Comments from the reviewer are shown in black and our modifications are given in blue.

We express thanks to the reviewer for their thoughtful comments as we note in the acknowledgements.

Reviewer comments on ”Hurricane impacts in the United States East Coast offshore wind energy lease areas”
April 4, 2025

1 General comments

The manuscript ”Hurricane impacts in the United States East Coast offshore wind energy lease areas” by Thompson et al. presents simulations of two hurricane cases along the U.S. East Coast. Four model configurations are analyzed for each hurricane case, including atmosphere-only WRF simulations and atmosphere-wave-ocean coupled COAWST simulations. In addition, the effects of wind turbines on the hurricanes are analyzed using simulations with and without wind farm parameterizations.
The manuscript contains novel aspects such as 1.) the use of buoys and IMERG data to validate tropical cyclone simulations, 2.) the presented analysis of the atmosphere-ocean-wave-coupled modeling framework applied to tropical cyclone cases including wind turbine effects. The manuscript addresses three clearly stated research questions that are relevant to the wind energy sector and of broad international interest. The methods are well described and the analysis is valid. The title and abstract give a good summary of the manuscript, the manuscript is well written and overall well structured.
Many thanks for your positive comments and assessment.

The manuscript uses eleven rather long tables, and not all of them may be needed in the main article. Many figures show panels for both WRF and COAWST simulations, although in some cases the difference between the two is not easy to see (see specific suggestions in the Specific Comments section). At the same time, some figures contain a lot of information while being rather small.
We fully accept that the manuscript as submitted contained an atypically large number of tables (6) in addition to the 10 figures.
We provide details of our changes to Figures below. With respect to Tables:

1) Moved Table 1 to Supplemental Materials (Table S1)
2) Moved Table 2 to Supplemental Materials (Table S2)
3) Integrated Table 4 into the text. Thus, the text at the start of Section 2.2 changed from: “In this research, both WRF (v4.2.2) and COAWST (v3.7 and MCT v2.6.0) simulations use two domains (Fig. 2a) and the coupling interval in COAWST is 10 min (Fig. 2b). The source of boundary and initial conditions and key physics options (Tables 3 and 4) are informed by previous simulations of Hurricanes Sandy (Zambon et al., 2014b) and Irene (Mooney et al., 2016). The MYNN2 planetary boundary layer scheme is used due to the compatibility with the Fitch windfarm parameterization (WFP) (Fitch et al., 2012) that is

used here to compute power production, momentum extraction, and turbulent kinetic energy (TKE) induced by the action of wind turbines."

To:
"In this research, both WRF (v4.2.2) and COAWST (v3.7 and MCT v2.6.0) simulations use two domains (Fig. 2a) and the coupling interval in COAWST is 10 min. At this coupling interval, a number of variables that are critical to air-sea coupling and lower atmosphere structure and/or WT design standards are exchanged between the model components (Fig. 2b, Fig. S3, and Table S2). The selection of these variables is based on previous research (Warner et al., 2010; Zambon et al., 2014b) and include sea surface temperature (SST) that is passed from ROMS to WRF, 10 m u- and v-wind components which are passed from WRF to SWAN, plus Hs and Tp (period of peak energy in the wave spectrum) that are passed from SWAN to WRF and ROMS. The source of boundary and initial conditions (Table 1) and key physics options are informed by previous simulations of Hurricanes Sandy (Zambon et al., 2014a) and Irene (Mooney et al., 2016). Physics settings include the WRF single-moment 6-class (WSM6; (Hong and Lim, 2006)) microphysics scheme, the Rapid Radiative Transfer Model (RRTM; (Mlawer et al., 1997)) for longwave radiation, the Dudhia scheme (MM5; (Dudhia, 1989)) for shortwave radiation, and the Unified Noah land surface model (Chen and Dudhia, 2001b, a; Ek et al., 2003; Tewari et al., 2004). The Kain-Fritsch (Kain, 2004) cumulus parameterization is used in the outer domain and no cumulus parameterization is used in the inner domain. The Mellor-Yamada Nakanishi and Niino Level 2.5 (MYNN2; (Nakanishi and Niino, 2006)) planetary boundary layer scheme is used due to the compatibility with the Fitch windfarm parameterization (WFP; (Fitch et al., 2012)) that is used here in both domains to compute power production, momentum extraction, and turbulent kinetic energy (TKE) induced by the action of WTs."

2 Specific comments

1. Introduction: Lines 34-40: You might consider extending this argument for tropical cyclone events, and include that tropical cyclones may not be adequately covered by available offshore measurements.

