

1 Response to Reviewer Comments

2 Kelsey Shaler¹, Eliot Quon¹, Hristo Ivanov¹, Jason Jonkman¹

3 ¹National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 80401, USA

4 Correspondence to: Jason Jonkman (jason.jonkman@nrel.gov)

5 Thank you for supplying us with a thorough review of WES-2023-138. The comments were valuable and we tried to address
6 them all appropriately.

7 Here are our responses to the specific comments, with the referee comment in **green**, our response in black, and changes made
8 to the paper indented black.

9 Referee #1

10 As indicated previously, I believe the work is very important for the wind energy community and should eventually be
11 published. Unfortunately, the main concerns of the referees have not really been addressed in the updated manuscript, and the
12 additional information that is provided in the answers is also limited. Let me rephrase my comments in the hope that this
13 clarifies things. My view remains that it is very important work, but major revision is still required to clarify the presented
14 results.

15 - Manuscript provides limited details on what exactly has been done and, for many things, refers to previous work. Even in
16 places where clarification was requested, limited information was added, for example, on the wake tracking algorithm (around
17 line 175).

18 *Author response:* The cited references provide a lot of information that does not need to be repeated here. Nevertheless, we
19 reworded this paragraph with a few more details as follows:

20 In addition to experimental turbine load comparisons, the wake evolution between FAST.Farm and SOWFA-
21 OpenFAST-ALM results are compared. For each turbine, the wake center position was computed using the Simulated
22 and Measured Wake Identification and CHaracterization ToolBox (SAMWICH Box, Quon (2017), an open-source,
23 Python-based library of wake-tracking algorithms. There are several wake-tracking algorithms available in the
24 SAMWICH ToolBox. The one chosen for this work is the two-dimensional Gaussian fit model, which solves an
25 optimization problem to determine the wake position, two-dimensional shape, and rotation parameters of a Gaussian
26 wake-deficit function. This method is able to estimate the wake center, size, and shape and was successfully applied
27 to identify wakes under non-neutral atmospheric conditions (Doubrawa et al. (2020)). This and other wake-tracking
28 methods available in SAMWICH Box are discussed in more detail in Quon et al. (2019). Because the wake-tracking
29 algorithm may be sensitive to instantaneous mean wind conditions and the presence of background turbulence

30 structures, the resulting wake center time series can include non-physical discontinuities. To minimize this, filtering
31 is applied to remove spurious results as was done previously by Doubrava et al. (2020). For each wake-center time
32 series, a moving median filter was first applied to remove the majority of non-physical spikes in the data. A moving
33 median rather than moving mean was applied to help preserve the extrema in the identified wake positions. Any
34 remaining spikes were removed by eliminating high gradients in the position histories that correspond to abrupt
35 changes in wake position, and then a final moving median filter was applied. The resulting filtered trajectories were
36 manually verified to be representative of the simulated wake motion.

37 - Figures 7 and 8 compare "good" and "poorer" agreements at 10-minute intervals. However, it is unclear how these different
38 intervals are selected. Furthermore, which 10-minute intervals are selected is not mentioned, which would allow comparison
39 to the other graphs.

40 *Author response:* Regrettably, we no longer have the data to provide the exact time stamps that were used to generate the
41 PSD plots, so, we are left with this qualitative assessment. We have provided some additional clarity in the text on how the
42 time periods were chosen as best as possible.

43 - I am especially confused about figures 7 and 8. Given the number of panels and the reference to the "top" and "bottom"
44 panels, it is not even exactly clear what panel shows what results. Note, for example, that in Figure 8, all the top panels ("good
45 agreement") are for Tr02, and all the bottom panels are for Tr03. This almost suggests that agreement is "poorer" for Tr03 in
46 general. It is also unclear what the left and right PSD panels indicate. I mentioned this in my previous report [in a different
47 way]. However, unfortunately, the description of what is shown and learned from these figures is still very difficult to
48 understand [changes to these sections are also limited].

49 *Author response:* Indeed we found some miswording in the captions. This has been corrected for both figure captions.

50 - Line 154: "This is due to the induction zone upstream of the turbines captured by SOWFA," --> Is this the reason why in
51 Figure 2 "FastFarm" is consistently above SOWFA, while this is not the case in Figure 5. Perhaps it is more how the induction
52 is accounted for? Some clarification on this would be helpful.

