Response to Reviewer #2 comments on Manuscript egusphere-2023-956: Microphysics of radiation fog and estimation of fog deposition velocity for atmospheric dispersion applications

Major comments:

In this paper, the authors have undertaken the task of characterizing radiation fog in around Barakah nuclear power plant in the United Arab Emirates. They have observed twelve fog events and conducted an analysis of microphysical and dynamical properties, and thermodynamics. Furthermore, they simulated a specific fog event (15 Feb. 2021) using various PBL schemes. The authors also delved into analyzing a particle dispersion model to comprehend the impact of fog deposition. Overall, this paper encompasses a wide range of analyses lack a thorough and cohesive understanding, making it challenging to arrive at a solid conclusion.

One notable concern is that fog events differ in each section and figure. For instance, section 3.1 focuses on the fog event of Feb 25, 2021 (Figure 5), while section 3.2 deals with fog events on Jan 27, Feb 4, and Feb 24, 2021 (Figures 6c and 6d). Similarly, section 4 concentrates on the Feb 16, 2021 fog event (Figure 7), whereas section 4 involves Jan 27, Feb 4, and Feb 24 (Figures 8 and 9). Section 5 centers around Feb 15. The reviewer is perplexed as to why different fog events are chosen for each section, leading to confusion regarding the author's primary focus. Furthermore, the connection between the WRF simulations and the preceding analyses (such as fog microphysical characteristics and the thermodynamic environment) is not well established. The instruments used to observe the fog events also appear to yield differing results.

In light of these issues, the reviewer strongly recommends that the authors narrow down their research topic and engage in more in-depth analyses. Addressing these concerns is crucial for enhancing the manuscript's coherence and overall quality. Given the current state of the manuscript, it is the opinion of the reviewer that it may not be suitable for publication in ACP.

Reply: Thank you sincerely for the detailed and insightful feedback. We recognize the significance of your concerns about the coherence and specificity of the analyses of various fog events, as well as the WRF simulations. Your suggestions for narrowing and deepening our research focus have been meticulously considered and addressed in the revised manuscript by considering all the 12 events throughout the manuscript except for the modelling part which is done for only 4 events due to computational requirement to run for the 12 cases. More specifically:

- In Section 3.1, we have updated our discussion, presenting findings from all observed fog events and articulating the common features and unique distinctions among them. Comprehensive insights from these events are now encapsulated in the updated Figs. 2-4 and 5c;

- In Section 3.2, the diurnal variations in relative humidity and wind speed have been scrutinized for all 12 fog events, as visualized in the revised Figs. 6a-b. We have enriched our discussion of the role of temperature inversions on Liquid Water Content (LWC) and number concentrations, providing detailed insights through representative temperature and specific humidity profiles in Figs. 6c-d. Additionally, the inversion strength analyses for all fog events is now depicted in Fig. A2;

- Regarding Section 4, due to the unavailability of eddy covariance data for the fog events in 2021, only fog events occurring in 2022 are used to derive fog deposition velocity, Turbulent Kinetic Energy (TKE), and Liquid Water Flux. This is explicitly mentioned in the text (Line: 736-740).

In connecting the analysis of fog microphysics with WRF simulations, we need specific details from fog microphysics, like the mean volume diameter and liquid water content, to estimate the fog deposition velocity. Through the analysis of microphysics, we first determine the fog deposition velocities. These determined values are then integrated into FLEXPART to assess the deposition of radioactive materials. In the revised version of our manuscript, we have incorporated the WRF simulation results for fog cases from 2022. For these 2022 fog events, we calculated the average fog deposition velocity for each instance and subsequently quantified the radionuclides deposition rates, which are illustrated in Figure 12. For instance, the average deposition velocity on January 27, 2022, was 7.87 cm s^{-1}. On February 4, 2022, it registered at 3.51 cm s^{-1}, and on February 24, 2022, it was 2.11 cm s^{-1}. These velocities were employed to ascertain the deposition rate of radionuclides. We have included this information in the revised manuscript (End of section 4).

We do believe these amendments and clarifications enhance the manuscript and address the pivotal points you have raised. Your insights have been instrumental in refining the quality and rigor of our study.

Minor comments:

1. Line 76: Remove the semicolon (;)

Reply: corrected (Line: 81)

2. Line 90-91: I am not clear what the sentence means. Also, it might need to consider a referent to support author's argument.