   Yes, quite. We have modified the text to read:
   "The offshore environment presents significant challenges for making long-term, climatologically representative robust measurements of properties such as wind speed at WT hub-height (HH WS) (Foody et al., 2024) that are critical for determining the wind resource and key aspects of operating conditions (IEC, 2019b, a; Mudd and Vickery, 2024). The relative paucity of measurements leads to financial uncertainty and thus potentially jeopardizes realizing national goals for achieving the energy transition (Hansen et al., 2024). It also means that numerical modeling is playing a critical role in projecting wind resource and operating conditions in offshore wind energy development areas (Kresning et al., 2020; Pryor and Barthelmie, 2021; Bodini et al., 2024; Pryor and Barthelmie, 2024a; Wang et al., 2024). Limited over-ocean observations also limit our ability to characterize the characteristics of high intensity hurricanes, including those of

relevance to the wind energy industry, particularly in environments such as the U.S. East Coast which has the potential to be impacted by tropical cyclones and/or transitioning tropical-extratropical cyclones (Xie et al., 2005; Baldini et al., 2016; Barthelmie et al., 2021; Wang et al., 2024) but experiences only relatively few such storms each century (Schreck III et al., 2021)."

2. Line 184: Note that the effective model resolution using WRF is about 7 times the grid spacing Skamarock (2004).

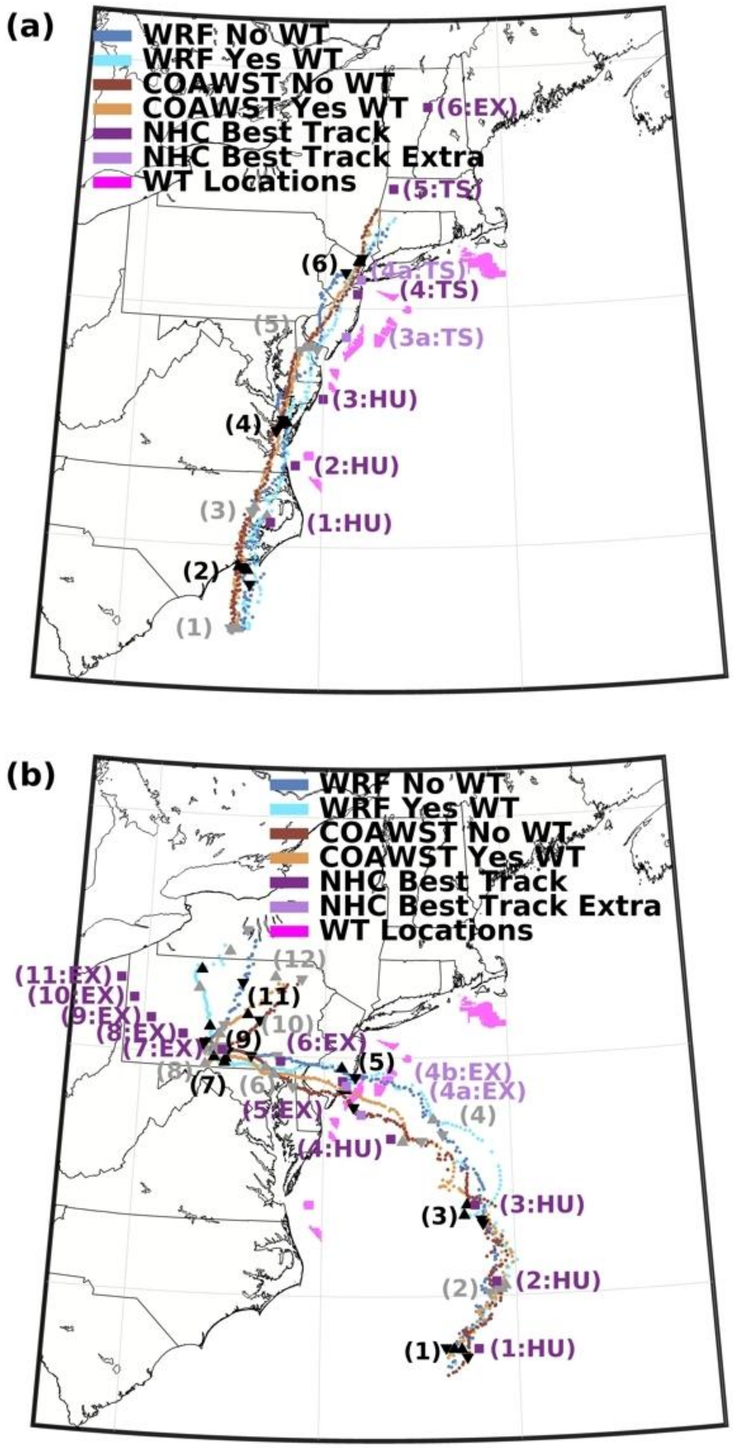
   Agreed. We have changed this sentence:
   "Note the wind speeds output from d02 are for a nominal model time step of 2 s but are representative of a spatial average of 1.33 km by 1.33 km, while the design standards are for a sustained wind speed at a point (Larsén and Ott, 2022).

