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WIND ENERGY SCIENCE DISCUSSIONS

WESD

Interactive comment

Interactive comment on "Offshore wind farm global blockage measured with scanning lidar" *by* Jörge Schneemann et al.

Greg Poulos (Referee)

greg.poulos@arcvera.com

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Schneemann et al. 2020 Off shore wind farm global blockage measured with scanning lidar (two presentation attachments also provided)

Overall, congratulations on a study that advances knowledge of wind farm-atmosphere interaction and the combined induction effect slowing the wind approaching a wind farm. Scanning Doppler lidar is an excellent choice for this application, as is dual-Doppler with carefully planned coordinated scanning strategies to pinpoint vector hub height wind speed at different distances upwind of different portions of the first row.

I think it is important to distinguish the fact that reverse pressure gradients caused by the wind farm that induce gravity waves and cause reduced wind speed upwind of the

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Discussion paper

wind farm are in fact the true atmospheric science name for “global blockage”. I am not objecting to the use of the term “global blockage” and rather hoping for some recognition for confusion over physical phenomena that are already known well and the new lingo. All obstacles cause reverse pressure gradients, or block, the flow and wind farms are no exception. Wind farms are different from typical obstacles, such as mountains, buildings, trees, etc in that the wind farm actively produces thrust (reverse pressure gradient) above that of a simple obstacle (e.g. turbines that are not operating). This reverse pressure gradient upwind phenomenon, which induces gravity waves in stable atmospheric conditions, is not included in wake loss models (which are in fact being tuned to be wind farm-atmosphere interaction loss models because blockage is not wake) that have been tuned to reproduce energy losses based on the first upwind row production as a benchmark for 100% production. A benchmark expected free stream energy production value that is established suitably far upwind of the first row would alleviate the exclusion of gross energy production impacts due to the slowing of the wind and allow wind farm-atmosphere interaction effects to be included in engineering models that also include all-important wake effects.

I’ve attached a presentation that contains a summary of four case studies as yet unpublished, as I think you will find it interesting. Meteorological masts were in position in front of turbine rows before and after construction for long periods of time so the velocity-deficit impact could be measured relative to distant, highly-correlated unblocked, unwaked masts. We find overall total wind velocity deficits 2.5 RD upwind of the first row in the few percent range in the most affected positions; the most affected position is generally the center of the first string of turbines, upwind of more than a few downwind turbine strings.

Abstract:

Change “platform” on line 7 to “turbine hub”. Change this sentence to “Our results showed a 4.5% decrease (range 2.5% to 6.5%) at XXX-m turbine hub height X.X km upwind of the wind farm with the . . . ”. This would be more informative and concise without the subjective use of “significant”. Include a summary of the net measured global blockage among all conditions, if possible. Include lateral and string spacing in rotor diameter dimensions of the subject wind farm.

1 Introduction

Line 50: While Allaerts and Meyers do not call the gravity wave effects blockage that is likely just semantics as they are discussing the same phenomenon.

Overall, this is a good literature review and introduction.

2 Methods

2.1 Global Tech 1

Line 127: Please add the hub height of the Adwen turbines. This is important as the reader should be aware that your 24.6 m elevation measurements do not correspond to hub height, and by how much, for proper interpretation (e.g. relative to IEC standards and applicability to different circumstances. Line 131: “cluster is located 24 km southwest of GTI (see Figure 1). Figure 1: Please label the wind farms in the figure, or at least Borwin 1, Hohe See and Albatros. Figure 1b: Please indicate Hohe See and Albatros. Line 132: “were under construction within 1-5 km of GTI and our the lidar location with . . .” Please discuss how hard target hits were treated in the lidar scans as regards potential effect on the outcome of your investigation of global blockage. Line 137: I recommend inserting a new Figure 2 showing a photograph of the Windcube 200S on the “transition piece” and explaining what a transition piece is – I’m not familiar with the term although I infer that you mean the junction of different tower sections. The reader would be interested in the experimental set up (height above surface, the nature obstacles on the platform, etc.). Line 139: the timeline stated here can be substituted in Line 125 in place of “first half of 2019” in Line 125 to be more specific. Line 141: I see that hub height measurements were not taken (or at least 24.6 m is indicated here). Please explain why you didn’t use an elevation angle that would allow for a measurement closer to hub height (vector geometry noted as a complicating factor). Does this lower-than-hub-height result affect interpretation, or limit the study. Nygaard points out that ground-effect (surface roughness) is a consideration in the degree of blocking. Line 144: The 150 degree scan sector does not match the 210 degree or greater sector in Figure 1b. You can consider clarifying this incongruity. I believe the maximum extent of various 150 degree scans is depicted in Figure 1b but I'm not certain. Line 145: You should explain here that given the range of 0.5 km to 8 km that the experiment is able to acquire data from X RD to Y RD upwind of the wind farm which, based on XX literature, is sufficient to find unblocked free stream inflow wind speeds, without being so far away as to mistake changing atmospheric conditions for global blockage-induced wind fluctuation. NOTE: Later, in Line 193, you mention that data were only taken to 7000 m and you could clear up this inconsistency (I assume data recovery beyond 7 km range was too low and not of consequence). Lines 150-155: The discussion of extrapolation is a bit unclear. I think you are saying that you rectified all measurements to 24.6 m using a kind of extrapolation method. How was this done, by shear exponent? Lines 156-161: I believe you are saying that you calculated the Delta T portion of the RiB calculation by taking the difference between the 24.6 m temperature and reanalysis ocean surface temperature. Perhaps you could explain why you didn't monitor the SST with a sensor placed at the base of the turbine (water surface) for greater accuracy. Also, perhaps explain why you didn't place a temperature sensor further up tower (or use temperature at hub height from the turbine itself). Please describe the accuracy of the method as found in previous literature to comfort the reader regarding accuracy. Line 176: I think you should conclude this section by explaining the extrapolation method (that the so-derived (RiB etc.) logarithmic wind profile was used to correct data taken at height different than 24.6 m to 24.6 m. I'm assuming that is what was done it just isn't quite clear from the text. Line 202: Do you mean < 60% as stated on Line 192? Or is 80% a new and different threshold? Line 206: Perhaps create a table to show the matrix of possible scenarios based on stable/unstable and wind speed/thrust coefficient with the scenarios you included in your study highlighted in the table? I think you are saying that you only looked at 4-13 m/s cases bifurcated into stable or unstable based on L. It looks like you decided to look at stable, non-operating (< 4 m/s), and stable, rated or above, cases as well. You call this a "cross check" but it isn't clear why that term applies. What do you mean by cross-check? Please include the limits of L included in stable and unstable definition in the table (or in a sentence here, if you do not include a table). Line 214: Finish the sentence, "This cross-check allowed a clearer interpretation of the results because ....(?? insert reason for the reader)". Line 216: Why not use the thrust coefficients of the Adwen turbine specifically? Lines 218 to 233: This is the crux. It is unclear why you chose different wind speed and thrust coefficient ranges for Scenarios 1 and 4 (why not use the 10-13 m/s range for both? Or 7-13 m/s?). This seems to introduce an unnecessary variable and would make comparing the stable/unstable results apples-to-oranges and hard to interpret. Why didn't you use the same wind speed and thrust coefficient ranges in Scenario 1 and Scenario 4?

