Author comments in reply to anonymous referee #1

We thank the anonymous referee #1 for their positive feedback on our revised manuscript. We very much appreciate the time invested in reviewing our work. We thank the referee for their critical and thorough review. We have addressed each of the referee comments as detailed point by point below, which we believe further improves the quality of the manuscript. For brevity, only the major comments on written English are shown here.

We hope our revised manuscript can be accepted for publication.

Adithya Vemuri, on behalf of all co-authors

Overall comments

I think that there was little consistency across these three case studies for which parameterizations tended to perform better or worse is itself still interesting, and points to the need for more robust statistics with (much) larger sample sizes to make more general conclusions with confidence about a "best configuration" for accurately modeling the wind speed and wind direction at offshore wind farms in that region, or whether the "best configuration" will change based on the weather regime. I would like to see the authors state that caveat more clearly, especially in the Conclusion.

We thank the referees this feedback, we have added the following lines to emphasize the caveats of the study.

Line 437: The results indicate little consistency across the three EWEs for different parameterizations.

Line 443: Overall, the inconsistency across different EWEs found in the current work suggests that a general best model configuration for the Belgian North Sea does not exist, and that best practices are highly dependent on the weather regime under consideration. However, it is important to note that this conclusion is based on a limited sample of EWEs over a single observation point at the offshore wind farm. To further justify and generalize this conclusion, a much larger sample considering more weather events, more observations, and more model configurations is warranted.

Minor comments

Comment 1 & 2: *1. Uncapitalize terms that are abbreviated if they are common nouns (e.g., extreme weather events, numerical weather prediction, planetary boundary layer, lateral boundary conditions, mean absolute error, etc.), but retain capitalization only for proper nouns (e.g., normalized Euclidean distance).*

2. When defining an abbreviation, the term that is abbreviated should be singular. For instance, EWE should stand for extreme weather event. If there are multiple extreme weather events, then use EWEs. The same principle applies to LBC: LBC should mean lateral boundary condition, while LBCs should mean lateral boundary conditions. Once this change is made, ensure that all subsequent mentions of the abbreviation correctly refer to the singular (EWE, LBC) or plural (EWEs, LBCs) usage.

We thank the referee for pointing this out. Common nouns in the revised manuscript are no longer capitalized. All abbreviations in the manuscript are changed to their singular forms, e.g., extreme weather events (EWEs).

Comment 3: *3. Generally speaking, single-digit numbers should be spelled out. For instance, "3 PBL parameterizations" should be "three PBL parameterizations" (line 59), "5 classes" should be "five classes" (line 94), and "1-way nested" should be "one-way nested" (line 177). There are exceptions to this general rule, of course (especially when pertaining to things like measured values, time, etc.), but there are quite a few more cases like the three I mentioned that should be corrected.*

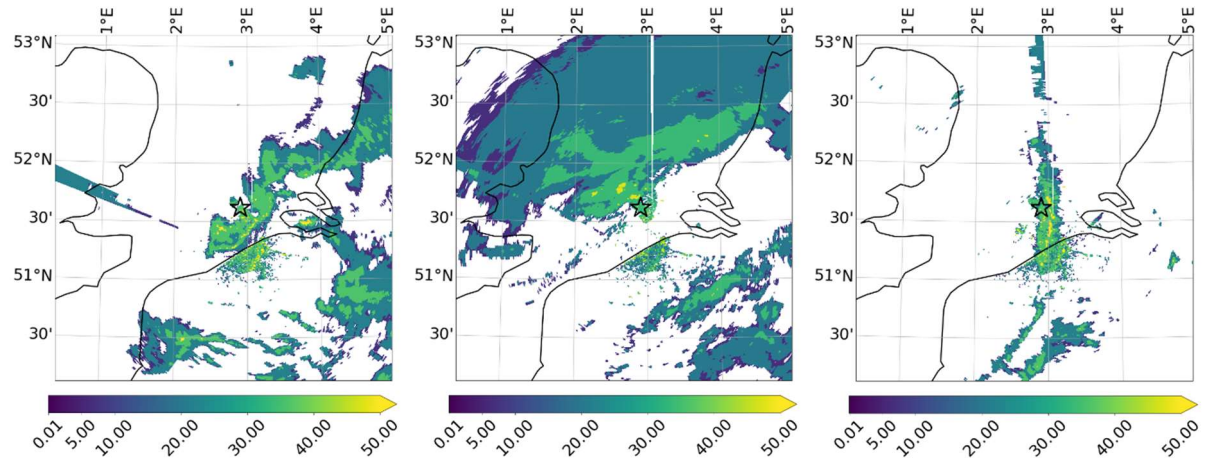
We thank the referee for this comment. We have changed the single-digit numbers to their spelled-out forms throughout the manuscript. This is not further shown here.