   To read:
   "Note it is not an expectation that spatially averaged model output will perfectly match time-averaged point observations and further, the design standards are articulated for a sustained WS at a point (Larsén and Ott, 2022). The WSs presented here are output from d02, represent a nominal model time step of 2 s, and are from a grid cell with an area of 1.33 km by 1.33 km, but the effective model resolution is ~ 7 times the grid spacing (Skamarock, 2004) thus any spatial gradients will be under-estimated."

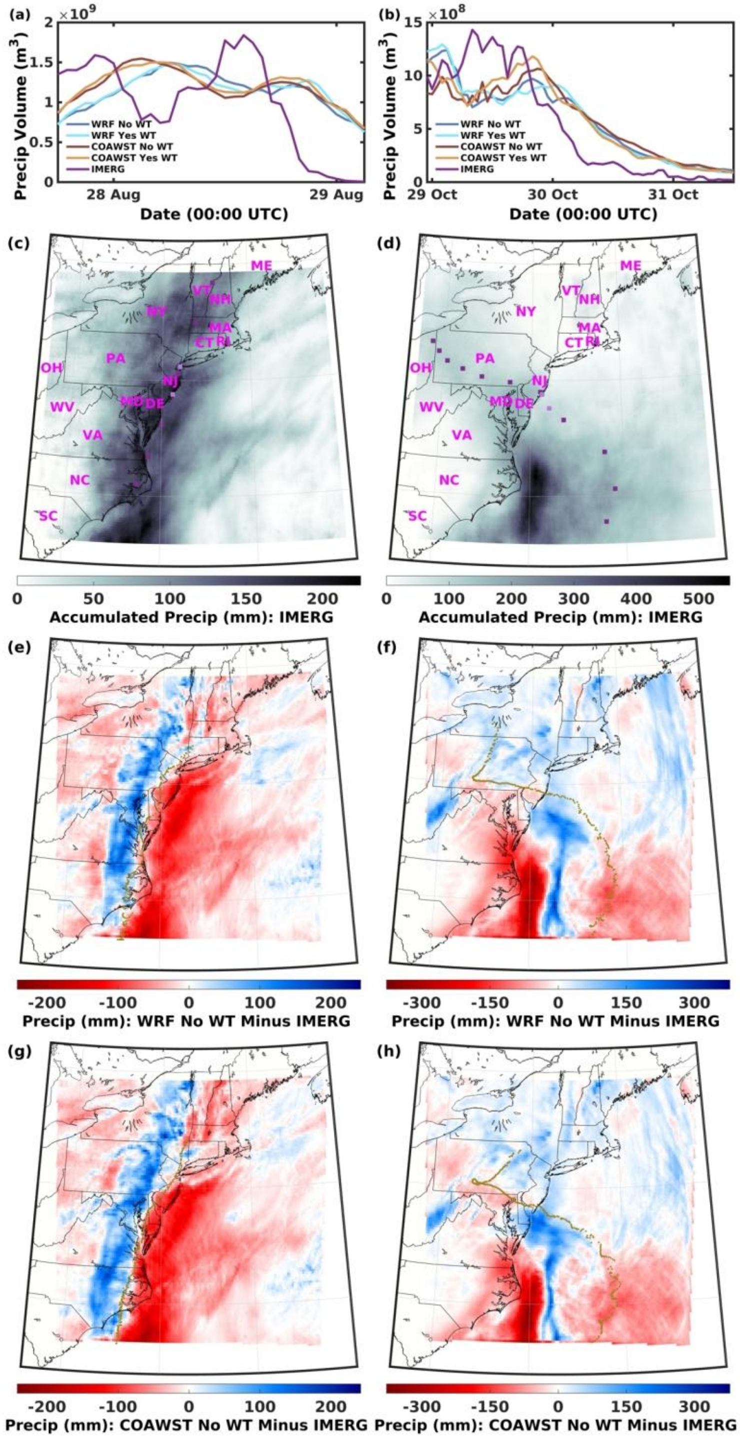
3. Figure 1a,b): I think it would be helpful to the reader to show these two panels larger in the main article. This would help to better see the agreement between the observed and simulated track, and you could also consider not showing Table 1. The precipitation time series is also shown in Fig. 10, I think one of the two figures should be sufficient.

   The hurricane tracks in panels (a) and (b) from Figure 1 have become a separate figure (new Figure 1) and the other figure panels are now their own figure (new Figure 3, see below). Table 1 is now located in the Supplemental Materials (Table S1) and key information from that table is now included in the Figure 1 caption (see below).

   Figure 10 and Figure 1 show slightly different time series. Figure 10 shows the 10-min precipitation volume within a 375 km radius of the minimum SLP and Figure 1 (now Figure 3) shows the 1-h precipitation volume within a 375 km radius of the minimum SLP.



