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WESD

Interactive comment

Interactive comment on "Does the rotational direction of a wind turbine impact the wake in a stably stratified atmospheric boundary layer?" *by* Antonia Englberger et al.

Anonymous Referee #2

Received and published: 29 September 2019

The manuscript presents research using LES to investigate the effect of wind veer and wind turbine rotation direction on the mean wake structure. A simplified superposition-based model combining variable veer and shear inflow with a Rankine vortex to represent the effect of wake rotation is able to recreate the general trends and sign of mean wake velocities.

Overall the study appears well designed to answer a basic question about the effect of wake rotation direction on the structure and rate of wake recovery for a horizontal axis three-bladed wind turbine. The structure of the manuscript is well organized, however there are a number of important details that need to be included regarding the descrip-

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Discussion paper

tion of the simulations and additional analysis to support interpretation of the results. The simple empirical model is shown to demonstrate some of the general physical influences on the structure of the wake. However, it is not apparent if the model may be useful beyond to demonstrate the interaction of wind veer and wake rotation on momentum recovery due to the number of empirical parameters that were adjusted to fit the simulations without physical explanation or generalization.

It is my judgement that Major Revisions are required before the paper can be considered for publication.

Specific comments:

1) Title: Although titles in the form of a question can generate curiosity, I find it more impactful to simply state the main hypothesis of the study, such as for example: Parametric study on the effects of wind veer and wind turbine rotation direction on the structure and recovery rate of the mean wake.

2) Introduction: There is a mixture of future and present tense used throughout. Please be consistent. Careful editing of the text is needed throughout the manuscript to ensure clarity of the presentation, particularly clear physical explanations and accurate word choice. For example, in the first paragraph of the Introduction. “The diurnal cycle is driven by shortwave heating during day and radiative cooling at night.” Both are radiative processes, shortwave solar heating for the land surface and longwave radiative cooling. This is followed by a statement about forces acting on velocity: “The interaction between the Coriolis force acting on the velocity components. . .”

3) Pg 2: the review of previous research could be more descriptive. For example what methods are employed in the various studies to investigate stability dependence on the ABL? Are there any important features that have been regarding the wake of wind turbines operating in stable and convective boundary layers compared to neutral?

4) Pg 2, Line 24: I believe Hui Hu’s group at Iowa State published a number of pa-

pers on wind tunnel experiments to investigate the counter rotating, dual-rotor turbine, starting around 2014. It would be good to provide a comprehensive review for studies considering rotor rotation given the focus.

5) Fig. 1: note that rotor blades must be rotating to generate axial thrust, however this affect may be modeled using a drag disk, not including the effect of conservation of angular momentum. If I understand the text, this is the approach represented by subfigures 2c and 2d, but the language used is a bit confusing.

6) Section 2, Numerical Model Framework: The details of the model pertinent to the simulations conducted in this study should be explained in detail. It is appropriate to point to a former paper if validation is reported in support of this study. It is not clear if the paper cited provides these details. Nevertheless, the details of the specific model implementation in this study should be explained.

7) Pg. 4: Equation 2 appears incomplete. It may be easier to follow if first the description of Equations 1-3 are provided followed by explanation of the terms and definition of each variable. Details about the implementation of the turbulence closure and turbine actuator model should be included. Are the implementations similar to Wu and Porte-Agel, or C. Archer?

8) Please explain how the inflow velocity profile is imposed in the simulations. How is a proper turbulence profile established for each case?

9) Was the TKE model tested or calibrated to ensure the correct balance and transport is modeled in the wake region under the different flow and turbine operating conditions?

10) Pg. 5: How is the turbine model scaled? Based on geometry only? Or also considering operational characteristics? What are the details?

11) Pg. 5: Please include a schematic and complete description of the simulation set-up, including size of the domain. What is the fraction of the channel cross-section occupied by the rotor disk? Is the grid spacing uniform? How many grid points rep-

resent the rotor? Are the turbine forces applied uniformly or based on some scheme related to the blade geometry and aerodynamics?

12) Pg. 6: What is the corresponding land surface roughness, thermal stability, and latitudinal location represented by the imposed profiles uses in the simulations.

13) Regarding the turbine operation, what tip speed ratio and thrust coefficient are modeled? Are these typical operating conditions?

14) Please check throughout and change "turbulent intensity" to "turbulence intensity".

15) Table 2: It is not clear from the later discussion of the results if both the 60 deg and 90 deg sectors are used in the analysis?

16) Pg. 7: The use of index notation for velocity commonly refers to components of the vector, which may be confused with the (x, y, z) coordinates intended here.

17) Fig. 3: Labels on the contours are difficult to read due to crowding and may be improved for clarity.

18) Consider plotting distributions of turbulence intensity in the wake and provide any insight on the patterns seen for the distributions of the mean wake velocity.

19) Section 3: Check the use of z, z_h, k_h, and k_*. There appears to be some inconstancy that may lead to confusion.

20) Pg 9, Lines 3-5: Would be useful to show plots of TKE to support the point about enhanced production effects on wake recovery.

21) Pg 9, Line 10: Check NV_VR, should be NV_NR.

22) Figs 4 and 5: Quantification of the y-direction momentum budget could be used to support the assertion that the inflow veer and direction of wake rotation either partially cancel out or enhance wake deflection in the upper and lower portions of the wake.

23) Are there any data to support the simulation results of the wake you observe in the

y-z plane?

24) Fig. 7: Please explain the relatively stronger CW rotation in subfigure 7g compared to 7d and 7h. Why does the wake rotation switch from CCW sense to CW?

25) You might consider quantifying the Circulation within the rotor region to quantitatively compare the cases.

26) Fig. 8: Please comment on the relatively strong counter rotating structures observed between the rotor and the corners of the domain. Might these be weaker if the domain were enlarged? How might this affect the comparison with the simple model?

27) Sect 4.1, Model Development: It would be useful to relate the models, particularly for the axial component of velocity to existing analytical wake models. For example, what is the physical meaning of the 0.3 used in Eqn. 9? What are the axial and tangential induction factors used and are they appropriate for the turbine being modeled?

28) Be sure to define all variables and subscripts used throughout the model development. For example, _RV, _M, _fad are not explicitly defined.

29) Eqns 18 – 20, Given the premise that at least some of the flow conditions are caused by thermal stability, how could stability be included in the model, as the normal and shear components of turbulence fluxes will significantly affect the wake evolution.

30) How are the values of the parameters x_rec, x_fad, gamma, and delta chosen? Is it possible to estimate them without the flow data from simulations?

31) Pg 16, Line 14: Please check the single sentence paragraph.

32) Fig 9: It would be easier to compare the model with the LES output if they were plotted together and instead separate the CCW and CW cases. Note that the legend above the figure does not coincide with the figure description below for the vertical velocity plots.

33) Please check that average velocity is defined and used consistently. Note in Fig 9,

an overbar is used, but not in the figure description or elsewhere. Are the plotted data based on the 60 deg or 90 deg sectors defined in Table 2?

34) Consider comparing the results to field data. In particular, there are a number of case experiments that have used lidar to measure the wake. Even if not the data are not directly compatible due to different turbine models or operating conditions, it would be useful to see if measurements see the same trends presented in this study.

35) Section 5: It is not clear if thermal stability was actually modeled, or only the Ekman spiral effect on the wind direction. The language used throughout the manuscript may contribute to confusion about what physics are considered in this study. This can be avoided by using explicitly clear language.

36) Statements in the Conclusion that provide interpretation with various supporting references should be moved up to the Discussion. The Conclusion should focus on the main outcomes of the present study.

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