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Interactive comment on "A case study of wind farm effects using two wake parameterizations in WRF (V3.7) in the presence of low level jets" *by* Xiaoli G. Larsén and Jana Fischereit

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Response to the comments about the submitted paper

A case study of wind farm effects using two wake parameterizations in WRF (V3.7.1) in the presence of low level jets

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Discussion paper

We thank the reviewer for his constructive comments. We have addressed each and every one of them and modified the paper accordingly. Our detailed answers follow.

Please note that reviewer's comments are in italics while our answers are not. Additions to the original manuscript are indicated in blue.

To this reply, we attach here two files: text file README.md and a marked-up revision of the paper. We will update the new version of our zenodo-repository as the next step, following this response-to-reviewer. Please read the README.md-file for all the updates.

Answers to Reviewer 1

General comment:

In general, this work makes an important contribution to the wind energy resource assessment. The two most prominent wind farm parametrizations are evaluated by the use of airborne measurements and are compared against each other. This is important as the wind farm parameterization of Volker et al. (2015) has been used in a recently published report, indicating that wakes in the German Bight could have a massive impact on the energy harvesting in the future, although this parameterization was so far only poorly evaluated for offshore wind farms. However, three major points have to revised in this manuscript:

Comment R1.M1 *First of all, the description of the TKE coefficient (CTKE) that determines the amount of TKE added by the wind farm parameterization is highly confusing. In this manuscript they authors describe CTKE as a constant value. This is irritating as in existing literature this coefficient is described as the difference of thrust and power coefficient i.e. CT - CP. In contrast, I assume they mean a factor in front of difference CT - CP, resulting in CTKE = anyFactor * (CT - C P), as it was pointed out in a recently published study (Archer et al. 2020). In case they really used a constant CTKE for the comparison with the work of Siedersleben et al. (2020), the comparison is wrong.*

Answer to R1.M1 We thank the reviewer for pointing this out. Indeed it is confusing that we have used C_{TKE} for the correction factor. In fact it is as the reviewer speculated that it is the correction factor we are addressing to the numbers 1 and 0.25. In the new text we re-wrote it, so that $C_{TKE} = \alpha(C_T - C_P)$, and α is used both in the main text and the figure captions.

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Comment R1.M2 *Secondly, although they have shown that the bug corrected version of the wind farm parameterization of Fitch et al. (2012) has an large influence on the TKE within the rotor and wake area, the impact of the enhanced TKE on the wind speed is not discussed although this is the most crucial point of this study. I would assume that increased TKE would cause a weakening of the wakes due to enhanced mixing. This point should be added! A figure similar to Fig. 13 should be added for the horizontal wind field or Fig. 9a) should be replaced with the bug corrected Fitch parameterization.*

Answer to R1.M2 It is a good point. Results and analysis from the Fitch scheme with advection on are included (see new figures from Fig. 6 to 15). This includes the corresponding spatial distribution of wind speed as Fig. 14 as suggested by the reviewer.

Comment R1.M3 *Thirdly, a table with the conducted simulations would help the reader to have an overview about the different model setups.*

Answer to R1.M3 Good point. Such a table is now made available in the new vision as Table 3.

Specific comments:

Comment R1.1 *P1 L9: "However, their skill is limited... the farm edge." This is not related to the parameterizations, this is a purely numerical issue. Considered omitting this sentence.*

Answer to R1.1 We agree that in order to reach the conclusion as we gave, more work needs to be done. This sentence is therefore removed.

Comment R1.2 *P1 L18: The turbulence is modified by wind farms within the wake but not necessarily increased. For example, see Platis et al. (2018).*

Answer to R1.2 We agree that the response of turbulence with changing wind conditions could be rather complicated. Under wake effect, turbulence is enhanced comparing to same wind speed, but it can also decrease with reduced wind speed, resulting in a net value that is not necessarily higher than a condition in the absence of wind farm. To avoid confusion, we changed "increase" to "change".

Comment R1.3 *P3 L59: The Bundesnetzagentur does not host any open source flight data! The Bundesnetzagentur does host wind turbine location data!*

Answer to R1.3 Indeed. This reference was added by mistake previously and is now removed. Thank you for pointing this out.

Comment R1.4 *P5 L128: Could you please comment why you used WRF 3.7 and not a newer version of WRF by now WRF-4.2.2 is already released? Is the EWP scheme only compatible with WRF 3.7?*

Answer to R1.4 It is of course interesting to find out how each version of WRF produces results and if the latest version is the best. Though, regarding the purpose of this study, the importance of the version investigation is secondary. We expect the main findings be consistent with different versions of WRF. Also, EWP is compatible with any version of WRF.

Comment R1.5 *P5 L136: The spin-up time is really short, especially with regards to your domain with an 18 km horizontal grid? Have you worse results using a longer one?*

Answer to R1.5 It is a relevant topic: how long is long enough for a spin-up time. A

long spin-up time is essential when we would like to resolve the more or less stationary mesoscale variabilities. At other times, when a special atmospheric phenomenon is developing, it is more important to make sure that the initial conditions are properly introduced to the simulation: in this case, the development of low level jet. We see no obvious problems in running the simulation this way when most of the analysis are in the second half of the simulation.