Modified Figure 1



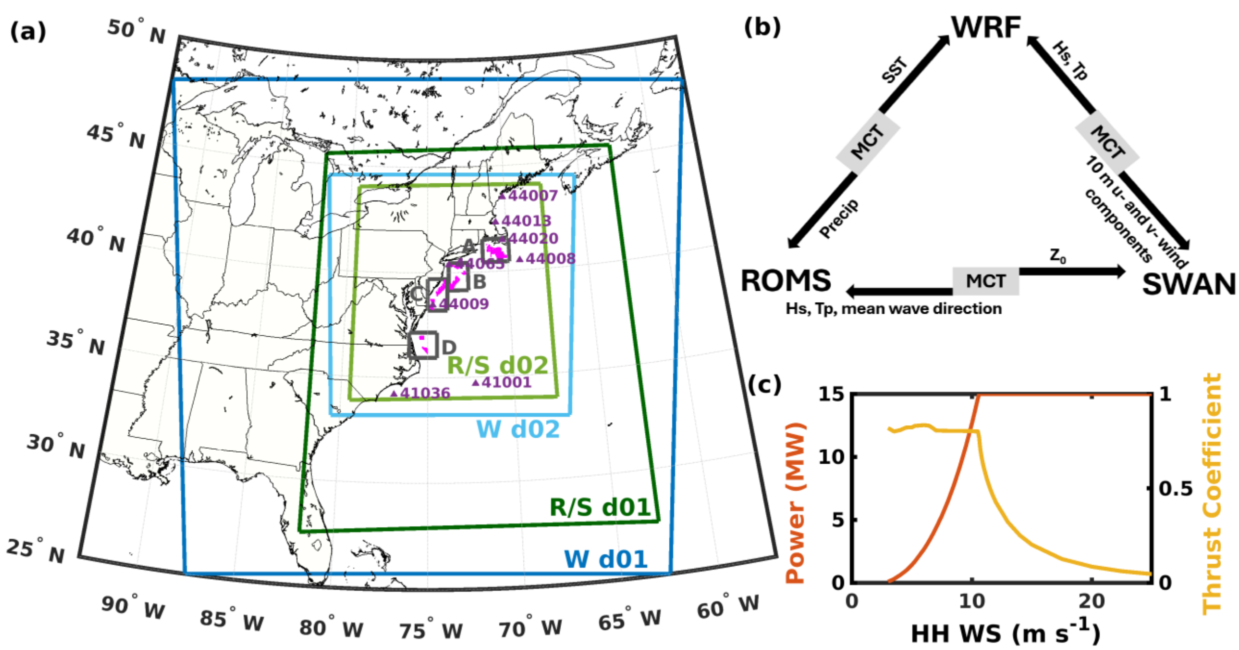
Modified Figure 3

4. Fig. 2b and Table 2), the scheme of COAWST is not further explained in the text. So I would suggest not to show Fig. 1 b and Table 2b in the main article, but to give them in the supplement.

We apologize – the text we provided was too brief. The first paragraph of Section 2.2 that began:
"The source of initial and lateral boundary conditions (Khaira and Astitha, 2023) and specific model configurations employed within WRF and COAWST (including the coupling system) have a critical impact on simulated flow conditions (Mooney et al., 2019). In this research, both WRF (v4.2.2) and COAWST (v3.7 and MCT v2.6.0) simulations use two domains (Fig. 2a) and the coupling interval in COAWST is 10 min (Fig. 2b)."

is now expanded to include this further sentence:
"At this coupling interval, a number of variables that are critical to air-sea coupling and lower atmosphere structure and/or WT design standards are exchanged between the model components (Fig. 2b, Fig. S3, and Table S2). The selection of these variables is based on previous research (Warner et al., 2010; Zambon et al., 2014b) and include sea surface temperature (SST) that is passed from ROMS to WRF, 10 m u- and v-wind components which are passed from WRF to SWAN, plus Hs and Tp (period or peak energy in the wave spectrum) that are passed from SWAN to WRF and ROMS."

Panel (b) from what was Figure 2 has become Figure S3 and Table 2 has become Table S2. A new panel (b) has been included with only variables discussed in the main text and is shown below.



