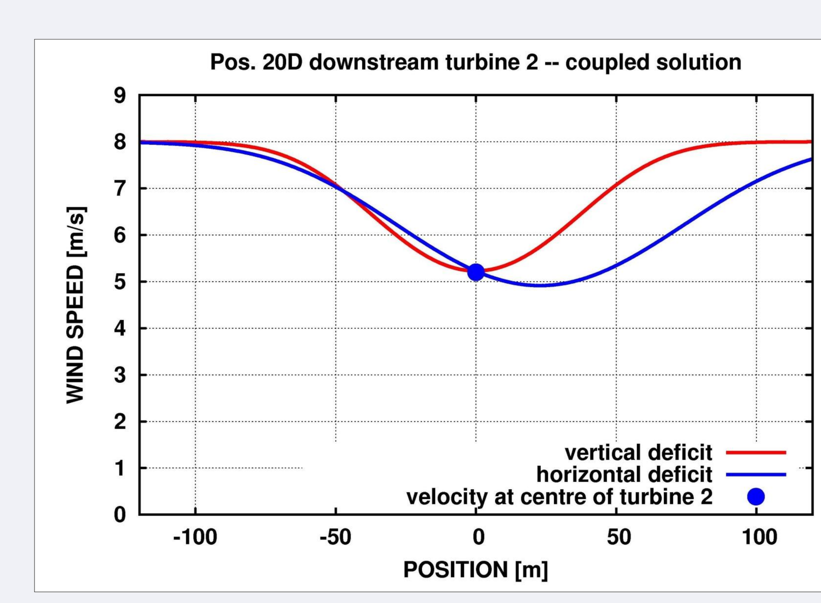


The downstream development of the vertical deficit is now computed with the AS model and the horizontal deficit with the 2D model.



A comparison of the horizontal deficits computed with the AS2D BLE model and the ACL model.





A coupling factor on the eddy viscosity in the AS model and in the 2D model, respectively, is used to force the two solutions to give the same velocity at the hub center where they intersect.

Conclusions and acknowledgement

A coupled axis-symmetric and 2D boundary layer equation model for approximate and fast computations of merging wake deficits has been developed. The basic procedure to compute the initial deficit and expand the deficit downstream is principally the same as already used in the dynamic wake meandering (DWM) model. The two BLE models (AS and 2D) used for the vertical and the horizontal deficit, respectively, are coupled together on the hub centerline, using a coupling factor on the eddy viscosity in each of the models. The model will be integrated in the optimization software, developed within the TOPFARM project, for optimization of wind farm layout.

The work has been carried out within the TOPFARM project 2007-2010, funded by EU: Contract no. TREN07/FP6EN/S07.73680/038641

References

1. Madsen, HAa, Larsen GC, Larsen TJ, Troldborg N, Mikkelsen RF (2010), Calibration and Validation of the Dynamic Wake Meandering Model for Implementation in an Aeroelastic Code. Journal of Solar Energy Engineering — 2010, Volume 132, Issue 4, pp. 041014 (14 pages))
2. Troldborg, N., Larsen, G. C., Madsen, H. A., Hansen, K. S., Sørensen, J. N. and Mikkelsen, R. , Numerical simulations of wake interaction between two wind turbines at various inflow conditions. Wind Energy, n/a. doi: 10.1002/we.43