Line 234: 2.5 Uncertainty estimation, thank you for including this section. I did not check every step in detail but the fact that you took the time to characterize and plot uncertainty bounds is helpful to the reader. Line 305: 3.1 Scenario 1 and Figure 3. Figure 3 shows wind speed deviation data out to ∼40 rotor diameters or near 5 km (40 times 116 m RD). This is not 8km as mentioned earlier, or 7 km as mentioned later (see notes above). Can you explain why you only show to ∼5 km so the reader doesn't wonder? Line 321 Scenario 2 (not operating, stable) Line 343: – this is a tricky case and the apparent mean INCREASE in wind speed closer to the first wind-facing row of the wind farm is unusual and calls into question the results. I understand that you mean to explain that due to low winds and high uncertainty that the result is meaningless – e.g. that there is no evidence of a true increase in wind approaching the wind farm. However, this is an average across 60 cases, so it is statistically robust – could it be recovery of speed from the wind farms under construction and upwind? A clear statement as to the meaning of these results in the final sentence of this section, such as, "Due to x and y and z we conclude that for low wind speed and stable conditions that there is not a material change in wind speed from -40 D to -4 D." as appropriate.

Line 344 3.4 Scenario 4 and Figure 6: It appears in Figure 6a and 6b that the wind speed is not free stream at -40 D. What does Figure 6 look like if extended to -50D or -60D? Can you find a free stream speed? Perhaps without showing the 50D or 60D plot you can simply tell the reader? What do your results suggest for the wind speed reduction at the IEC 61400-12-1 standard upwind distance of 2.5 D – larger values than 2.5% to 6.5% yes? Figure 6: Does the change in shape of the global blockage effect correspond to a particular shape, such as a parabola? The effect seems most pronounced in the direction immediately upwind perpendicular to the row in which the lidar sits? Is that correct? Would the effect be worse to the southeast toward the center of the row in which the lidar sits? Line 386: Use a label "Scenario 1" here for consistency with the body text. Line 395: "Scenario 2" Line 402: "Scenario 4" In this section it is important to describe what percent of the operating time is affected by these conditions. For example, a 5% effect for 20% of the operating time of the wind farm over it's lifetime is a much smaller impact on overall energy production (such as applied in wind energy resource assessment and with wake loss models. A 5% effect over 80% of the operational lifetime is much more significant. Thus, the fraction of time a wind farm is in stable atmospheric conditions is a key governing factor for a site-specific analysis.

It is also important to note that your findings only go to 4 D, not to the standard 2.5 D from the turbine assumed by IEC 61400-12-1 and thus the results could well be worse. Line 439 and paragraph: Indeed, onshore cases are very different meteorologically, with stable atmospheres occurring in very site specific ways, requiring site specific measurements. Another key factor is the momentum reservoir above blade tip and the stability of the air in that region, as regards wake loss recovery. Line 452: Nice discussion. The need for good onsite stability measurements is clear. Line 466: We find that blockage effects maximize at the center of a turbine string (with strings down wind) and fades to zero near the edges, based on three met towers spanning the width of a turbine string. There is acceleration immediately off the edge of the last turbine in the row. See the presentation I attached for more information.

I very much appreciate the time and effort you put into this paper and I hope the comments above are helpful.

Please also note the supplement to this comment:
https://wes.copernicus.org/preprints/wes-2020-124/wes-2020-124-RC3-supplement.pdf

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