Review of revised version (R1) Changing the rotational direction of a wind turbine under veering inflow: A parameter study, previously titled as *Should wind turbines rotate in the opposite direction?* by Antonia Englberger, Julie K. Lundquist, and Andreas Dörnbrack

Reviewer: M. Paul van der Laan, DTU Wind Energy

The authors have rewritten the article significantly, and the new version has doubled in length. I like the added Sections 3 and 4, which help understanding the interaction of rotor rotation and wind veer. Most of my previous comments are addressed appropriately and I have listed the remaining comments below, including new comments related to the newly added content. My RANS simulations still predict the opposite trend as the present article, which I do not full understand. (It is not a must that my RANS simulations should predict the same trend as your LES in order to accept the article, because my RANS simulations could be wrong.) I have listed the main comments below.

Main comments

1. It is nice that you have added Section 3 and I now better understand your arguments. You mention that different magnitudes of wind veer or directional wind shear (ds) can result in different trends of wake deflection direction. In Figure 7, you show that for small ds (0.04 and 0.08 °/m), a CCW rotating rotor has less wake deficit compared to CW rotating rotor (for the Northern Hemisphere). For large values of ds (0.16 and 0.20 °/m), your simulations show the opposite. Both CW and CCW show a similar wake deficit for $ds = 0.12$ °/m. I have summarized your results below (for an aligned case on the Northern Hemisphere):

ds	0.04	0.08	0.12	0.16	0.2
Favored rotor rotation present article	CCW	CCW	similar	CW	CW

   I have performed two additional RANS cases with different values of ds: 0.028, 0.045, corresponding to turbulence intensity values of 4.5 and 4% at hub height, respectively. The results are plotted in Figures A1 and A2. I had previously simulated $ds = 0.095$. (Note that there is a misunderstanding regarding my RANS simulations from the first review round. I had used the NREL-5MW wind turbine, which has a rotor diameter of 126 m. The total wind veer of 12°then represents a wind veer of about 0.095°/ m.) I have also summarized the results below for the RANS simulations (for an aligned case on the Northern Hemisphere):

ds	0.028	0.04	0.095
Favored rotor rotation reviewer	similar	CW	CW

   I still get the opposite results compared your LES model. If I would try to further increase the amount of directional shear in the RANS model, then the resulting boundary layer height would become smaller than the wind turbine, and then the RANS simulation would not converge because the wind turbine operates partly in the free atmosphere where the eddy-viscosity is very small. If I decrease the amount of directional shear then the effect of rotor rotation direction on the wake is negligible at 7D. To be fair, it could be that my RANS model predicts the wrong results and your LES simulations are correct.

The favored rotor rotation is also dependent on the relative wind direction, as shown in Figures A1 and A2. If your mean wind direction at the AD is slightly off because the inflow is developing downstream, then you could have post processed a two wind turbine case with a misaligned wind direction. I would therefore recommend strongly to also post process different wind direction cases, similarly to Figures A1 and A2. For example, you could add another figure for the cases listed in Fig. 7, taken at 7D, but as function of wind direction (or y), similar to my RANS figures, but then for wind speed not wind turbine power. If you have saved the time averaged 3D flow fields, then you should be able to just process your LES results to obtain such a plot.

2. I now understand that the inflow is based on a parametrization of LES precursor simulations, performed in previous work, and it is good that you have added more clarifications in the revised the article. I have looked at the articles where this method was introduced and I wonder how well the parametrized inflow is in balance with the LES model when the parameters are changed significantly. For example, there are quite large deviations of the fitted LES profiles (as shown in Fig 1. of your previous work Englberger and Dörnbrack (2018)). I am aware that this review should be focused on the current work, but it is important that your inflow profiles are in balance with the LES model, especially when the goal is look at relatively small differences caused by rotor rotation directions. If the inflow profiles are not in balance, then the wake deflections can also be caused by a downstream development of the inflow. On other hand, an LES inflow is never fully in balance with the 3D domain because of the transient nature of the model. So it could be that your parametrized inflow model is just as good (or bad) as using a traditional LES precursor inflow. It is very good that you have added a few lines in the conclusion, where you discuss the short comings and possible issues with using a parametrized LES inflow model compared to using a non-parametrized LES inflow model.