Modified Figure 2

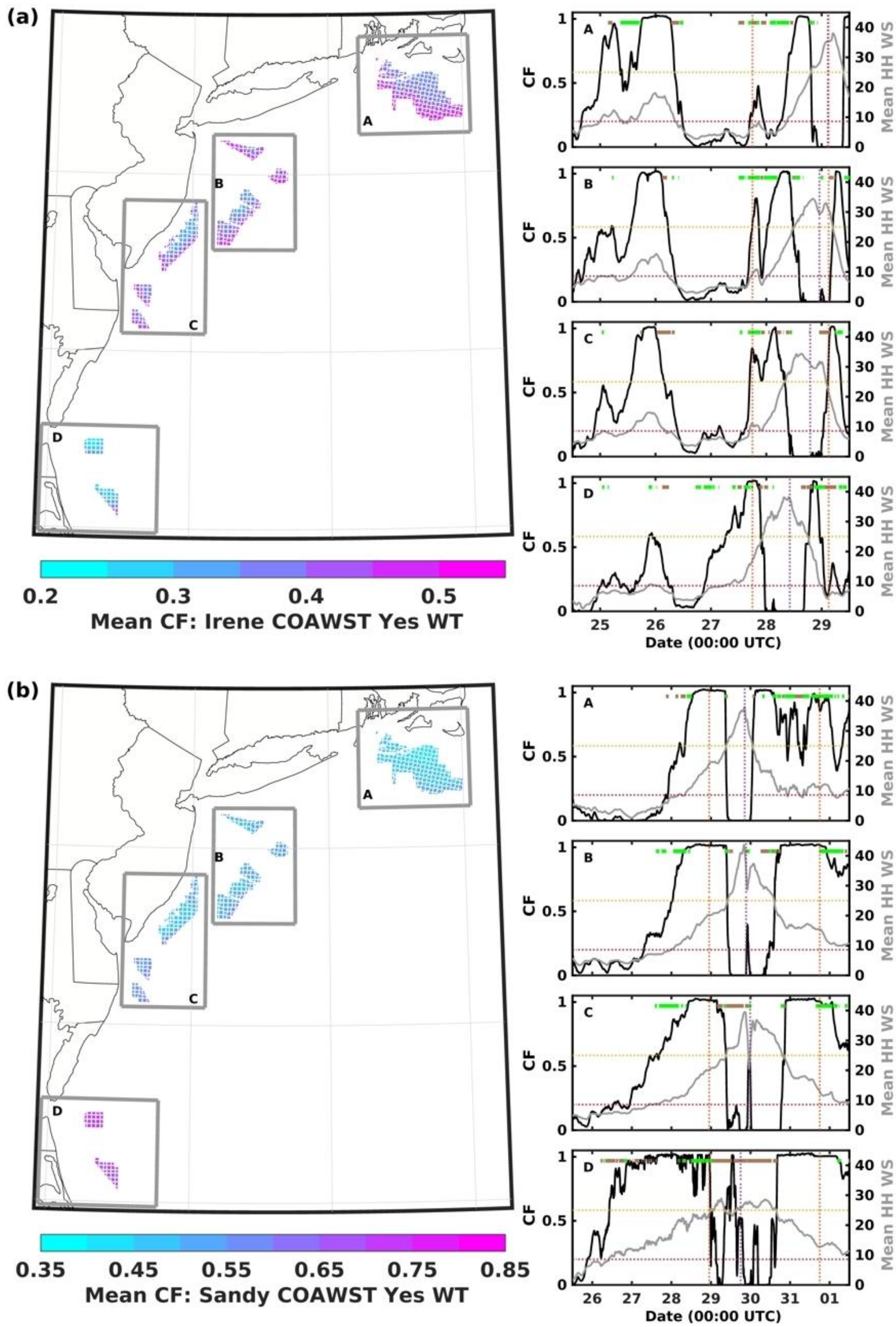
5. line 255: Could you explain what 3 × 3 smoothing means?

   This sentence:
   "Hurricane centroid locations are computed every 10 minutes as the minimum SLP after 3x3 smoothing is applied to the model output and are used for comparison with the NHC best track information."

