

## Authors response to AMT 2022-906 Anonymous Referee #2 Report

We would like to express our gratitude to the referee for taking the time to review our first response. Your comments and suggestions have been invaluable in helping us improve the quality and clarity of our work. The referee comments/suggestions are in black, and our responses are in red; the listed line numbers refer to the lines of the original manuscript where the new corrections are observed.

This paper uses ceilometer data to identify potential cases of virga in El Paso, TX. It looks at the impact of virga on PM<sub>2.5</sub> concentrations, where certain (columnar virga) cases at times led to surface enhancements of PM<sub>2.5</sub> while others (non-columnar virga) did not.

The authors' response to initial reviewer feedback updated sections related to Case 1 (lines 265-290; columnar virga event with a dry microburst) and Case 2 (lines 320-345; non-columnar virga event) of the originally submitted manuscript. Both of those updates, including their updated figures, provide clarity, and improve the manuscript.

Thank you for taking the time to review our response to your first review report.

Given the relatively brief time scales involved in the outflow of microbursts, the statistical analysis of the influence on PM<sub>2.5</sub> by potential virga-induced microbursts can be strengthened by using 5-minute averaged data from the continuous air monitoring stations network rather than hourly averaged data.

We agree with the referee, however, we tried hard and were unable to get access to the finer resolution dataset.

1. Does the paper address relevant scientific questions within the scope of AMT?

Yes

2. Does the paper present novel concepts, ideas, tools, or data?

Yes

3. Are substantial conclusions reached?

For the two highlighted case study examples, yes. For the analysis of the 50 cases over the 7 year period, using higher temporal resolution surface data would help substantiate possible correlations between wind gusts resulting from virga-induced dry microbursts and enhanced PM<sub>2.5</sub> concentrations.

4. Are the scientific methods and assumptions valid and clearly outlined?

The methods are clearly outlined.

5. Are the results sufficient to support the interpretations and conclusions?

In general, yes. There is a note described below that

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Yes, enough of a description is provided to allow other researchers to carry out similar studies.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Yes

8. Does the title clearly reflect the contents of the paper?

Yes

9. Does the abstract provide a concise and complete summary?

Yes

10. Is the overall presentation well structured and clear?

Yes, particularly with the updated portions provided in the authors' response to initial reviewer feedback.

11. Is the language fluent and precise?

With minor suggested edits (provided) and the improvements in the descriptions of updated sections in the authors' response to initial reviewer feedback, it is on the right track.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

In the updated versions of Figure 6b and Figure 8b provided in the authors' response to reviewers, please use m/s for the wind speed and max gust instead of miles/hr. Figures 6a, 6c and 8a, 8c, use Fahrenheit whereas the Skew-T plots (Figures 6b and 8b) use Celcius. Suggest using Celsius for all.

**Thank you for the suggestions. We have revised the above-mentioned figures with appropriate units to address the referee suggestions.**

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

Aside from the minor note above regarding units, the updated versions of Figure 6 and Figure 8 provided by the authors' response to initial feedback address this.

14. Are the number and quality of references appropriate?

Yes

15. Is the amount and quality of supplementary material appropriate?

N/A

Comments and Suggestions:

1. Line 150: “a few miles away from the study site”: clearly specify the distance in kilometers and the directional heading. CAMS 12 is later mentioned with a lat/lon provided, would make sense to do the same for the NWS Santa Teresa sounding site location.

The following revision is made to the manuscript:

Radiosonde observations were obtained from the nearest National Weather Service (NWS) (31°52'33" N, 106°36'39" W) located at Santa Teresa, New Mexico, 21 km away from the study site.

2. This paper provides a way of identifying virga events using ceilometer data. Confidence in proper identification of virga events will be higher for some cases than others. What suggestions do the authors have for other researchers to further confirm virga events? This is just a suggestion for consideration and the authors should not feel compelled to include this: The authors' could add suggestions for future researchers to help identify such cases and their influence on PM<sub>2.5</sub> surface concentrations, such as (1) having an all-sky camera on the roof that saves one picture each minute, (2) releasing collocated radiosondes on demand during such events, and (3) obtaining higher temporal resolution data from surface monitors. Granted, this would require some additional funding but could provide things to consider for those who perform similar studies.

Thank you for the excellent suggestions. We do appreciate it. The last paragraph which describes the future scope of the work is revised to include the suggestions from the referee.

The availability of higher temporal resolution ground measurements will undoubtedly improve and solidify the correlation between the various parameters discussed in Table 1. If funds are available, using an all-sky camera (capable of capturing finer temporal resolution images) in conjunction with the ceilometer would greatly aid in capturing the virga precipitation. During the virga event, launching collocated radiosondes could provide an excellent dataset of vertical atmospheric profiles, especially the wind flows. A comprehensive study that includes such instrumentation and approaches would allow researchers to investigate the possibility of a strong connection between vertical winds, virga, and a local rise in PM levels. It also emphasizes the importance of having diverse instrumentation at the El Paso site, such as sonic anemometers, wind profilers, and barometers, which will provide a comprehensive dataset that will further enhance our understanding of virga and dry microbursts in the region. This research work will undoubtedly be a starting point for researchers to better comprehend the link between virga events and air quality. It will be worth analyzing the impact virga has on the climatology of precipitation in the semi-arid region.