Comment 4 to 10: *4. Lines 42, 221: Delete the "see" before "e.g.". The "see" is already implied.*
5. Lines 48, 49, 53: Add "the" before "PBL".
6. Lines 73–74: "by translating it into compensating subsidence, a combination of vertical advection, moisture, and temperature." — This is awkwardly worded and needs to be revised.
7. Line 89: Change "vertical" to "the 3D".
8. Line 138: Change "therein" to "herein".
9. Line 142: Change "Storm Ciara is" to "Storm Ciara was".
10. Line 150: Change "British isles" to "British Isles" (capitalize Isles, as the term as a whole is a proper noun).

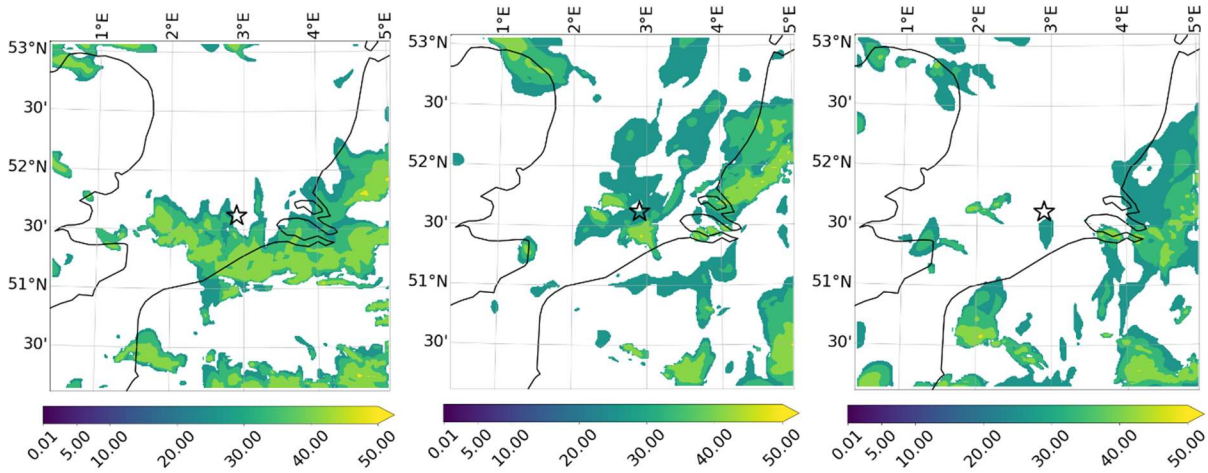
We thank the referee for pointing out the mistakes and missing articles, these have been corrected to the suggested. This is not further shown here.

