Thank you to both reviewers for taking the time to review our restructured manuscript and for your valuable comments. Below, we include your comments in **black**, followed by our responses in **blue**.

Considering that this round of revisions will result in a third manuscript iteration, in our response we will term the versions as follows to avoid confusion:

- Manuscript A: original submission from 12 Feb 2025
- Manuscript B: first revision submitted on 14 Apr 2025
- Manuscript C: second revision submitted on 01 Jun 2025

Report 1

Review: ***Wind turbine wake detection and characterisation utilising blade loads and SCADA data: a generalised approach: Revision 1***

General Comments

The authors have re-structured their manuscript, resulting in a more concise paper that is easy to follow and reads well. They have addressed the majority of comments raised, and there are only a few further points I recommend addressing as listed below.

We appreciate your kind feedback. We are happy to hear that the changes we implemented addressed your concerns.

Specific Comments

1. Wake classifications: It would be useful to have a clear statement on how the training (and testing) datasets for different wake impingement categories were labelled. There are occasional references to different wind directions (5 degrees on line 122) or "manual review" on line 238 – if the wake impingements for training were all classified manually by eye, then this should be stated.

The samples representing each class are taken only from a specific simulation subset that shows a given wind direction. Manual inspection refers to the action of us making sure that the samples are showing what they are supposed to. Thanks to that action, we were able to realise that wind speeds over the 15 m/s threshold could not serve as the training data, under the assumptions that we made that all samples need to portray a clear wake. We have modified the entire section 2.4 (now titled Framework implementation: wake detection) to address this and the next comment. The labelling process is now more explicitly explained.

2. Section 2.4: The removal of all ambiguous training data (~line 242) invites the question of how the final model would classify such cases. Given the model outputs probabilities of different impingement classes, it should be able to handle a wake that is a "edge case" between e.g. fully and right-impinged by predicting ~50% probability of both. Some additional text around this could help to clarify why training on these data would be an issue as presumably they could be given labels of equal probability between the two potential classes?

The data from the 15-25 m/s range is eliminated, because in the simulations defined as full or partial wake impingement (which would be used for the full/partial labelled samples, as explained above) a clear wake deficit was often missing from the YZ snapshot samples. We believe that is due to a) higher meandering that these wind fields exhibit, b) weaker wake deficit resulting from smaller thrust force in the above-rated operation. Consequently, we would feed the training process with samples that are labelled as 'wake impingement' even when they do not portray a wake. To avoid a tedious process of manual labelling in this ambiguous range, and because we already had an abundance of training data from the 5-15 m/s range, we decided to eliminate the problematic dataset. Ultimately, the wake steering brings largest benefits in the low-wind conditions, so this action actually tailors the training data to the specific application. We have modified the entire section 2.4 (now titled Framework implementation: wake detection) to address this and the previous comment. We have added our reasoning behind the elimination of ambiguous samples.

3. Figs 16 & 17: Compared to the previous version of the manuscript, Figures 16 and 17 are paired with different Uamb values in the current version. Switching these wind fields speed values would also make more sense with the discussions on these figures in Section 4.2.

The wind fields used for the detailed analysis shown in Fig. 16 and 17 (manuscript B/C) have been changed compared to the original (manuscript A) for several reasons. Firstly, the new quantitative analysis allowed to properly look into the models' accuracy and describe it across several wind conditions (Table 5 of manuscript B). As a result, we believe that a detailed qualitative analysis of six different wind fields is no longer necessary, as the discussion can now strongly rely on the more representative quantitative results. For this reason, we have trimmed the selection to 4 wind fields. Secondly, the entire structure of the Results section has changed between manuscripts A and B; the visual inspection of wind sensing, wake detection and wake characterisation is now showed on a single figure for each wind field. This was done to satisfy the reviewers' comments and make the paper more concise, and to make the narrative flow better in light of the new quantitative results. We believe that showing six different wind fields in the expanded manner (4 subplots per wind field) could overwhelm the reader, especially considering the manuscript is already quite long. With that in mind, and to avoid redundancy, on Fig. 14-17 we are showing just the four wind fields portraying four significantly different cases (wake impingement under high and low turbulence intensity, no impingement under high and low wind speed). We believe that such visual representation of four distinct wind fields is enough to inform the reader about performance in various conditions and provides a lot of content to assist the discussion.

Technical Corrections

1. Abstract: I recommend not using acronyms in the abstract as they have not been defined; however RMSE and DWM are probably known to readers of this journal.

We have removed SCADA and DWM acronyms. We believe that RMSE is such a wide-used technique in the field, that it doesn't require explanation.

2. Lines 118, 321, 404: Suggest writing out "approximately" rather than "approx."

Sorted.

3. Lines 196, 204, 231: Italicise "U" for consistency with first use on line 154.

Sorted.

4. Line 199: Capitalise "Discrete Cosine Transform" in DCT acronym definition.

Sorted.

5. Line 248: Suggest "monotonically" rather than "iteratively", or delete the word "iteratively".

We have removed the word "iteratively".

6. Equation 7: Given "t" is part of the limits, it shouldn't be a variable in the integral – suggest changing the instances of "t" within the integral to something else e.g. θ

We have changed the instances of "t" with theta as you suggested.

7. Line 310: Suggest re-wording title of Section 3.1 to e.g. "Performance evaluation"

Sorted.

8. Table 5: For ease of comparison, could the two types of RMSE be presented in the same way e.g. percentages for both?

Good point – we have changed the RMSE_det, it is now in percentage instead of fraction of 1.

9. Equation 11: Variable "i" has been used in previous equations to represent timestep, please use a different variable for wind direction.

Good point – we have replaced "i" with "k".

10. Lines 380, 453: It reads as though full impingements are under (high or) low Iamb and partial are under the other Iamb.