3. Section 2: You mention extremely small rotational frequencies of the rotor: 0.058 - 0.23 °/s, which would correspond to a time of 103 and 26 minutes for a full rotation, respectively. This does make sense to me. Are you sure these numbers are reported correctly? You could also report the corresponding tip speed ratios, which are more common to use in wind energy. A common tip speed ratio of MW-sized wind turbines below rated wind speeds is 7.5, so then you rotor rotational frequency would be 86 °/ s for a wind speed of 10 m/s.

4. I think you should clarify the point of view a bit better in the caption of Figures 3 and 4. Instead of *This picture is looking downwind on the wake* you could use: *This picture is looking from upwind towards downwind*.

5. Figure 7:
   - You could also normalize the wind speed by the rotor averaged wind speed taken from either the inflow, or a distance upstream of the AD or at the AD location without AD.
   - Should case *_ds18* be *_ds16*?

6. Section 4.3: You could mention that the main influence of wind speed is the wind turbine thrust coefficient C_T through your AD controller. In addition, the shape of the mean inflow profile is dependent on the geostrophic wind speed, which most likely follows a Rossby similarity, see for example van der Laan et al. (2020b). (Without Coriolis and buoyancy related sources terms, your simulations should be Reynolds-number or wind speed independent for a fixed C_T, turbulence intensity and turbulence length scale, see for example van der Laan et al. (2020a)).

Minor comments

1. Figure 4 caption: ... the the ...

2. The x and y labels often include a variable and a unit that are separated by a divide or slash symbol. It would be more clear to use square brackets, for example: x [m].

References

Englberger, A. and Dörnbrack, A.: A Numerically Efficient Parametrization of Turbulent Wind-Turbine Flows for Different Thermal Stratifications, Boundary-Layer Meteorology, 169, 505–536, https://doi.org/10.1007/s10546-018-0377-z, 2018.

van der Laan, M. P., Andersen, S. J., Kelly, M., and Baungaard, M. C.: Fluid scaling laws of idealized wind farm simulations, J. Phys.: Conf. Ser., 1618, 1–10, https://doi.org/10.1088/1742-6596/1618/6/062018, 2020a.

van der Laan, M. P., Kelly, M., Floors, R., and Peña, A.: Rossby number similarity of an atmospheric RANS model using limited-length-scale turbulence closures extended to unstable stratification, Wind Energy Science, 5, 355–374, https://doi.org/10.5194/wes-5-355-2020, https://wes.copernicus.org/articles/5/355/2020/, 2020b.