Reply: In the revised version of the manuscript we have rephrased the referred sentence accordingly (lines 89-91). Rephrased sentence is given below,

"Although previous analyses of fog in the UAE have been conducted using satellite data (Weston and Temimi, 2020a) and in-situ measurements for a single fog event (Weston et al., 2022), a comprehensive analysis of fog microphysics and dynamics has yet to be carried out in this region."

3. Line 101: If the author would like to emphasize this (first observation-derived fog deposition velocity for the UAE), it would be great if the author presents a distinct feature about the first study by comparing the previous studies with different regions.

Reply: Thank you for your insightful suggestion regarding emphasizing the distinctiveness of our study – the first to derive fog deposition velocity based on observations in the UAE. In comparison to previous studies in different regions, our observed fog deposition velocities range from 2.1 to 7.8 cm s^{-1} (Figure 8a). These findings are comparable in order of magnitude with the values reported by Tav et al. (2018), particularly for the bare soil category. However, they are notably smaller than the 16 cm s^{-1} and 40 cm s^{-1} observed for cypress and grass surfaces respectively in the aforementioned study. This comparative analysis underscores the variation in fog deposition velocities across different geographical regions and surface types, highlighting the unique contribution and criticality of our study in understanding these dynamics within the UAE.

4. Figure 1: It could be very helpful the author can mark the observational sites on the map, because the instruments installed the different sites. Also, please change the color for the ocean, because it looks land since the lowest elevation over land also shaded blue color.

Reply: We genuinely appreciate your meticulous observation concerning Figure 1 and wholeheartedly agree that marking the observational sites and adjusting the color scheme will enhance the clarity and in formativeness of the figure. In the revised Figure 1, we have now annotated the observational sites clearly, ensuring that readers can effortlessly identify the locations where instruments were installed. Furthermore, we have modified the color scheme to eliminate any confusion between the ocean and land areas with low elevation, by opting for a distinct color for the ocean, ensuring an unequivocal differentiation between the two. These enhancements aim to facilitate a more intuitive and insightful interpretation of the geographic contexts relevant to our study. We trust that these adjustments will amplify the figure's utility and clarity for our readers and sincerely thank you for pointing out these opportunities for improvement.

5. Table 1: It could be very helpful if the author can add the measurement bias at each instrument.

Reply: We greatly value your suggestion regarding the enhancement of Table 1 by incorporating the measurement accuracy of each instrument. Acknowledging the significance of transparency and thoroughness in presenting instrument data, in the revised Table 1, we have provided the measurement accuracy for each respective instrument. Your pointed suggestion substantially contributes to the improvement of our manuscript by enhancing the depth and reliability of the information presented. Thank you once again for your prudent observation.

6. Table 1: There were two analysis period in one box. Please modify the box correctly. The period was not same among the instruments. How the author analyzes the data? Does them use the same period of case?

Reply: Thank you for your insightful comment regarding the analysis periods outlined in Table 1. We acknowledge the variability in the measurement periods for the instruments utilized, largely due to the challenges posed by conducting field measurements in a hyper-arid environment. In this study, our analysis strictly employs data from the 12 fog events detailed in Table 3. Additionally, we sought not only to judiciously utilize available data but also to highlight the data availability periods for the international research community. This approach aims to promote transparency and foster potential collaborative insights in future research endeavors. We trust that this clarification and additional context regarding our methodology and data usage will provide a clearer understanding of our approach, alleviating any potential concerns. We extend our appreciation for your diligent scrutiny, which undoubtedly enhances the transparency and comprehensiveness of our manuscript.

7. Line 221: Why the author uses the WSM3 rather than WSM6 as microphysics scheme? The WSM6 provides the 6 class hydrometeor types including ice, snow, and graupel.

Reply: We would like to thank the reviewer for raising this issue. The physics schemes selected in this work are those found to be optimal for western UAE following the sensitivity experiments conducted by Abida et al. (2022). We have clarified this in the text (Lines: 257-260, section 2.4.1).

8. Line 289-290: Form what?

Reply: Thank you for pointing out the concern on Line 289-290. We infer that you are seeking a reference for the fog definition provided. In response, we have cited the relevant source, the World Meteorological Organization report (WMO, 2008), in the revised manuscript to validate the definition utilized. We appreciate your suggestion, which enhances the accuracy and credibility of our work.

9. Figure 2: at Barakkah? Does this mean at BNPP?

Reply: Thank you for catching that oversight. We apologize for any confusion caused by the use of "Barakah." You are correct, it does indeed refer to BNPP. To prevent any future misinterpretations, we have clarified this by explicitly mentioning BNPP in the captions of Figure 1 and Figure 2 in the revised manuscript. We appreciate your diligence and your constructive suggestion.