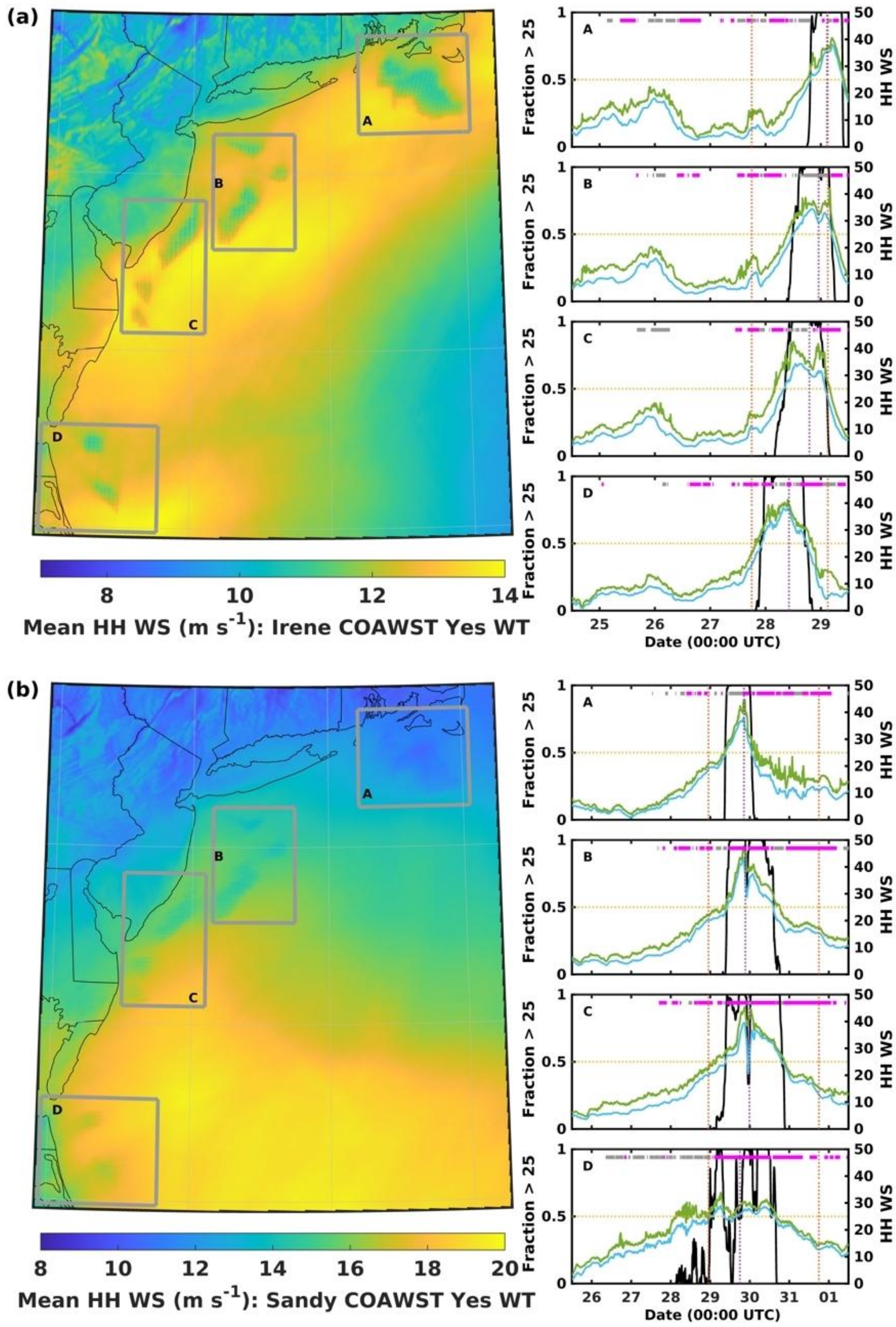
   has been modified to read:
   "Hurricane centroid locations are computed every 10 min as the minimum SLP after 3×3 smoothing is applied to the model output (a mean value of SLP is computed for each grid cell based on output for that grid cell and the eight adjacent grid cells) and compared with the NHC best track information."

6. Figures 1, 3, 6, 7: The difference between the WRF and COAWST simulations is not easy to see in these figures. While the difference between the two is discussed to some extent in the text, one could consider not showing both panels in all cases, or showing the difference between the two. For Figures 6 and 7, you might consider showing the map and wind field for either the COAWST or WRF simulation only, while showing the time series for both in the same plot.

   Please see (3) above for changes to Figure 1. With Figures 3, 6, and 7 (now Figures 4, 7, and 8), the COAWST panels remain in the main text; all four (WRF and COAWST) panels are included in the Supplemental Materials (Figures S4, S12, and S13). With Figure 7, the time series plots now mark when the WRF CF exceeds the corresponding COAWST CF by > 0.05 in brown and when the COAWST CF exceeds the corresponding WRF CF by > 0.05 in green. With Figure 8, the time series plots now mark when the WRF HH WS exceeds the corresponding COAWST HH WS by > 0.5 m s^{-1} in gray and when the COAWST HH WS exceeds the corresponding WRF HH WS by > 0.5 m s^{-1} in magenta.



Modified Figure 7



Modified Figure 8

7. Figures 8, 9: It is difficult to read the Tp, HH WS, and Hs from the 3-D bubble plots. Can you consider a different visualization; this could be adding the Tp via contours or colors in the plots (e-h), or showing a separate joint probability of HH WS and Tp.

   3D plots are indeed inherently tricky. We did evaluate a range of different options before selecting bubble plots and frankly found the bubble plots to be the best option given; Tp is categorial (integer seconds) and contouring in 3D space is hard particularly when the data are highly "concentrated" – e.g., panel b and noting we wanted to preserve information regarding the co-occurrence of the three variables.

3 Technical corrections

1. Line 21: The abbreviation HH WS is used only once in the abstract. Therefore, I would recommend not introducing it.

   With apologies for our error, the abbreviation HH WS has been removed from the abstract.