Comment 11: *Figs. 1 and 19: These maps are much improved in this revision. That said, I suggest (but do not require) additional revisions to these plots, specifically the contour intervals. Specifically, I think the upper limit of the range should be something more appropriate to the data (even 10 mm/h barely appears on the filled contour maps, so why is 100 mm/h the upper limit?). I would suggest something like [0.01, 0.10, 0.50, 1.00, 5.00, 10.00, 20.00, 30.00), or whatever set of contour intervals would be helpful to capture the meaningful variations in the data better. This is not a critical fix, but is a principle that can be applied to all sorts of figures; you do not have to stick with uniformly spaced contour intervals, whether in linear or exponential space, if that is not the most meaningful way to display the field. Also, is the star filled white, and thus blocking any view of precipitation behind it, or is it transparent/not filled? Ensuring the star is transparent/not filled white would be a small but important fix.*

We thank the referee for their positive feedback on our revised figures. Thank you for further suggestions. The colors in the figures were plotted using LogNorm in matplotlib with limits, 1e-2 to 100, we have changed this to, 1e-2 to 50 for better readability. The star in the plots has been made transparent as well. The updated the are shown below:



Caption: Figure 1. Observed precipitation rate in mm h−1 provided by a C-band Doppler radar located in Jabbeke on the Belgian coast. The star in the plots represents the offshore wind farm of interest. For the meteorological events: (a) Storm Ciara on 10 February 2020 at 04:40 UTC. (b) Low-pressure system on 24 December 2020 at 02:00 UTC. (c) Trough passage on 27 June 2020 at 15:30 UTC.



Caption: Figure 19. Contours of WRF precipitation rate in mm h^{-1} for the case of Storm Ciara on 10 February 2020 at 04:40 UTC. The plots are presented for cumulus simulation pair H for domain d04. The star in the plots represents the offshore wind farm of interest. (a) Simulation run 9: 1h SH msKF Morrison, on 10 February 2020 at 04:40 UTC (b) Simulation run 10: 1h SH GD-3D Morrison, on 10 February 2020 at 04:40 UTC (c) Simulation run 11: 1h SH GF Morrison, on 10 February 2020 at 04:40 UTC.

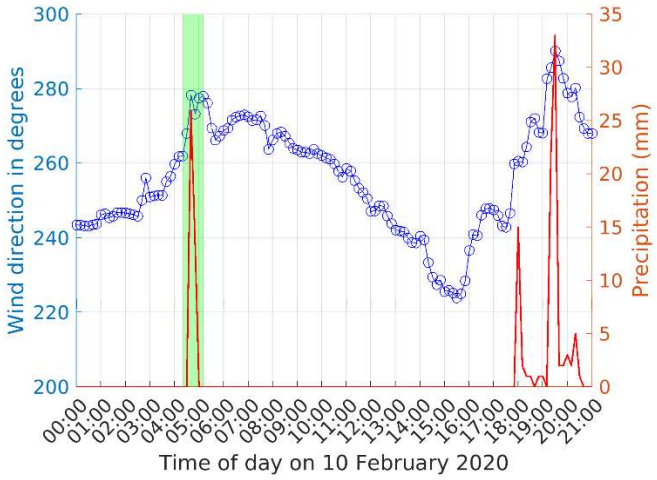
Comment 12: *Line 157: Note that the low in Fig 2b is centered over the English Channel and Normandy, not over the North Sea.*

This has been corrected in the revised manuscript.

Line 157: Fig. 2b indicate the presence of a low-pressure system over the English Channel and Normandy.

Comment 13: *13. Fig. 3: Because you made the right axis red to match the line color, you should do the same for the left axis and data series (either make both blue or both black). Also, the green dotted lines are tough to see. Maybe shade that strip green instead? Or make the linewidths thicker.*

Thank you for pointing out the mismatch and low visibility of green lines. We have chosen to keep SCADA data as blue to be consistent throughout the manuscript. The replotted Fig.13 is shown below:



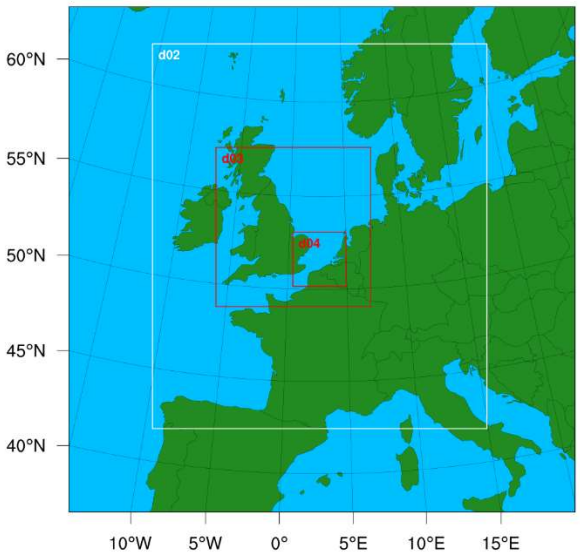
Comment 14: *14. Lines 178–179: Change "terrain following pressure levels" to "terrain-following model levels".*

The following changes were made:

Line 179: In the vertical direction, 57 terrain-following model levels are considered …

Comment 15: *15. Fig. 4: Delete "and WRF Post-processing System (WPS)", as it is unnecessary (it is also the WRF Pre-processing System, anyway). You can either crop the title out of the figure to avoid needing to define WPS here, or you can modify the title in the plotgrids NCL script to something like, "WRF Domain Configuration".*

We have chosen to crop the picture, the updated Fig. 4 and caption as shown below:



Caption: Figure 4. WRF nested domain configuration (one-way nesting) considered common to all simulation runs in this study.

Comment 16: *16. Table 1. In the row for horizontal grid spacing, use commas instead of x symbols to separate the values of the different domains, as you already did for the time steps a few lines below.*

The table has been updated to with commas instead of x, not further shown here.

Comment 17: *17. Line 194: Singular-plural agreement: It should either be "a combination…is considered" or "combinations…are considered".*

Thank you pointing out the mistake, the sentence has been corrected to:

Line 194: … WRF physics parameterizations and options available, a combination of different simulation pairs as described in Table 2 is considered.

Comment 18: *18. Line 195: Change "variations of update interval of LBC, PBL, cumulus, and microphysics schemes" to "variations of the update interval of the LBCs, and the PBL, cumulus, and microphysics schemes".*

Thank you pointing out the missing articles, the sentences have been changed to the referee suggestion. This is not further shown here.

Comment 19: *19. Lines 212–213: "NED is defined as the resultant of…" — Resultant has a reserved meaning in mathematics, and the right-hand-side of the definition of NED is not a resultant. It is the square root of the sum of squares—maybe there is a fancy mathematical term for that?*

We have refrained from using the term 'resultant' in the revised manuscript, and simply define NED through the equation as

Line 211: To recover a single performance metric, a so-called normalized Euclidean distance (NED) is defined by $NED = \sqrt{MAE_{WDn} + MAE_{WS}}$, with MAE_{WDn} the normalized MAE of wind direction, and MAE_{WSn} the normalized MAE of horizontal wind speed.

Comment 20: *20. Sec. 4.3: It would also be interesting to note that Run 2, while the best member for Case 2, was the worst member for Case 3. Different weather situations lead to different skill for various schemes. And here MYNN PBL was not that bad (or at least not as consistently poor as in other cases).*

Thank you for the suggestions, we have included this in the revised manuscript. The following lines were added:

Line 264: Interestingly, the best-case setup for the low-pressure system case performed the worst for the trough passage case.

Comment 21: *21. Line 272: Change "Errorbars" to "Error bars".*

Thank you pointing out the mistake, we have corrected this in the revised manuscript. This is not further shown here.

