REVIEWER 1

Reviewer's comments appear in italics, **our responses appear in boldface blue text and new text included in the manuscript appears in *boldface italicized blue text***.

Quint et al. have produced a nice comparison of low-level jet occurrences and features based on simulations with and without offshore wind farms present. This study is of value to the wind energy community, especially in light of the extensive activity occurring offshore of the United States northeast region. The topic is deeply delved into by the authors, and the accompanying graphics are of high quality. I especially appreciated that the authors performed what validations they could, while acknowledging the limitations imposed by the vertical extent of available observations.

We thank the reviewer for their time and thoughtful consideration in reviewing our manuscript. We especially appreciate their kind words.

General comments

I have some concerns about the strength of the wording throughout the manuscript as it pertains to making bold physical statements based on simulations. Even the title would imply a well-documented observation-based study of offshore wind farms modifying LLJs instead of a comparison of simulations that lack extensive validation. There is still a lot of value in such a study, I just think care needs to be taken with the messaging.

Thank you for the thoughtful comment. We have changed the title to "Simulations suggest Offshore wind farms modify low-level jets" and have softened the language throughout to remind readers that we are interrogating a simulation dataset. Some examples, with underlining denoting the new softened text:

- **Abstract: "In the absence of observations or significant wind farm construction as yet, we compare one year of simulations from the Weather Research and Forecasting model with and without wind farms incorporated,"**
- **Abstract: "In the NOW-23 simulation dataset"**
- **Conclusions: "In this simulation-based study, we assess occurrences of LLJs in the US East Coast wind resources areas and how these LLJs are influenced by the presence of wind farms as they appear in numerical weather prediction simulations."**
- **Conclusions: "Modeled LLJs occur less frequently when wind farms are present in the simulations"**
- **Conclusions: "We also document how very low-level jets – LLJs with jet nose heights below 260 m – are significantly eroded by wind farms in the simulations.**

There are extensive details that the reader must keep track of with not a lot of helpful reminders along the way. The phrase "the WF (wind farm) simulation" is used throughout the text, and it is easy to forget that you're actually talking about three WF simulations being used to analyze five unique locations. And those five unique locations are reduced to two, with the other three placed in the appendices, but then the Conclusions section again discusses all five. In the Results section, Figure 7 presents five locations and is immediately followed by Table 5, which presents three locations, while most of the text in Section 4 discusses "both locations." I recommend streamlining by picking the locations of greatest research value *to you to focus the bulk of the paper on, and then briefly point to the additional details available in the appendices.*

Thank you for pointing out the potential confusion here. We have been specifically requested to assess these five locations and so streamlining by eliminating locations is not an option. To try to clarify, we have added a column to Table 1 to specify clearly which simulation is used, and we added a sentence to the end of section 2.2 to state this:

"Throughout the manuscript, we refer to wind farm (WF) simulations, and the appropriate simulation depends on the location as specified in the rightmost column of Table 1."

We have also clarified that Table 5 only includes three sites because only three sites have a full year of data available:

"The NEbuoy and SWbuoy sites do not appear in Table 5 because only four months of data are available for those two sites."

Finally, there are several locations in Section 4 in which we focus only on two sites because they represent bounding conditions in which there is not much variability between the five sites. We have added sentences in those areas pointing out that the omissions are generally because of redundancy and directing readers interested in those specific locations to the appendix and highlighting cases in which the buoys behave differently. For example:

"Similarly, very unstable conditions (−200 m ≤ L < 0 m) are less common during LLJs than for all times (Fig. 11), and this pattern holds for the other three sites (Fig. B1). During neutral conditions (|L|>500 m), differences between LLJs and normal conditions are small, although few LLJs occur during neutral conditions."

and

"The LLJ occurrences in the NWF and WF simulations differ the most at slower wind speeds but are nearly identical for wind speeds faster than 20 m s-1 (Fig. 12 and Fig. C1).

and

"Mean nose heights in the NWF simulation are around 300 m at all five locations (Fig. 13 and Fig. H1), but mean jet height is slightly lower at the southLA site than at the ONEcent site. In the NWF simulation, mean nose height increases with jet classification at all locations (i.e. faster jets have higher noses) except for the NE buoy. The southLA site also has a larger range of heights for the middle 50 % of data (Fig. 13) Nose height differences between WF and NWF simulations are much larger at the buoys, with very little overlap between the middle 50 percent of data for each classification (Fig. H1), likely due to the very large wind farms in their vicinity."

Several similar changes have been made throughout Section 4 to more completely include all five sites, including references to the figures in the Appendix.

