Comments on the Review of Should wind turbines rotate in the opposite direction? - Reviewer 3

Antonia Englberger[1], Julie K. Lundquist[2,3], and Andreas Dörnbrack[1]

[1]German Aerospace Center, Institute of Atmospheric Physics, Oberpfaffenhofen, Germany
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder, Boulder, USA
[3]National Renewable Energy Laboratory, Golden, Colorado, USA

Correspondence: Antonia Englberger (antonia.englberger@dlr.de)

Dear Reviewer 3,

Thank you for taking the time to carefully review our paper. We read your review in detail and appreciate you sharing your own simulation results. Regarding your comments, we think there are several misunderstandings with the first version of the paper. Therefore, with the help of your comments, we performed some far-reaching changes to the manuscript. Here is a list of the major changes.

– We changed the title.

– We explained in detail the turbulence generation method we applied in the simulations.

– We included a section, introducing a simple analytical model predicting the expected changes in the spanwise velocity field in the wake by a superposition of a veering inflow with a Rankine vortex. (New section 3)

– We added additional simulations with different directional shears.

– We investigated the impact of the rotational frequency on the wake differences.

– We added additional plots, explaining the wake differences and its occurrence for different rotational direction of the actuator.

– We added a section comparing the numerical results predictions of the analytical model. This section explains in detail the source of the difference in the wakes between a clockwise and a counterclockwise rotating rotor in case of a veering inflow.

– We added an Appendix, verifying the application of the turbulence preserving method for this theoretical and idealized parameter study.

Referee comments

The authors argue that counter-clockwise rotation wind turbines in northern hemisphere (as opposed to clockwise as is currently done) can lead to a power increase of 11% in the downwind turbine due to constructive interactions between the axial vorticity in the wake and veered Ekman layer, especially when strong stable stratification is present. While I am fascinated by the overall theme of this research, I do not feel that the authors have done a thorough investigation to corroborate their hypothesis. While the paper uses a provocative title and well written, I hesitant in recommending publication at this time since I have the following serious concerns regarding the quality of the numerical simulations performed.

The intent of the manuscript was not to be provocative. The question was chosen as title for the paper as it is simple and interesting and for motivation to consider this issue. But we agree with the reviewer that is could lead to misunderstandings. Therefore, in the revised version, we changed the title to 'Changing the rotational direction of a wind turbine under veering inflow: A parameter study'

Further, there seem to be some misunderstandings with the simulations. The simulations in this manuscript are wind turbine simulations performed under prescribed wind and turbulence conditions. In the parameter study presented in this work, we applying a very simplified set-up with a turbulence generation method. This is not a stable boundary layer input applied in the wind-turbine simulations. But we agree the manuscript could give the impression as we talk about veering wind in a stably stratified regime. In the revised version of the manuscript we only talk about a veering inflow or a backing inflow or no veer at all. Further, we added a detailed explanation of the turbulence generation method, instead of only referring to the corresponding paper. We also added the basic equation for this. The modification should make it clear that no SBL LES is performed. Further, we rerun all simulations as implicit LES also excluding the Coriolis force. With that we would like to make clear that it is only an idealized parameter study, and the Coriolis force has only an effect on the prescribed inflow wind field whether the resulting differences between clockwise and counterclockwise rotating turbines not results from an interaction effect of the vortex with the wake. It is not affected by the Coriolis force interacting with the wake and delecting it.

We apply the turbulence parametrization instead of the SBL precursor simulation as it provides a computationally fast testbed for wind-turbine simulations on a small domain. Regarding the large number of performed simulations, it would be computationally very expensive running them all as SBL simulation and a resolution refinement down to 0.25 m is not possible with the current supercomputer resources we can use. Especially considering the effect that the simulations with varying wind speed and directional shear would require different precursor simulations to conduct the SBL wind-turbine simulations.

This parameter study with a very simplified numerical setup was the first attempt to investigate the impact of the atmospheric parameters (geostrophic wind speed and directional shear) and the impact of the vortex paramter (rotational frequency) on the wake differences between clockwise and counterclockwise rotating actuators. The results allow us to identify which SBL precursor simulations are required to investigate the interesting cases in detail in future simulations.

1. The Ekman layers being simulated are highly stratified with very high gradient Richardson numbers. TKE based eddy-viscosity SGS closures are notoriously terrible at stably stratified layers; see the work by Sullivan et. al, (JAS, 2016) where they show grid sensitivities up to 0.25m for similar states of stratification. You must show that the Ozmidov scale is larger than the grid scale, especially for your strongest stratification case for me to accept the accuracy of the SBL simulated using your SGS closure. This is not done in the current version of the manuscript.

The presented simulations represent a wind-turbine simulation with prescribed wind and turbulence conditions. It is not an SBL simulation with a rather fine resolution close to the ground. To make this clear, we rerun all simulations as ILES excluding the SGS closure. The applied resolved turbulence develops from small fluctuations impressed on the flow field by our 'turbulence preserving method'.

2. Since much of the argument made in the paper relies on axial vorticity, the authors need to present a strong case showing that the axial vorticity captured by the their grid resolution and actuator-line parameterization is correct. A grid convergence study might help, although I remain skeptical regarding whether actuator lines can correctly represent axial vorticity. There is substantial discussion on this topic in open-literature.

There is a misunderstanding, we did not apply an actuator line technique, we run the simulations with an actuator disc approach. The disc is resolved with 21 grid points. Following Ivanell et al. (2008), Wu and Porté-Agel (2011), and Gomes et al. (2014), the minimum number of grid points to result in the same resolution independent wake structure for acutator disc models is 10 grid points in vertical and spanwise direction.

3. There is new evidence that suggests that ignoring the horizontal component of Earth's rotation (as the authors have done) has a significant quantitative impact on wakes of large turbines representing small Rossby numbers. See the recent work by Howland et al. (2020, JFM) on this topic. Even at approx.. 45deg. Latitudes, I would speculate the direction of wind (Westerly vs Easterly) would affect the power of the downwind turbine by similar order of magnitude as shown by the authors for CW vs CCW rotation.

In the present study, we only consider the Coriolis force as cause for the inflow profiles. To make this clear, we rerun all simulations without a Coriolis force.

These only recently published results, however, are rather interesting and we will include the horizontal component of the Coriolis force in the fine resolved SBL WT simulations we plan to perform next.

References

Gomes, V. M. M. G. C., Palma, J. M. L. M., and Lopes, A. S.: Improving actuator disk wake model, in: The science of making torque from wind. Conference series, vol. 524, p. 012170., 2014.

Ivanell, B. S., Mikkelsen, R., and Henningson, D.: Validation of methods using EllipSys3D, pp. 183–221., Technical report, KTH, TRITA-MEK 2008:12, 2008.

Wu, Y. T. and Porté-Agel, F.: Large-Eddy Simulation of Wind-Turbine Wakes: Evaluation of Turbine Parametrisations, Boundary-Layer Meteorol, 138, 345–366, 2011.