Reply to reviews – WES-2023-124

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Reviewer #1

We appreciate your positive feedback on our manuscript. The details of these revisions are described below, and for clarity, the original comments from the reviewers are presented in black, while our corresponding responses are highlighted in blue:

This work compares the performance of two wind farm parameterizations in WRF for their skills at wake representation versus a large-eddy simulation. The analysis is thorough, relevant, and considers single and multiple turbine layouts and each atmospheric stability regime. The paper is very well written with compelling figures. This work is recommended for publication after the following minor suggestions and corrections are addressed.

1. The results section would benefit from the addition of numerical values throughout to help the reader understand what the authors mean in statements such as "nearly negligible," "larger errors," "considerable differences," and "best agreement." A few sentences that would benefit from such numerical additions are explicitly stated below, but a comprehensive review of the manuscript in support of the addition of numerical findings is recommended.
Thank you for pointing this out. We have revised the manuscript in the manner suggested and replaced such statements with quantitative ones. In a number of instances, we have used a relative difference (i.e. $(experiment - reference)/reference$) with the reference being the LES runs. Specific changes are highlighted in the diff text document.

2. In the discussion section, it would be of interest to tie the results to wind generation by employing the reference turbine's power curve. For example, it would be interesting to see what the sensitivities in generation or capacity factor estimates over the analysis hours are relative to the sensitivities noted for each WFP, correction factor, and length scale.
As suggested by the reviewer, we have calculated (post-processed) the relative power difference (%) of the two-turbine simulations (Table 2). Since the power generation is a function of the wind speed, changes in the σ_0 parameter from the EWP have more impact in the extracted power than the cf parameter from the Fitch WFP that modifies the amount of TKE injected in the

atmosphere. The difference between the minimum and maximum relative power difference obtained from the various σ_0 tested, are 8.5, 13.1, and 15.4% under unstable, neutral, and stable atmospheric conditions respectively. We have added a paragraph in the Discussion section where we provide a discussion on the power sensitivity from the WFP parameters and their implications.

Table 2: Relative power difference (%) of the two-turbine layout for each simulation under different atmospheric stability regimes. In all cases, power is computed from the cell-averaged wind speed ($\langle\overline{U}\rangle$) at hub height and the reference is the LES runs.

	Atmospheric stability		
Run	Unstable	Neutral	Stable
EWP-0.6	2.74	−3.90	−3.21
EWP-1.0	6.32	3.45	5.52
EWP-1.7	11.21	9.17	12.19
Fitch-0.25	0.94	−3.0	−1.97
Fitch-0.0	−0.21	−4.34	−2.25

3. Line 124: "stated" should be "state"
   Fixed as suggested.

4. Line 133: Recommend adding some discussion as to why MYNN was selected as the PBL scheme for this analysis, along with speculation based on the literature on how an alternate scheme might impact your analysis and results.

   Our choice of the MYNN PBL scheme is primarily driven by the fact that the TKE advection is activated when using this scheme. This is not the case for other PBL schemes that include TKE. It allows for the transport of the explicit TKE source from the turbine from one grid point to its neighbours and for the TKE to be "remembered" from one time step to the next . Consequently, most wind farm simulations using the WRF model reported in the literature have utilized this PBL scheme. To our knowledge, only a few studies (Peña et al., 2023; Rybchuk et al., 2022) have employed the Fitch scheme with alternative PBLs, such as the NCAR 3DPBL (Juliano et al., 2022). However, the 3DPBL scheme has not been merged yet with the community-open WRF version. The EEPS PBL (Zhang et al., 2020) scheme also has advection of TKE, but we have not found an study of using the Fitch WFP and this PBL.

   In terms of atmospheric stability, using a different PBL scheme than the MYNN could be advantageous, as some PBL schemes demonstrate better performance in modeling wind speed for specific regions. For example, Draxl et al. (2014) suggested using the MYJ scheme for stable conditions, ACM2 for neutral, and YSU for unstable conditions in Northern Europe. These alternatives might offer improved wake representation under those atmospheric conditions. However our results indicate that the differences from the reference are larger when comparing the wake regions than when comparing the atmospheric stability cases. Actual wind farm simulations with the WFPs along different PBL schemes are needed to investigate the wake regions.

   We have acknowledged the use of the MYNN scheme in our methodology section and expanded the discussion to include the implications of employing different PBL schemes.

5. Line 217: Suggest adding numerical values throughout this paragraph to help the reader understand what is meant by "significant differences" and "considerable differences".
   As suggested, we have added supporting numerical values to these sentences

6. Line 259: Should the word "and" be removed from this line?
   Removed as suggested.

7. Line 308: "Fitch-0.25, Fitch-0.5, and Fitch-0.75 overestimate the added TKE by the turbines under all atmospheric conditions" By how much do they overestimate?
   Numerical values are added to support the statement. Now it reads: *Fitch-0.25, Fitch-0.5, and Fitch-0.75 overestimate the added TKE by 0.24, 0.50, and 0.74* m^2 s^{-2}*, respectively, under all atmospheric conditions at hub height.*

8. Line 318: "Fitch-0.5 and Fitch-0.75 greatly overestimate the LES reference" Again, by how much?
   As suggested, we have modified the sentence. Now it reads: *Fitch-0.5 and Fitch-0.75 greatly overestimate the LES reference at hub height by 209% and 326%, respectively.*

References

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