Many interesting findings are presented, but, in some cases, little to no physical suggestion or speculation accompanies the results. For example, the seasonal trends in wind veer reduction from the *presence of wind farms presented in Section 4.6.4 are quite pronounced. Can you provide some comments in the text as to why those seasonal trends might exist in the simulations?*

Yes, we should have included a discussion of this pattern, which is related to the seasonal variation in atmospheric stability. Summer months have more frequent occurrences of stable conditions, and stable conditions tend to have more wind veer due to frictional decoupling. We have added text to Sect. 4.6.4:

"This pattern is related to the seasonal variability in atmospheric stability. Summer months have more frequent stable conditions, and stable conditions are associated with more veer (Lundquist, 2020), especially offshore (Bodini et al., 2019, 2020)."

Check the intermingling of past versus present tense throughout the text. Lines 119-121 provide an example.

Thank you, we have thoroughly reviewed the tenses and changed to present tense throughout.

Specific comments

Line 10: It would be of interest to the reader to put some quantification here (percentage) on how many fewer LLJs occur in the wind farm simulations versus the no-wind-farm simulations.

We have modified the abstract to read

"*In the NOW-WAKES simulation dataset, we find offshore LLJs in this region occur about 25 % of the time, most frequently at night…Wind farms erode LLJs, as LLJs occur less frequently (19-20 % of hours) in the wind farm simulations than in the no-wind-farm (NWF) simulation (25 % of hours).*"

Line 19: Citing BOEM's website here would provide the reader with knowledge of the status of the lease areas at the time they read the manuscript.

We have added a sentence to include BOEM's website as requested*: "Wind turbines will be grouped into clusters within the 27 active wind farm lease areas that span the mid-Atlantic Outer Continental Shelf; current status of lease areas can be found at https://www.boem.gov/renewable-energy/lease-and-grant-information.*

Line 100: The Rosencrans paper does a nice job of discussing the validation, but it would be helpful here to reiterate at least some of the validating findings, particularly those that pertain to bias, in order to set expectations.

Thank you for the helpful suggestion, we expanded this sentence to include the bias: "These simulations without wind farms have been validated in comparison to floating lidar observations at two locations in the domain (Rosencrans et al., 2023), with a slow bias of less than 0.5 m s-1."

Line 102: "The period from 1 September 2019 00:00 UTC to 31 August 2020 23:50 UTC provides a temporal resolution of 10 minutes; we used hourly time steps for our analysis." Why?

In our experience, LLJs vary more slowly, over the course of several hours, and so we thought that using the higher-temporal resolution data would be redundant and not add much insight (and would require more computational resources to process the data).

Section 3.1: It would be helpful here to remind readers that there are no consistently agreed upon numerical thresholds to define LLJs. Please consider explaining why you felt the selected LLJ definitions were the best ones for this analysis as opposed to the numerous other options in the literature.

Thank you for this suggestion. We have expanded this paragraph (new text is underlined) to include the lineage of our approach as well as direct readers to other options.

"To identify LLJs in the simulations described above, we follow the established methodology described by Vanderwende et al. (2015), based on <u>the foundational</u> LLJ analysis of Bonner (1968) and Whiteman et al. (1997). T<u>his approach was also used by Song et al. (2005). However, we do</u> include slight modifications for the offshore environment. LLJs are detected if the maximum wind speed occurs in the lowest 750 m of the atmosphere and is at least 10 m s-1. The wind speed reduction above this wind speed maximum (the "nose" of the jet (Banta et al., 2002)) must be at least 3 m s-1; we considered heights up to 2 km for our analysis. Given the difference in mechanisms offshore and onshore (smaller force of friction leading to weaker super-geostrophic acceleration), we use a smaller shear threshold than in Vanderwende et al. (2015). <u>Several other approaches for identifying LLJs have appeared in the literature, often designed specifically for the features of the instrument platform used (i.e. Nunalee and Basu (2014) use radar wind profiler observations that offer deep layers of observations but lack measurements in the lowest 100 m). Many of the recent developments designed for relatively shallow profiling lidar observational datasets rather than deeper observational datasets (from scanning lidar, radar wind profilers, or radiosondes) or modeling sets used here. No consistent formulation currently exists, but several of the shallow approaches are summarized in Sheridan et al. (2024), including those of Kalverla et al. (2019) and Hallgren et al. (2020).</u>"

Line 179: The authors should add references to other recent studies that classify modelled LLJs into hits, correct rejections, misses, and false alarms, namely, Hallgren et al. (2020), Kalverla et al. (2020), and Sheridan et al. (2024).