Comment R1.6 *P5 L148: The CTKE coefficient wasn't set to 1 in S2020! They used the default WFP in which CTKE = CT – CP! Please comment if you have modified the code within the Fitch scheme. If you have done so a comparison with the results of S2020 is difficult! Could it be that you mean: CTKE = factor* (CT – CP)?*

Answer to R1.6 Indeed as the reviewer says. We made the correction. See our response in answer to comment R1.2.

Comment R1.7 *P5 L154: See comment before, in case you used the power coefficients and thrust coefficients and you haven't modified the code in WRF 3.7 in module_fitch.F, your CTKE is not constant i.e. unity. Please comment on that!*

Answer to R1.7 See our response in answer to comment R1.2.

Comment R1.8 *P6 L164: How have you determined the initial length scale for the EWP? Have you conducted a set of sensitivity studies to get a best fit? Was the same initial length scale used in Agora Energiewende et al. (2020)*

Answer to R1.8 We agree this sentence is oversimplified and it has been re-written. In the literatures, values 1.5 (e.g. Agora Energiewende et al. (2020)) and 1.7 (Volker et al. 2015) have been used. In Volker et al. (2015) it was also shown that the model output has only negligible difference for values between 1.5 to 1.9 that are used. For

our study, we tested the values from 1.5 to 1.7 and it showed almost no difference. Thus the value 1.6 was used.

Comment R1.9 *P7 L192-204 Is this comparison really necessary, you are comparing a point measurement to a vertical profile?*

Answer to R1.9 The reviewer is right on this. We removed this comparison in the new version.

Technical comments:

Comment R1.10 *P2 L54: ... the increased wind resource → increased wind resources?*

Answer to R1.10 Suggestion taken.

Comment R1.11 *P3 L79 ... here as Fig. 2 → in Fig. 2?*

Answer to R1.11 Suggestion taken

Comment R1.12 *P3 L87 Horizontal flight data → horizontal flight data*

Answer to R1.12 Suggestion taken

Comment R1.13 *P4 L124 ERA5: Be more precisely here, where did you get the data from? In case you have downloaded it from the Copernicus Climate Center you should definitely cite the source according to their terms of usage!*

Answer to R1.13 The source of the data has been provided in the data-availability

section and a citation is added.

Comment R1.14 *Fig. 2 The green and red colors are not color-blind safe, i.e. the flight track 1 and 3 are hardly to distinguish. Please consider redoing this figure!*

Answer to R1.14 Thanks for pointing this out, which we haven't given it a good thought before. We have revised all figures using color-blind safe color-codes and checked that through the firefox add-on. For figure 2 we used colors based on the 'Color Cycle Picker' https://github.com/mpetroff/color-cycle-picker.

Comment R1.15 *Fig. 3 An indication of the location of the close-up shown in Fig. 3b) in the Fig 3a) would help the reader.*

Answer to R1.15 Suggestion taken

Comment R1.16 *Fig. 5 These colors aren't the state of the art any more. Please consider redoing this figure as they are not colorblind safe. Is the TKE scale of 5e) similar to 5f). I am wondering as the last tick label in 5f) is missing.*

Answer to R1.16 The figures are revised as suggested. The same color-code as in figure 2 has been used.

Comment R1.17 *Fig. 6 Could you please indicate the rotor-area, that would make it easier to follow the corresponding text.*

Answer to R1.17 Suggestion taken.

Comment R1.18 *Fig. 11 Rainbow is dead. Please consider redoing this figure using color-blind colorbars as pointed out in several publications (Stauffer et al. 2015; Thyng*

et al. 2016...).

Answer to R1.18 We used color-blind safe colormap viridis is used in the new version.

Comment R1.19 *Fig. 11 - 12: First of all: Please add a clear caption describing what is actually show in Fig. 12. It is possible to guess that (a-b) is showing wind speed due to the order of magnitude compared to (c-d). However, someone who is not that familiar with the units of TKE might have difficulties to draw the correct conclusions. Please use up to date colorbars as it is mentioned in the technical section (rainbow is dead). Secondly, describe where this cross-section is located within the caption and make clear how this cross-section is orientated i.e. south-north or north-south!*

Answer to R1.19 Suggestions taken. The south-north coordination is expected to be seen as the latitude increases on the x-axes.

Code and data availability

Comment R1.20 *On 29 January 2021 the reviewer could not access the following address: https:// zenodo.org/ record/ 4133350.X5aZOO3cBaR*

Answer to R1.20 Apologies for that! The link was https://zenodo.org/record/4133350#.X5aZOO3cBaR. We hope the new version works.

Comment R1.21 *The authors should provide a corrected module_pbl_driver.F file, to account for the bug in wind farm parameterization of Fitch et al. (2020). In the official WRF repository they provide, the WRF bug is not fixed for version 3.7.*

Answer to R1.21 The file along with a detailed description in the README is provided in the new version of our zenodo-repository. Please see the README.md file below

for the updates. We will update the new version of our zenodo-repository in the next step, following this response-to-reviewer.

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