10. Line 509-511: Need result/figure or reference to support the argument.

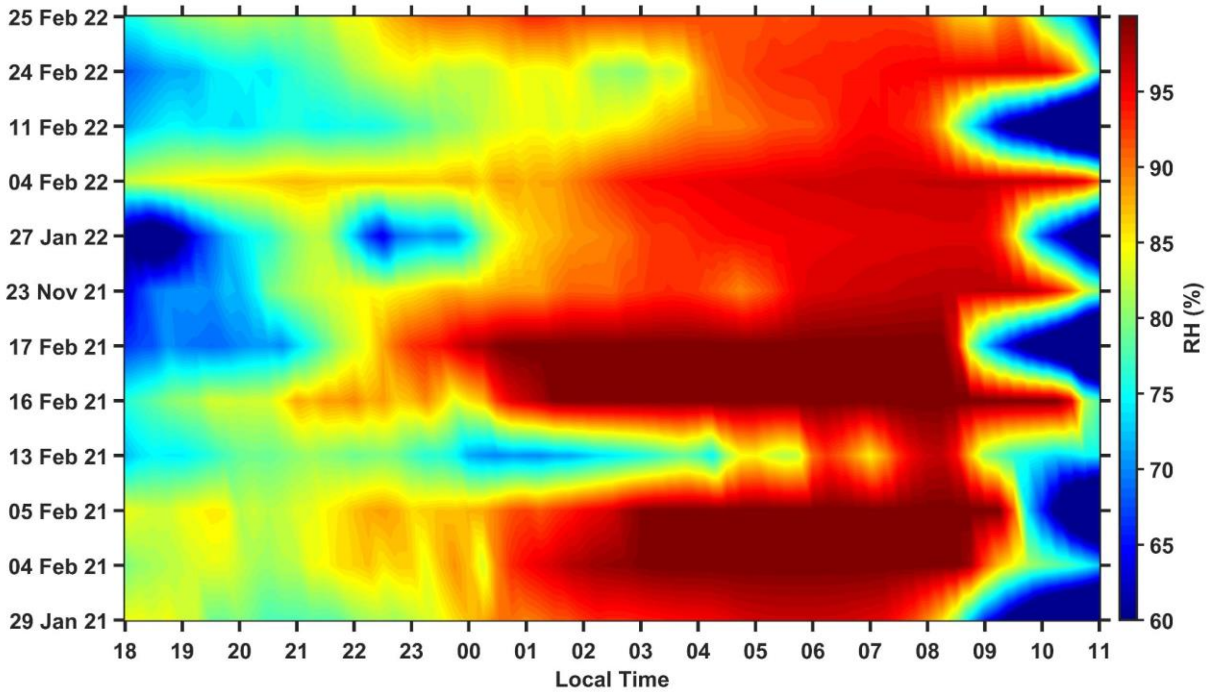
Reply: We have added two references Tav et al. (2018) and Weston et al. (2022 to back up our statement. (Lines: 641-674).

11. Figure 6a,b: Hard to see the lines

Reply: Thank you for your valuable feedback regarding the visibility of the lines in Figure 6a,b. In our initial revision, a different reviewer highlighted the value of maintaining the line plots, emphasizing their relevance and utility for conveying specific aspects of our findings. As such, we have opted to retain Figure 6ab in its current format to uphold the integrity of these insights.

However, we deeply appreciate your concern regarding clarity and, to that end, a contour plot illustrating the diurnal variability in Relative Humidity (RH) and wind speed during the 12 fog cases is provided below for enhanced visualization and clarity. We hope this additional figure aids in the understanding of our analyses and we sincerely thank you for your astute observation.

