# Reviewer Comments and Responses
# Wind Energy Sciences, Manuscript ID WES-2024-51

A series of revisions has been made to the paper addressing each of the reviewer comments. Below is a table listing the reviewer comments, author responses, and resulting changes that have been made to the paper.

In addition to the changes addressing the reviewer comments, the author has removed the figures from the Appendix and instead included them in a Data Supplement. These figure files are very large in size (taking one page each) and, per the WES submission policies, are eligible to be included in a Supplement as very large images. The images have been numbered according to the WES guide for data supplements.

| | **Reviewer Comment** | **Author Response** | **Changes to Manuscript** |
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| 1 | Line 12: I would add mention of the pilot interview when mentioning the qualitative parts of the study, e.g., "Videos and pilot statements were also collected..." | We agree, this additional wording has been added to the abstract. Thanks for this suggestion. | The sentence in line 12 has now been changed to "Videos and pilot statements were also collected providing qualitative information…" |
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| 2 | Line 15: Nitpick: no comma needed after "noted". | We agree, thank you. | This has been fixed in the revised manuscript. |
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| 3 | Line 134: Define acronym IMU. | Thanks for pointing this out. This stands for inertial measurement unit. | This acronym has now been spelled out in the paper. |
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| 4 | Line 188: Define a "flap configuration" and its relevance. | Thanks for pointing this out, a brief explanation is warranted for readers that are not familiar with aircraft. Wing flaps are retractable extensions on the trailing edge of the wing that are typically extended (i.e., deflected downward by a certain angle) during approach and landing to allow for higher lift production at lower flight speeds. | We have now added a sentence at this point in the paper to explain what a wing flap is and how it is used during approach and landing to produce more lift at lower flight speeds. We believe this addition should be sufficient to explain the meaning and significance of this term for readers unfamiliar with aircraft. |
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| 5 | Figs 7-12: Remind the reader the dashed lines indicate the time spent in the estimated wake region on the plot or in the caption (as I suspect these figures will be reused or borrowed by others in future presentations or discussions). | This is a great point and we agree that this reminder is necessary in case these figures are used in a standalone context. We have now added a sentence to this effect in the captions for each of Figures 7-12 as well as the figures in the Supplement. | The following sentence has been added to the captions for Figures 7-12 and those in the Supplement: "Dashed lines indicate the time period during which the aircraft was present in the estimated wake region of turbine T1." |
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| 6 | Line 209: I agree that the author's experiment represents, as he states, a "fairly worst-case scenario". | This is a great point about nighttime wake passes generally being worse for added turbulence | In the paragraph following Fig. 4, an explanation has been added about nighttime conditions being |