Comment 22: *22. Line 276 and elsewhere: Change "observations" to "results" (or similar). You frequently use "observations" or "is observed" in this manuscript to describe what you noticed in a figure or table, but that is confusing when "observations" elsewhere refers to measurements used as truth for validation. You should generally find other words than "observations" or "is observed" when describing the results or conclusions you saw or determined from figures, tables, etc.*

Thank you pointing this out, we have updated the revised manuscript in places where we could change the words observation/observed to more appropriate ones. For brevity, this is not further shown here.

Comment 23: *23. Line 360: Change "schemes" to "scheme".*

Thank you pointing out the mistake, we have corrected this in the revised manuscript. This is not further shown here.

Comment 24: *24. Line 367: Change "highlighting" to "highlight". I will also add that the other thing that this finding highlights is the case-to-case variability in skill.*

Thank you for pointing out the mistake and the note, we have included this in the revised manuscript. The following lines were added:

Line 369: This appears to highlight case-to-case variability in skill and the importance of the combination of cumulus and microphysics schemes.

Comment 25 to 29: *25. Line 372: Change "better in comparison" to "better by comparison".*
26. Line 380: Change "3 unique case studies" to "three EWE case studies".
27. Line 396: Hyphenate "lower-order".
28. Line 405: Add a comma after "(Newman et al., 2022)".
29. Line 406: Change "latter raw data" to "raw radar observation data".

We thank the referee for pointing out the mistakes and missing articles, these have been corrected to the suggested. This is not further shown here.

Comment 30: *30. Line 420: "In addition, the simulated precipitation is qualitatively compared to radar data from RMI-B." — Precious little qualitative analysis in precipitation rate was performed here. You simply included Figs. 1 and 19, and stated that precipitation in WRF varied by physics configuration, but*

you did not describe any qualitative analysis. Either some text should be added in the Discussion (or elsewhere) that better describes your qualitative analysis, or you should remove this part.

We have rephrased this sentence in the revised manuscript to:

Line 423: Qualitatively, precipitation results are found to be highly sensitive to model setup and type of EWE. No clear tendency towards better accuracy with increased complexity of parameterizations is found.

Comment 31 to 32: *31. Line 421: Change "impact of update interval of LBC" to "impact of the update interval of the LBCs". Also change "used for PBL" to "used for the PBL".*
32. Lines 433–434: Change "combine scale-aware" to "combine the scale-aware". Change "with scale-aware" to "with the scale-aware". Change "and 5-class single moment" to "and the five-class single-moment".

We thank the referee for pointing out the mistakes and missing articles, these have been corrected to the suggested. This is not further shown here.

Author comments in reply to anonymous referee #2

We thank anonymous referee #2 for their positive feedback on our revised manuscript and their useful comments on the same. We very much appreciate the time invested on a thorough review of our work. We have addressed each of the referee comments as detailed point by point below, which we believe address all of the reviewer comments. For brevity, comments on technical English are not shown here but will be indicated in the mark-up.

We hope our revised manuscript can be accepted for publication.

(Throughout this document, specific modifications to the revised manuscript are shown in blue)

Adithya Vemuri, on behalf of all co-authors

Specific comments

Language corrections:

Comment 2: *l. 267: "underpredict wind direction" → I am not sure what "underpredict" means in the context of the circular wind direction variable. I would suggest using something like cardinal directions (e.g. southwards shift or something like that) or terms like counter-clockwise shift to indicate the direction of the bias in wind direction.*

We have rephrased the statement to better point out the intended message.

Line 268: Qualitatively, simulation runs 1 through 11 underpredict the fast changes in wind direction for the evaluation period, whereas wind speeds are underpredicted by all runs.

Tables:

Comment 6: *Table 1: I think "physics parameters" is a bit misleading, since it is not single parameters but whole schemes/parameterisations that are changed as well. I would suggest something like "model settings and physics parameterizations".*

The caption for Table 1 has been updated to:
WRF model setup and common parameters for all simulation runs. The varied model settings and physics parameterizations are highlighted in italics. Scale-aware physics parameterizations are underlined.