2. Line 28: The abbreviation IC is used only once in the abstract. I would recommend introducing abbreviations only if they are used more than once.

   Thank you for pointing this out, we have corrected this.

3. Line 135: Personally, I have never come across the term "storyline simulations" and would prefer to use "case study" instead.

   "Storyline simulations" as a concept has evolved in the climate science community (see discussion in Doblas-Reyes, F. J., and Coauthors, 2021: Linking global to regional climate change. Climate Change 2021: The Physical Science Basis, V. Masson-Delmotte et al., Eds., Cambridge University Press, 1363–1512.). In brief, the difference between a case study and a storyline is that a case study is purely a geophysical event while a storyline inherently is a geophysical event that is "impact" or decision maker relevant. For this reason, we prefer the term storyline since we are explicitly considering these hurricanes in the context of risk to the renewable energy sector.

4. Section 2.1: You could refer to Fig. 1a and b when describing the hurricanes.

   Section 2.1, "Characteristics of the hurricanes considered herein", is a good location to refer to panels (a) and (b) of Figure 1 (which are now a separate figure – as noted in the third comment in the previous section) – this has been added.

Section 2.1 now reads:
"Research presented herein focuses on two recent hurricanes:

1) Hurricane Irene became a category 3 hurricane, with 54 m s^{-1} WSs at 10 m height in the Bahamas on 24 August 2011 12:00 UTC (Avila and Cangialosi, 2011). It made landfall at Cape Lookout, North Carolina on 27 August 12:00 UTC with 39 m s^{-1} 10 m WSs. After moving out over the water, it again made landfall, this time as a tropical storm, with 31 m s^{-1} WSs reported at Brigantine, New Jersey on 28 August 2011 09:35 UTC (Fig. 1a). The cyclone then moved over Coney Island, New York with 28 m s^{-1} WSs reported at 13:00 UTC. Simulations presented herein are initialized on 24 August 2011 12:00 UTC and run through 29 August 2011 12:00 UTC.

2) Hurricane Sandy became a category 3 hurricane, with 51 m s^{-1} WSs at 10 m height in eastern Cuba on 25 October 2012 05:25 UTC (Blake et al., 2013; Lackmann, 2015). It grew to have a roughly 1611 km diameter of tropical-storm-force WSs, before making landfall near Brigantine, New Jersey as a post-tropical cyclone with 36 m s^{-1} 10 m WSs and a minimum pressure of 945 hPa on 29 October 2012 23:30 UTC (Fig. 1b). Simulations presented herein run from 25 October 2012 12:00 UTC through 1 November 2012 12:00 UTC."

5. For the date format, e.g. in Table 1 and others, following the mathematical notation and terminology guidelines of wind energy science, I would recommend using "27 Aug 18:00" instead of "1800 27 Aug".

   Thank you for highlighting the guidelines for date and time. Throughout the manuscript, "dd month yyyy, hh:mm UTC" formatting is now used.

6. Line 179: I would suggest referring to Fig. 1c in a separate sentence, explicitly stating that the figure shows the power and thrust curves used for the Fitch parameterization.

   Reworded to read: "Following previous research (Pryor and Barthelmie, 2024a, b), we assume that all auctioned offshore LAs along the U.S. East Coast (Fig. 2a) are populated with 2642 IEA reference 15 MW WTs, each of which has a hub height of 150 m, and a rotor diameter of 240 m (see power and thrust curves in Fig. 2c), at a spacing of 1.85 km for an average ICD of 4.3 MW km^{-2}."

7. Table 3: The table shows not only the sources of the initial and boundary conditions but also the model resolution; could you update the title?

   The title for Table 3 (now Table 1) has been changed from "Sources of initial and boundary conditions for WRF and COAWST" to "Model configuration for WRF and COAWST simulations".

8. Line 150: The abbreviation WS has already been introduced in line 58.

   The duplicate explanation of wind speeds (WS) has been removed with our apologies.

9. Line 278: I think you meant to write ”of 3 - 10.6 ms−1,...”?

   Sorry for any confusion. To make the three class ranges more clear, “to” has replaced “–”: The sentence now reads “… in HH WS classes of 3 to < 10.6 m s^{-1}, 10.6 to 25 m s^{-1}, and > 25 m s^{-1}, to represent …” and follows the format in the caption and legend of Fig. 8 (now Fig. 9) and Fig. 9 (now Fig. 10). The sentences on lines 452 and 523 have been modified to also use “to” instead of “–” (10.6 to 25 m s^{-1}).

10. Line 275: I suggest introducing the peak period with a few more words, e.g. ”period of the peak energy in the wave spectrum”.