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| | Though because wind farm wakes are generally stronger at night due to a lack of daytime-heating-induced vertical mixing diluting the wake, I would pose a nighttime wake intercept as the "ultimate" worst-case scenario. However, I assume that most general aviation aircraft are not flying during nighttime conditions, though I can't speak to general aviation aircraft flights times myself - maybe the author could offer some commentary on typical GA flight times for clarity? | compared to daytime. From a general aviation standpoint, however, night passes through the wake would likely be extremely infrequent. The two most common scenarios where a general aviation aircraft may be expected to fly below the tip height, within 10 rotor diameters of a turbine, would be during aerial application missions (crop dusting), or on takeoff or landing from an airport. Aerial application is done only during the daytime. Furthermore, in North America, airports located that close to a turbine tend to be small public airstrips in rural areas (which generally have minimal traffic at night) or private airstrips (where nighttime operations are almost always impossible due to lack of runway lights). That being said, it is worth mentioning this for clarity in the manuscript so a brief discussion has been added relating to the likelihood of wake encounters at night. Thank you for bringing this up. | more conducive to higher levels of added turbulence in the wake, and a new reference documenting this has been added. A further discussion has also been added regarding the relatively low likelihood of general aviation aircraft flying through wakes at night. We believe this additional explanation should clarify the fact that the encounter represents a relatively worst-case daytime scenario, which is the most likely time of day in which a general aviation aircraft would encounter the wake. |
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| 7 | Line 275: This interview with the pilot is fascinating and highly valuable. I'm curious if the author could comment more on how the interview was posed to the pilot and on the pilot himself: What did he know about the study beforehand? How long has he been a GA pilot? | These are great questions, and it is certainly relevant to include pilot qualifications. The pilot was a commercially-rated skydiving pilot who regularly flies skydiving missions at Edmonton Skydive Centre. He has a multi-engine and instrument rating, with 520 hours of total flight time and 247 hours of flight time in the Cessna 206 at the time of the flight tests. He knew the purpose of the study beforehand and was asked to fly a set of test points at different distances from the turbine. He was provided with a brief set of questions to answer after the flights. | A paragraph summarizing the pilot's qualifications has now been added after Fig. 2. This paragraph discusses both the pilot's qualifications as well as what he knew about the purpose and scope of the tests beforehand. In addition, more information has been provided in Section 3.2 about the way in which the pilot was debriefed about his experience. In this section, the particular questions that were posed to the pilot are enumerated. These additions to the paper now provide a clearer explanation of the pilot's qualifications and the manner in which the interview was posed. |
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| 8 | Line 288: There are several sentences in this manuscript that start with "This" that I think would be strengthened with a noun afterward, in this case something like "This statement matches…" | Thanks for bringing this up, and I agree that there were some instances throughout the paper where the object being referred to was ambiguous. In the revised paper I have reviewed all | All sentences starting with "This" have been carefully reviewed and in any instance where the object being referred to is possibly ambiguous, a noun |

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| | | sentences that start with "This" carefully and added a noun afterward in any cases where the meaning is possibly ambiguous. | has been added afterward to clarify. |
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| 9 | Line 333: To give more context for the fairly worst-case scenario I suspect is being shown in video 12: How often does a GA pilot typically fly within 2D of a turbine? I would suspect infrequently but would like to know for sure. | It is true that for the average GA pilot a pass this close would be infrequent; however, it depends on the context. An aerial spraying pilot who operates in the vicinity of wind farms may fly this close on a somewhat regular basis, while some pilots who fly in regions where there is no wind development may never fly near a turbine at all. The answer to this question really depends on the type of pilot (e.g., aerial spraying, recreational, etc.), the region in which they fly, the particular types and purposes of their flights, and other factors. Therefore, it is impossible to make any sort of definitive statement in an archival paper about the frequency of an encounter this close, without going into significant detail about operational needs and pilot choices for different types of GA flight operations (and having data to back up any claims made). Furthermore, the purpose of this paper is to assess whether there was a risk to the aircraft during the flight test passes that were performed, rather than assessing the frequency with which they are likely to occur for a typical pilot. In summary, if I answered this question it would be purely speculative and highly caveated, and the collection of data to address this is beyond the scope of this work. | The author would prefer not to add any statements to the paper regarding the potential frequency of wake encounters at particular distances, as no data has been collected on this topic since it is beyond the scope of this work (which was strictly to assess the level of turbulence and whether a hazard existed to a GA aircraft at different locations in the wake). This question could potentially be answered in a follow-on paper where air traffic control data could be analyzed to assess the frequency of GA wake encounters at different distances, although this would be very separate and distinct from the scope of the study performed in this work. |
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| 10 | Line 407: Does the author have a hypothesis for why wake pass 5 is an outlier? | It is interesting to note that the roll angle deviation magnitude in Wake Pass 5 is an outlier, but the pitch angle deviation and load factor deviation in this wake pass are not outliers and are consistent with the other results. This is in contrast to, for instance, Wake Passes 12 and 13 where both the roll, pitch (for pass 12), and load | I have now added a paragraph discussing this outlier after Figure 16. This new paragraph reflects the hypothesis discussed in the reply to the reviewer's comment. |