We have reworded to: “Table 6 shows the wake characterisation RMSE calculated for four example wind fields, comparing the model's accuracy for full and partial wake impingement under high and low I_amb”

11. Line 386: Suggest removing “raw” before simulated, or re-wording to e.g. “simulated (rather than estimated)”

Thank you for your suggestion – we have reworded to “simulated (rather than estimated)”.

12. Line 450: Suggested re-word: “with a few gaps”

Sorted.

13. Line 465: Suggest removing “the” from “after the consideration”

Sorted.

14. Line 471: Suggested re-word: “Wake steering control brings the largest benefits”

Sorted.

15. Line 483: Suggested re-word: “post-processing analysis which accounts for”

Sorted.

16. Line 493: Is the acronym “LSTM” ever used? If not, no need to define.

Sorted.

17. Line 507: The sentence beginning “Wake detection” could be worded more clearly, and context given to the RMSE e.g. writing as a % of times the correct type of impingement is identified.

We have reworded to: “Wake detection model correctly responds to the wake presence; averaging the RMSE across all wind fields used in testing indicates that the correct wake impingement case is identified for approximately 77% of the samples.”

18. Line 515: Suggested re-word: “accounting for more”

Sorted.

Report 2

Revision 2: Wind turbine wake detection and characterisation utilising blade loads and SCADA data: a generalised approach.

Dear Authors, Thank you for addressing the comments such detailed. I appreciate the implementations you made, and I especially like the increased level of discussion. Below, I gather a short list of additional comments on the revised manuscript. The line numbers I state refer to the document with tracked changes.

Thank you for your feedback. We are happy to hear you liked the extended discussion.

Comments

1. Line 61: "Despite achieving great performance [...]" please formulate this more neutral. Same as the load-based methods, the lidar-based concepts are not perfect. Their drawbacks are often a compromise between spatial or temporal observability (depending on staring / scanning lidar).

Good point. We have reworded to "Despite achieving good performance [...]". We believe that this wording describes their performance in a short but representative way.

2. Line 70: Onnen et al. (2022) do not make use of the in-plane blade loads, only out-of-plane.

Good catch, thank you. We have corrected the manuscript accordingly.

3. Line 80: "The up-to-date wake detection studies analysed the wake impingement in a scenario with a single upwind turbine [...]" – This is certainly a valid point. But does this paper fill this gap? In your author's response you mention that the wake overlap method in the simulation environment is "pick the maximum deficit at the point". So is the method really tested for complex overlapping wakes? Meanwhile you have a strong point showcasing the method for wakes shed at various upstream distances.

Thank you for this comment, we do agree that the research gap and how we fulfil it needs to be clearly defined. To clarify: in our wind farm simulation approach, every point at the 'wake receiver' (front-view) rotor plane, calculates the local wind speed independently. For each point on the grid, the strongest influencing upstream turbine is selected, and the corresponding shedding wake deficit is used to calculate the wind speed value. As a result, while we do not directly superpose the wake deficits at each rotor point, we are able to capture two wake deficits on the wake-receiving rotor plane; in other words, we could see one very wide deficit that is the combination of two wake deficits. This is, of course, a simplified model of wake overlap – but it gives reasonable approximation when it comes to e.g. power outputs of a turbine under multiple wakes. We didn't see such approaches in other wake detection/characterisation studies, which is why we believe it is reasonable to include this information in our statement of research gap. To satisfy your comment, we have decided the modify the text as follows:

- Statement of research gap, the fixed wake shedding distance is now strongly mentioned (line 70, manuscript C): "The up-to-date wake detection studies analysed the wake impingement in a scenario with a single upwind turbine at a fixed distance, for a fixed set of wind directions."
- Contribution to the research gap, we specify that our key contribution is testing the wake estimation under various shedding distances (line 84, manuscript C): "The trained models are tested under a full range of wind directions within a virtual offshore wind farm, evaluating the method's performance for wakes shed at various upstream distances."
- Discussion on the effect of wake superposition to wake detection performance, we now explicitly mention how the wake deficits are combined – and this is the primary aspect why we don't see the effect of superposition (line 436, manuscript C): "This is likely a consequence of the wake superposition approach used, where wind speed at each YZ grid point on the receiving turbine is derived based on the strongest influencing wake deficit."

4. Regarding comment 19 from the first review round: By 'overlap margins' I mean the definition of 'full' or 'partial' wake. E.g. a wake position y<0.25 D with respect to the wake exposed turbine might be denoted full wake, a position 0.25D < y < … denoted partial wake. I think your answer partly addresses this point already but I cannot see it in the manuscript. If it's not possible for you to state this, since the training data only considers inflow angles, please mention this in the manuscript. At the moment it says "The wind direction differs by 5 degrees between the fully and partially impinged cases. This setup allows to clearly differentiate between the effects of full/partial wake impingement and standalone atmospheric turbulence." The confusion chart is a good idea and helped here!

Thank you for clarification. In our work, we have made the distinction between full and partial wake simply by changing the inflow angle. The wake (as seen in the front-view YZ snapshots) differs between these setups, which provides the basis for three specific partial impingement classes that we then use in the CNN-powered image recognition. The overlap margins that you mention seems like a good and robust idea, and in future we might try the wake detection this way. It is worth noting, that even using our simple class definition, the wake detector is able to switch between full and partial impingement reasonably well (referring to the probabilities that the CNN outputs, Figures 14-17 in manuscript B/C). We have modified the entire section 2.4 (titled Framework implementation: wake detection) to address your comment and make the labelling process more clear.

5. Nice that you added explanation to the unexpected performance at 5 m/s and the role of training data here.

Thank you, we are happy to hear you liked that aspect.