Thank you for this suggestion. We have included the following sentence:

"This approach was also used by Kalverla et al. (2019),Hallgren et al. (2020), and Sheridan et al. (2024)."

Line 204: Can the authors provide any speculations as to why one location had more LLJs and another had fewer?

Because the differences in the numbers of LLJs are very small (i.e. 26% vs 25.1%) we do not find these differences significant enough to provide material for speculation.

Line 224: "Neutral conditions…" Suggest reformatting this sentence to follow the flow of the previous two for improved clarity. "Neutral conditions occur X%, and Y% of LLJs occurred during neutral conditions."

Thank you for the suggestion, we have changed the sentence to "Neutral conditions occur 5.3 % of the time, but 6.8 % of the LLJs occur during neutral conditions."

Figure 12: Cropped at the lower extent

Thank you for noticing that; we fixed it.

Line 298: This sentence is quite confusing. I think you mean that the trends are similar between ONEcent and southLA throughout the year, except for November and December. But the use of "with the exception of November and December at the southLA location, where the two simulations diverge" could also imply that the NWF and WF simulations are diverging from each other during these two months at this single location. Figure 22 indicates that it is the former assumption, not the latter, but this is another example where clarity is essential.

Thank you for identifying this confusing phrasing. We have rewritten *"Mean wind shear in the rotor region (30–245 m) ranges from 0.025 s^{-1} to 0.04 s^{-1} at both locations. Shear values are generally constant throughout the year, but minima occur in July at both locations. At the ONEcent site, wind shear increases in November and December (Fig. 22). The NWF and WF simulations are similar throughout the year at both locations, with the exception of November and December at the southLA location, where the two simulations diverge. The wind shear is positive throughout the year at both the ONEcent and southLA locations. "*

to be

"Mean wind shear in the rotor region (30–245 m) ranges from 0.025 s^{-1} to 0.04 s^{-1} at both the ONEcent and southLA locations. Shear values are generally constant throughout the year, but minima occur in July at both locations (Fig. 22). The primary difference between the two locations occurs in November and December, when shear decreases at southLA but increases at ONEcent. This regional variability could be due to the fact that the southern southLA location enters a more unstably stratified regime (with less wind shear) sooner in the winter than the more northern ONEcent location (with more stable conditions and more wind shear). At both locations, few differences occur between the NWF and WF shear. "

Line 302: "An extreme LLJ event was observed…" was it observed? Or did it appear in your simulations? If observed, please provide references to the data sources. If simulated, please rephrase the wording in Section 5 to indicate as such.

Yes, strong winds were observed by the lidars west of the Vineyard Wind area with similar wind speeds and wind directions as simulated, although this deep LLJ (with a nose well above 250 m) could not be fully observed by the lidar platforms. We have included a figure from the lidar observations to address this question and rephrased the discussion.

Line 359: Can you include the distances from the Martha's Vineyard and Long Island sites from the wind farms alongside the distances between the sites you did analyze and the wind farms, for comparison value?

The sites that we analyzed are within the planned wind farms, so a distance of 0 km. The south coast of Martha's Vineyard site is ~ 30 km from the closest part of the ONE wind farm. The closest distance of Long Island to Empire Wind I is ~ 22 km, per https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Fact-Sheets/LSR-offshore-wind-visibility-fact-sheet.pdf. We have added such text to the Appendix:

"Distance from the wind farm may play a role in these results: the south coast of Martha's Vineyard site is ~ 30 km from the closest part of the ONE wind farm. The closest distance of Long Island to Empire Wind I is ~ 22 km, per https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Fact-Sheets/LSR-offshore-wind-visibility-fact-sheet.pdf."

References:

Hallgren, C., Arnqvist, J., Ivanell, S., Körnich, H., Vakkari, V., and Sahlée, E.: Looking for an Offshore Low-Level Jet Champion among Recent Reanalyses: A Tight Race over the Baltic Sea, Energies, 13, 3670, https://doi.org/10.3390/en13143670, 2020.

Kalverla, P. C., Holtslag, A. A. M., Ronda, R. J., and Steeneveld, G.-J.: Quality of wind characteristics in recent wind atlases over the North Sea, Q. J. Roy. Meteorol. Soc., 146, 1498–1515, https://doi.org/10.1002/qj.3748, 2020.

Sheridan, L. M., Krishnamurthy, R., Gustafson Jr., W. I., Liu, Y., Gaudet, B. J., Bodini, N., Newsom, R. K., and Pekour, M.: Offshore low-level jet observations and model representation using lidar buoy data off the California coast, Wind Energ. Sci., 9, 741–758, https://doi.org/10.5194/wes-9-741-2024, 2024.