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| | | factors are all higher than the farther wake passes. My hypothesis is that there was a random roll perturbation that happened to occur in this time frame during Wake Pass 5 due to atmospheric turbulence, separate from the turbine-added turbulence. For instance, a small updraft due to ground heating that is stronger on one side of the aircraft than the other can cause a roll angle disturbance of that magnitude. Thanks for bringing this up - it will be good to mention this in the paper. | |
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| 11 | line 43 An overview of phenomena in a wind turbine wake, in addition to the mentioned effects in wind turbine wakes one could also mention the velocity deficit behind the turbine. Though less for a wind turbine park in comparison with a stand-alone turbine this has shown to affect the flight path. | This is a great point and something that has certainly been raised in the past as a possible concern. In this overview of wake phenomena I have now added a sentence about velocity deficit and also mentioned that velocity deficit, in addition to added turbulence, has been a source of possible concern regarding general aviation safety. | In the revised paper I have now added a sentence describing the velocity deficit in the turbine wake and mentioned that it, in addition to added turbulence, has in the past been raised as a possible safety risk for general aviation aircraft. |
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| 12 | line 105. In figure 1 It would be illustrative to add a 6 RD measure to the drawing (as well as in figures 5 and 6). | Figure 1 is fairly zoomed out and I tried putting a 6 RD circle around T1 but it looks very small and is generally not very helpful. However, I agree that this would be very helpful to include in Figures 4, 5, and 6, and have now added markers at 6 RD distance in those figures. | I have added markers at 6 RD distance in Figures 4, 5, and 6 as requested by the reviewer. |
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| 13 | line 190; Every wake pass was performed only once. To have a more consistent data set and to assess data quality and outliers it is advisable to repeat the flight test points. | I agree that the test points should be better explained. The pilot was asked to fly two passes each at 15 RD, 10 RD, 5 RD, and 3 RD, with one pass at each distance flown at the 90 kts configuration and one flown at the 80 kts configuration (see Table 4). In addition, the pilot was asked to repeat the 5 RD pass at 80 kts four times to provide more data at this specific configuration (Wake Passes 7-10). So, in some cases distance test points were repeated at different speeds and flap settings, while in others they were repeated identically. It should be | Additional description of the desired flight test points has now been provided in Section 2.4. This added text describes the repetition of each test point, as well as the observed small discrepancy between the desired closest distance of approach and the actual closest distance shown in Table 4. The goal of this additional description is to emphasize that some repetition of the test point was desired, and achieved, in the flight trials. |

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| | | noted that the closest distance of approach to the turbine requested for each trial sometimes differed slightly from the closest distance actually flown (shown in Table 4) simply due to small errors in flight path tracking during the flights (e.g., Wake Pass 1 was intended to approach the turbine within 15 RD but approached within 13.5 RD instead). Overall, in my opinion there was sufficient repetition of the test points to justify the conclusions of the study. | |
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| 14 | line 275. Not much information has been provided on the pilot's background. In flight test experiments it is common to note the pilot's professional background (private/commercial/test pilot) and number of flight hours. In addition aircraft handling qualities would normally be assessed by means of a more objective, generic rating scale (Cooper-Harper or equivalent). | Thank you for this comment, we agree that the pilot background is necessary to add and have now done so in a new paragraph after Fig. 2. Regarding objective rating scales such as Cooper-Harper, asking the pilot to assess handling qualities quantitatively was considered; however, although the pilot is a commercial pilot, he is not a certified test pilot and thus has no experience or training in providing quantitative handling qualities ratings for aircraft. It was determined that his qualitative descriptions of the experience flying through the wake, in combination with a detailed assessment of the flight data and videos, would be sufficient for assessing whether a hazard existed when flying through the wake. | A new paragraph has been added after Fig. 2 that describes the pilot's background, ratings, and number of total hours and flight hours in the Cessna 206. I believe this should provide the necessary information to assess pilot qualifications for the purposes of this study. |
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| 15 | line 330 For better comprehension instead of noting the pass number it would be more evident to state the RD case that was flown. | We agree and have made a change accordingly. However, we would like to maintain mention of the pass number as well so that the discussion can be easily cross-referenced with Table 4 and 5. Therefore we will present both the pass number and the RD distance for completeness. | In this section, right after listing the wake pass number, we have also mentioned the closest point of approach to the turbine in each wake pass (in terms of RD). This will help the reader clearly identify the distances without having to cross-reference Table 4 or 5. |