Figures:

Comment 7: *Figure 5, 6, 7: The gray lines of the individual ensemble members are very difficult to see and can be easily confused with the grid lines of the plot. I would suggest to make them a bit thicker or in a color of higher contrast.*

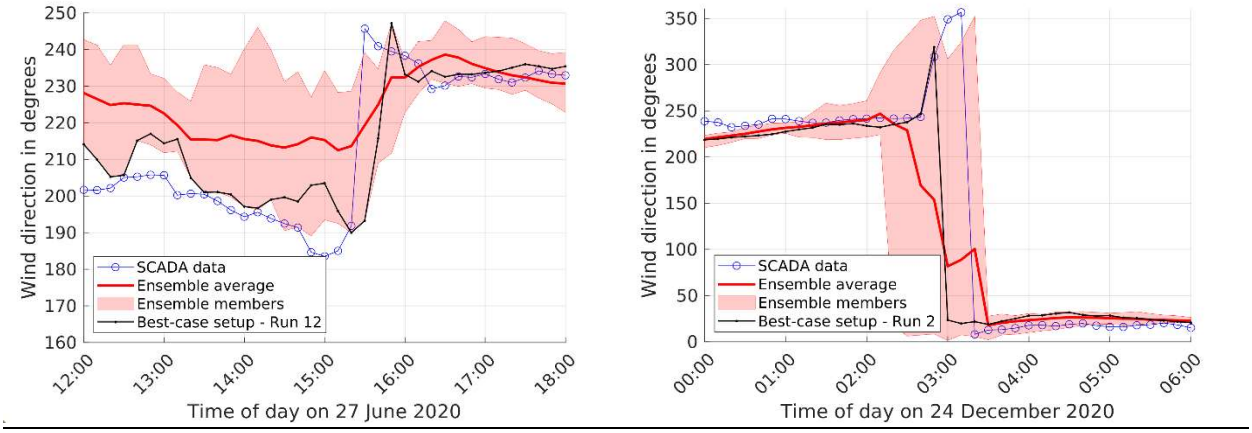
Thank you for the suggestion, we agree that the individual gray lines are difficult to see. However, making the individual ensemble members thicker resulted in a very disorderly figure. As a compromise, we have updated the plots to include the min-max envelope of the ensemble members, as indicated by the examples shown below.

Comment 8: *Figure 6, 7, 13: It is very unusual within the wind energy community to represent wind direction in negative degrees (also since Figure 5 seems to use the 0 to 360 deg convention). Consider adapting to the 0 to 360 deg wind direction convention in the plots for consistency and readability.*

Thank you for the suggestion, we have updated the plots to in a better manner, as indicated by the examples shown below.

Comment 9: *Figure 5,6,7,13: While it is indirectly implied what the x-axis values mean, it would greatly improve readability and minimize confusion if a x label similar to Fig. 3 could be added.*

Thank you for the suggestion, we have updated the plots to in a better manner, as indicated by the examples shown below.



Comment 10: *Figure 7: Caption text ("best-case setup simulation run 2") and figure label do not match (Best-case run 12). Please correct.*

Thank you for pointing out the mistake, we have corrected the figure caption (shown here, an example for trough passage case):

Figure 7. Timeseries plots wind direction and wind speed plotted along with the ensemble average and best-case setup simulation run 12 for the case of trough passage. The minimum and maximum envelope of ensemble members is highlighted in light red. (a) Wind direction. (b) Wind speed.

Comment 11: *Figure 8,9,10,11,12: While it was mentioned in the float text, I think it would be good to add also in the figure caption how the error bars are defined.*

Thank you for the suggestion, we have updated the captions of these figures to include the definition of error bars. For brevity, caption for Figure 8:

Figure 8. Performance evaluation for simulation pair A considering change in update interval of LBCs, as described in Table 2. Error bars indicate one standard error of the sample mean. (a) MAE comparison for wind direction. (b) MAE comparison for wind speed.