(a) Relative Humidity



(b) Wind speed

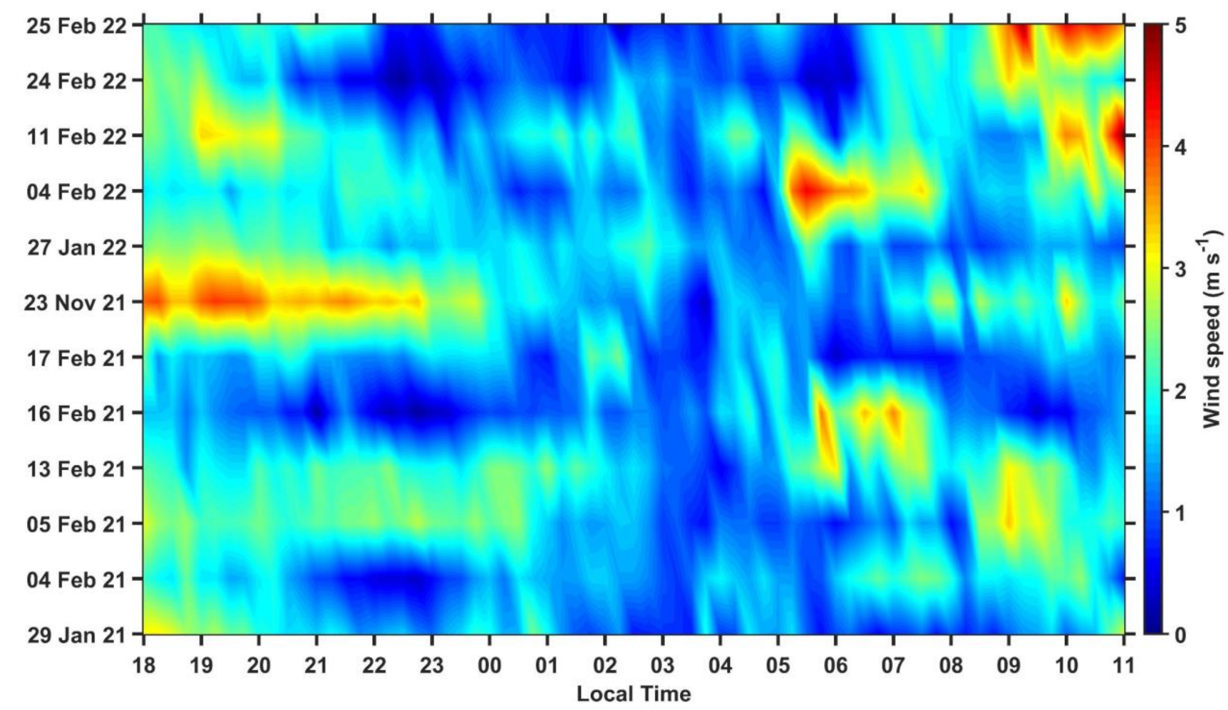


Figure R1. (a-b) Diurnal variations (18 LT - 11 LT) in relative humidity (RH; %) and wind speed (m s^{-1}) for all fog events.

12. Line 623-624: How can see this result? The reviewer can not find the result correctly in Figure 9a. The background map showed wide ranges. Please explain more about this.

Reply: We thank the reviewer for raising this issue and apologize for the poor wording of the text. The largest contribution to the total LWC (black line) comes from the droplets of sizes 20-45 μm (darkest blue shading in the background), cloud droplets of smaller sizes play a much reduced role as evidenced by the lighter shading. We have rephrased the referred sentence for clarity in the revised version of the manuscript (Lines: 803-805).

13. Line 677-678: What the author refers to? FLEXPART?

Reply: No, we are referring to the convention used in Fig. 9 regarding the total liquid water flux. We have rephrased the text for clarity (Lines: 793-794).

14. Figure 10: Why the author shows only two simulations (ACM2 and MYJ)? The simulations were performed five (Table 2), so please add more figures for all simulations.

Reply: Following the reviewer's suggestion we now show the results for all five PBL schemes considered in Fig. 10 and have expanded the discussion in the text (Section 5).

References

Abida, R., Addad, Y., Francis, D., Temimi, M., Nelli, N., Fonseca, R., Nesterov, O. and Bosc, E.: Evaluation of the Performance of the WRF Model in a Hyper-Arid Environment: A Sensitivity Study, Atmosphere, 13(6), 985, https://doi.org/10.3390/atmos13060985, 2022.

Tav, J., Masson, O., Burnet, F., Paulat, P., Bourrianne, T., Conil, S. and Pourcelot, L.: Determination of fog-droplet deposition velocity from a simple weighing method, Aerosol and Air Quality Research, 18, 103–113, 2018.

WMO, 2008: Aerodrome reports and forecasts: A user's handbook to the codes. World Meteorological Organization, 81 pp.

Weston, M., Francis, D., Nelli, N., Fonseca, R., Temimi, M. and Addad, Y.: The first characterization of fog microphysics in the united arab emirates, an arid region on the arabian peninsula, Earth and Space Science, 9(2), https://doi.org/10.1029/2021EA002032, 2022.