53 *Author response:* Reviewer 1's understanding is correct. The turbine inflow velocity shown in Figure 2 for the SOWFA-
54 OpenFAST results includes the effects of the induction zone upstream of the rotor, while in FAST.Farm, this velocity does not
55 include the induction zone of the rotor, as stated in the text.

56 - Line 251: "All results show near-constant means and spectral content peaks at the 1P frequency." --> I see significant
57 variations in the peaks at the 1P frequency.

58 *Author response:* This has been clarified in the text. The authors do believe that there are consistent results between the
59 computational methods for the "good agreement" subplots, which has been better reflected in the updated text.

60 - Line 257-259: "Relative results for Tr03 compare better in this time period, with the effects of wake interaction captured by
61 all computational methods."

62 --> Where the results for Tr03 are normalized by the results of Tr02, it really shows something different, namely the wake
63 effects. The formulation in this paragraph can be clarified to emphasize that point. Differences for Tr02 (reproduction of
64 atmospheric conditions) and Tr03 due to wake effects.

65 *Author response:* We have clarified the text to better highlight this point.

66 - Line 284: "though discrepancies in standard deviation are observed more for Tr01 and Tr05 results, especially close to the
67 rotor." --> For Tr01 at 9D in Figure 9B, there are also substantial differences, which is not mentioned.

68 *Author response:* We have now documented the Tr01 differences in the text.

69 - In general, what is meant by good or poorer agreement remains unclear. Can this be quantified a bit more?

70 *Author response:* As mentioned in the previous comment, we no longer have the data to provide the exact time stamps that
71 were used to generate the PSD plots, and so, we are left with this qualitative assessment. We have provided some additional
72 clarity in the text around Figure 7 on how the time periods were chosen as best as possible.

73 - Figures general: The text of the horizontal and vertical axis should not overlap.

74 *Author response:* We rechecked all figures and see that there is negligible text overlap and the figures are easily interpreted
75 without changes.

76 - Figure 3: How much wake steering is used in the lower panels? Are there any specific differences the reader should see?

77 *Author response:* These yaw positions are shown in Figure 2, which has been added to the caption for Figure 3.

78 - Figure 4: The figure has a very low resolution. As indicated previously, from the figure, it is unclear whether the crosses
79 correctly reflect the wake center. A not-so-helpful comment is added in lines 183-185. Can you show the corresponding data?
80 [half of Figure 4 is just white space, so the additional data can be added without making the figure larger]

81 *Author response:* We have reduced the size of Figure 4, in the hopes that this improves the appearance. As is the issue with
82 the PSD results, we no longer have access to this data so cannot add these details to the figure. The authors do not see an issue
83 with the cross placement in the figure, but have also clarified that it is an instantaneous wake center calculation.

84 - Figure 5: Please clarify in the caption / vertical axis what is plotted in the right column; now, this is only defined in the text.

85 *Author response:* The caption of Figure 5 has been clarified as follows:

86 Time-series (TS) results for rotor power of all turbines for all computational methods and experimental results. The
87 subplots on the left (a) are dimensional and on the right (b) are non-dimensionalized. Dots show 10 minute averages
88 and bands extend to ± 1 standard deviation from the mean. Results from each wind turbine are shown in separate sub-
89 figures. Experimental results for Tr04 are invalid.

90 - Figure 6: Indicate that the lower panels are normalized. The vertical axis, for example, "Rotor power [kW]," refers to upper
91 and lower panels, which is incorrect.

92 *Author response:* The caption of Figure 6 has been clarified as follows:

93 Time series results for rotor power, torque, and speed for all computational methods and experimental results (not
94 SCADA). The subplots on the top are dimensional for Tr02 and on the bottom are non-dimensionalized for Tr03.
95 Dots show 10 minute averages and bands extend to ± 1 standard deviation from the mean. Results from each wind
96 turbine are shown in separate sub-figures. Vertical shaded regions are used to show when wake steering of more than
97 $\pm 10^\circ$ is present (red) and when there was prominent wakening of Tr03 (purple).

98 - Figure 6 and 8: Why mention "prominent wakening of Tr03 and Tr04 (purple)." When there is no Tr04 data presented in this
99 figure, why is this relevant? I think only the time periods in which Tr03 is waked should be shown [as this is the turbine that
100 is analyzed]. Arguably, these time periods should only be shown in the Tr03 panels (the waked turbine) and not in the Tr02
101 panels, reflecting that these panels show different information.

102 *Author response:* The captions of Figures 6-8 have been edited to remove mention of Tr04.

103

104