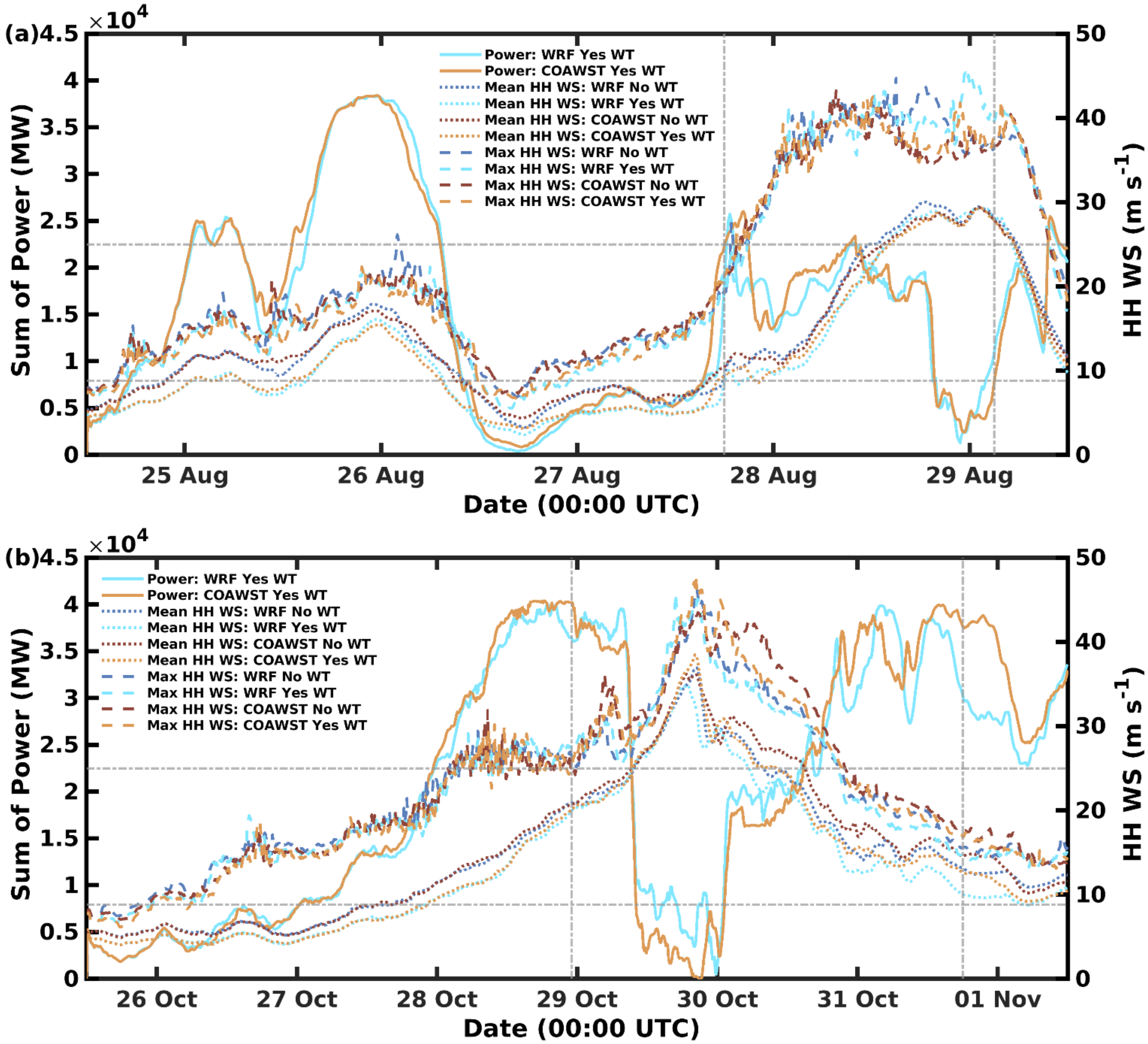
    Done

11. Table 5, 6: To help the reader, you might consider removing the horizontal lines between the buoy, WRF, and COAWST data of the same buoy location.

    Table 5 and Table 6 (now Table 2 and Table 3) have been modified to remove the horizontal lines between the buoy, WRF, and COAWST data of the same buoy location.

12. Fig. 5 and others: While the idea of grouping the colors is good, the colors between ”COAWST No WT” and ”COAWST Yes WT” and between ”WRF No WT” and ”WRF Yes WT” are too close together to be clearly distinguished.

    We want to make sure that everyone can clearly distinguish between the different colors. We have chosen a new color scheme (see below) that is also suggested in the Crameri et al. (2020) reference and is now used with the updated figures. Additional line styles are now also used in Figure 6 (previously Figure 5).



Modified Figure 6

References

Skamarock, W. C.: Evaluating mesoscale NWP models using kinetic energy spectra, Mon. Weather Rev., 132, 3019–3032, https://doi.org/10.1175/MWR2830.1, 2004.