3. Using 5-minute instead of hourly data for the analysis in Table 1 was suggested in the initial review response and the authors responded:

The 50 virga episodes that were classified in this work are unevenly distributed throughout the study period of 7 years. Since the 5-minute data was not available to us we decided to use the one-hour average data which is readily available in the public domain. We are grateful for your suggestion and will seek the 5-minute data for future use.

The authors' response is understandable, but it would be a missed opportunity to further improve this manuscript. The dry microburst events are short-lived and the 5-minute data may strengthen the analysis.

We agree with the referee, however, we tried hard and were unable to get access to the finer resolution dataset. Based on the availability, future work will include higher temporal resolution data.

Minor suggested edits that do not change authors' intended meaning:  
Line 30: "before even reaching" → "before reaching"

The sentence has been revised.

Line 35: "reviewed earth's climate system" → "reviewed Earth's climate system"

The sentence has been revised.

Lines 47-48: "radar and lidar, both ground-based, airborne, and satellite observations"  
please rewrite for clarity

Previous studies investigated it using remote sensing instruments such as ground-based or airborne radar and/or lidar, and in some cases satellite observations.

Line 48: "(Wang et al., 2018)" → "Wang et al. (2018)"

The citation has been revised.

Lines 51-52: "(Saikranthi et al., 2014)" → "Saikranthi et al. (2014)"

The citation has been revised.

Lines 53-54: "(Airey et al., 2021)" → "Airey et al. (2021)"

The citation has been revised.

Line 70: “(Jullien et al., 2020)” → “Jullien et al. (2020)”

The citation has been revised.

Link 71: “(Grazioli et al., 2017)” → “Grazioli et al. (2017)”

The citation has been revised.

Line 74: Use the degree symbol (in Word, go to ‘Insert’ and then ‘Symbol’) rather than a superscripted “0”

Symbol revised

Line 79: “(Tost et al., 2016)” → “Tost et al. (2016)”

The citation has been revised.

Line 94: Change the semicolon to a period (or could use semicolons throughout that list of the different section topics).

Revision made

Line 100: “doppler” → “Doppler”

Revised

Line 102: Use the degree symbol rather than a superscripted “0”

Symbol revised

Line 104: Delete “urban”

Revised

Line 105: “Sun city’s” → “Sun City’s”

Revised

Line 113: “aerosol layer height which can” → “aerosol layer height, which can”

Addressed

Line 121: “CL31 was installed” → “A CL31 was installed”

Addressed

Line 122: “CL51 has a” → “The CL51 has a”

Addressed

Lines 135-136: “planetary boundary layer heights (Schafer et al. 2004) from the measured attenuated backscatter profiles.” → “planetary boundary layer heights from the measured attenuated backscatter profiles (Schafer et al. 2004).”

Addressed

Line 137: “for detection” → “for the detection”

Addressed

Line 140: “doppler” → “Doppler”

Addressed

Line 142: “diamter” → “diameter”

Revised

Figure 2 caption: “We can observe lighter precipitation at the research site UTEP shown in red dot.” → “We can observe light precipitation at the research site (UTEP) shown by the red dot.”

Addressed

Line 216: “years’ ” → “years” (no apostrophe)

Addressed

Line 216: “at UTEP” → “at the UTEP”

Revised

Line 218: “section 3” → “Section 3”

Addressed

Line 227: “Similarly, to 2021, most” → “Similar to 2021, most”

Addressed

Lines 228-229: “2015 saw the least number of virga events” → “2015 had the fewest virga events”

Addressed

Figure 4 caption is missing a period at the end of it.

Addressed

Line 256: “Case study 01” → “Case study 1”

Addressed

Line 259: (till 22:45 UTC) → “(until 22:45 UTC)”

Addressed

Line 263: “During the virga episode cloud base appears to be well above 4 km.” → “During the virga episode, the cloud base appears to be well above 4 km.”

Addressed

Line 312: “ground around 21 CST” → “ground at approximately 21 CST” (and from the authors’ response to reviewers the times throughout may end up in UTC)

Addressed

Line 354: “(Table 1)” → “Table 1”

Addressed

Line 354: “calculated p-value” → “calculated the p-value”

Revised

Line 355: “P values” → “p-values”

Addressed

Lines 355-356: “higher than 0.05. Which means” → “higher than 0.05; meaning”

Addressed

Line 357: “vs” → “vs.”

Addressed

Lines 357-358: “had higher R-squared value in” → “had a higher R-squared value in”

Addressed

Line 358: “indicate” → “indicates”

Addressed

Lines 372-373: “We significantly extended our research and investigated the virga’s impact on ground level PM concentrations.” → “Our research extends the literature by providing an



initial investigation into virga's impact on ground level PM concentrations." (or something to that effect)

Revised

Line 373: "Cl31" → "CL31"

Addressed

Line 389: "March 10, 2019," → "10 March 2019" (for consistency in how dates are formatted and is something to check throughout, most have DD Month YYYY)

Modified

Line 403: "in the semi-arid region." → "in semi-arid regions."

Addressed

Minor suggested edits the authors' response to initial reviewer feedback:

Figure 5 caption: "around 20-22 UTC" → "approximately 20-22 UTC" or "~20-22 UTC"

End of Page 5: "virga in case 1 was" → "virga in Case 1 was"

Last page: "(figure 8b)" → "(Figure 8b)"; "figure 8 c" → "Figure 8c"; "figure 8d" → "Figure 8d" \_

All the points have been addressed in the manuscript.

Once again, we appreciate your time and expertise.