Appendix A: Additional Reynolds-averaged Navier-Stokes simulations from reviewer

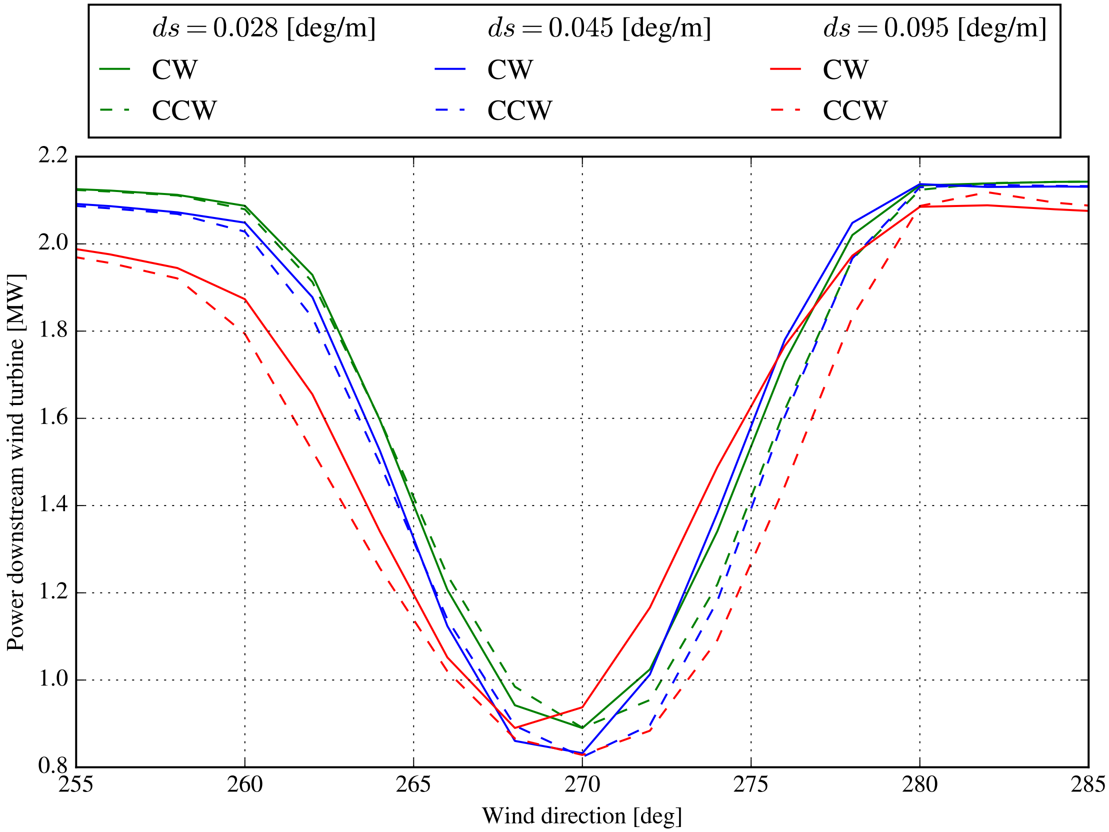

Figure A1. Power of downstream wind turbine for clockwise and counter-clockwise rotor rotation using an atmospheric boundary inflow with three different magnitudes of directional shear for the Northern Hemisphere.

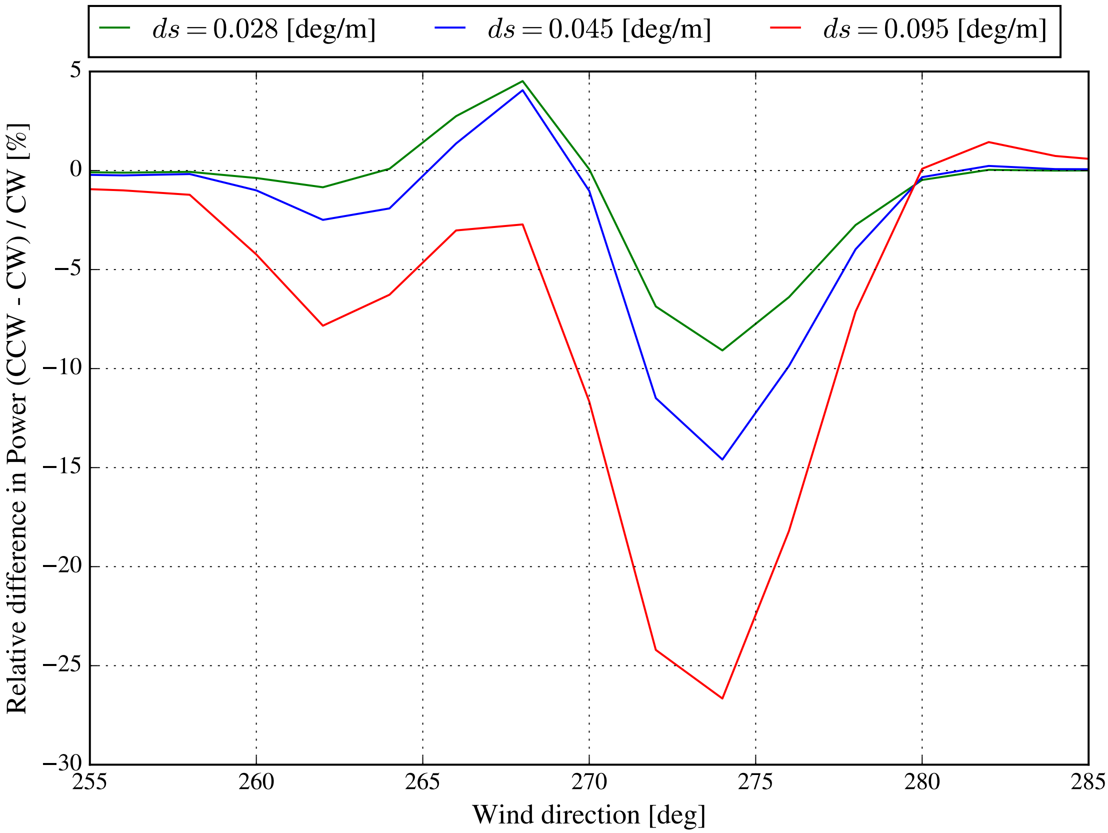

Figure A2. Relative difference in power of downstream wind turbine for clockwise and counter-clockwise rotor rotation using an atmospheric boundary layer inflow with three different magnitudes of directional shear for the Northern Hemisphere.