Dear Editor,

Thank you for agreeing to consider a revision of our manuscript "The Spatial, Temporal, and Meteorological Impact of the 26 February 2023 Dust Storm, Increase of Particulate Matter Concentrations Across New Mexico and West Texas ". We modified and revised the manuscript to address the reviewers' comments as well as to clarify points that they found confusing or unclear.

We would like to thank the two reviewers, Dr. Allison C. Aiken and the anonymous reviewer for their helpful comments and suggestions, and many thanks to you for your time and efforts with this revision. In line with the comments and suggestions, we revised the manuscript and made the requested additions and changes. Below are all the comments (in bold) followed by the replies. The parts that are in italics are corrections that are included in the revised version of the paper:

Sincerely,
Karin Ardon-Dryer

Review of "The Spatial and Temporal Impact of the Dust Storm During February 26, 2023, on Meteorological Conditions and Air Quality Across New Mexico and West Texas" by M.C. Robinson, K. Schueth, and K. Ardon-Dryer
General Comments: This paper examines the meteorological conditions and air quality impacts of a severe dust storm in New Mexico and West Texas in February 2023. Multiple observational datasets are used to characterize the features of the event and associated weather conditions. It is found that the upper-level jet streak, the passage of a cold front, and the formation of thunderstorms along the dryline all contribute to the high wind speeds during the event. The resultant visibility reduction and dramatic increase in PM values highlight the severity of the event. Overall, the study provides a timely and detailed analysis of an extreme dust storm (e.g., the highest PM2.5 record at Lubbock, Texas, in the past 20 years), which can potentially advance the current understanding of severe dust storms in the southern U.S. However, I found a few aspects that can be further improved. See my comments below for details.

We would like to thank the reviewer for the suggestions, corrections, and comments.

Specific comments:
1. The introduction section can be improved by adding a brief review of dust storms in the southwestern U.S., particularly over New Mexico and western Texas, as background information and by adding a few lines to highlight the motivation and novelty of this study. For instance, what are the key research questions that would be addressed in this study?

Per the reviewer's comments, additional information was added to the introduction in order to provide more information on dust in the southwestern U.S., particularly over New Mexico and western Texas. The last paragraph of this introduction was modified to reflect the reviewer's comment.

These parts were added to the revised manuscript:

Dust events and storms occur across the United States (Tong et al., 2023), mainly across the southwestern portions, due to its drier and warmer conditions with low soil moisture from desert regions (Achakulwisut et al., 2017). Among the states, the most susceptible to dust events are Arizona (Nickling and Brazel, 1984; Lei et al., 2016; White et al., 2023), southern California (Bach et al., 1996; Evan, 2019; Huang et al., 2022), Utah (Hahnenberger and Nicoll, 2012; Hennen et al., 2022) and states across the Great Plains, mainly the Southern Great Plains area including New Mexico and Texas (Kandakji et al., 2020; Hennen et al., 2022; Ardon-Dryer et al., 2023b; Robinson and Ardon-Dryer, 2024). The multiple dust sources in the region, mainly cropland, contribute to the high number of dust events (Lee et al., 2012). In a recent study, Robinson and Ardon-Dryer (2024) found an average of 22 dust events annually (between 2000 to 2021) across four dust-prone regions in West Texas. Most of the dust events in the region occur in the spring to early summer months, mainly due to synoptic disturbances, while a smaller percentage of dust events are formed by convective disturbances, and rarely are dust events formed by the combinations of these two disturbances (Robinson and Ardon-Dryer, 2024).

The air quality across West Texas and New Mexico is good overall (Zanobetti and Schwartz, 2009; Kelley et al. 2020). Anthropogenic pollution such as industrial facilities and transportation emissions, which can lead to Ozone, can be found mainly in the two large urban cities of El Paso, Texas, and Albuquerque, New Mexico (Gaffney et al., 1997; Chen et al., 2012; Kavouras et al., 2015; Craig et al., 2020; Karle et al., 2020; Van Pelt et al 2020; Huang et al., 2023). The entire area is impacted by dust events and dust storms which lead to an increase in PM and degradation of the air quality (Tong et al., 2012; Stout, 2015; Herrera-Molina et al., 2021; Kelley and Ardon-Dryer, 2021; Ardon-Dryer et al., 2023b; Albuquerque-Bernalillo County, 2024). In Sunland Park, New Mexico, Li et al. (2005) found during dust events that $PM_{2.5}$ *and* PM_{10} *hourly concentrations were 170* $\mu g\ m^{-3}$ *and 2346* $\mu g\ m^{-3}$*, respectively, while daily averages were 12* $\pm$ *8* $\mu g\ m^{-3}$ *and 68.5* $\pm$ *72* $\mu g\ m^{-3}$*, respectively.*

Kelley et al. (2020) analyzed $PM_{2.5}$ *concentrations in Lubbock, Texas over 17 years (2001 – 2018) and found that the majority of the hourly* $PM_{2.5}$ *concentrations were lower than 10* $\mu g\ m^{-3}$ *(80%), but there were several days with high PM including 15 April 2003 and 15 December 2003 that had* $PM_{2.5}$ *hourly values of 433 and 486* $\mu g\ m^{-3}$*, respectively. Rivera Rivera et al. (2009) also examined the impact of these two dust storms in El Paso and found on 15 April 2003 hourly* PM_{10} *concentrations of 4724* $\mu g\ m^{-3}$ *with a daily* PM_{10} *concentration of 375* $\mu g\ m^{-3}$*, while the hourly* PM_{10} *concentrations on 15 December 2003, was >1200* $\mu g\ m^{-3}$*. Daily* PM_{10} *concentrations on 15 December 2003, for another site in Texas, was >160* $\mu g\ m^{-3}$ *(Tong et al., 2012). Yin et al. (2005) examined hourly* $PM_{2.5}$ *and* PM_{10} *measurements from different stations across New Mexico and Texas during the same dust storm (15 December 2003). They found hourly* PM_{10} *concentrations in New Mexico >700* $\mu g\ m^{-3}$*, while* $PM_{2.5}$ *hourly concentrations ranged from 12 up to 36* $\mu g\ m^{-3}$ *(Yin et al., 2005). Both of these dust storms were caused by synoptic disturbances. In Lubbock Texas, it was found that* $PM_{2.5}$ *daily concentrations during synoptic dust events had slightly higher* $PM_{2.5}$ *average concentrations compared to convective dust events. Ardon-Dryer and Kelley (2022) also found that synoptic dust events had higher* $PM_{2.5}$ *and* PM_{10} *daily concentrations compared to convective dust events, but short-term observation (based on 10 minutes) showed that convective have much higher PM concentrations. The impact of* $PM_{2.5}/PM_{10}$ *and* PM_{10}*-*$PM_{2.5}$ *values during, dust events in the region, were examined but only by a handful of studies. In New Mexico,*

$PM_{2.5}/PM_{10}$ values ranged from 0.05 up to 0.58, and the $PM_{2.5}/PM_{10}$ ratio was extremely low (0.079 up to 0.093) during dust events (Li et al., 2005). Measurements of daily $PM_{2.5}$ and PM_{10} using multiple Interagency Monitoring of Protected Visual Environments (IMPROVE) stations in New Mexico and Texas also found a significant drop in the $PM_{2.5}/PM_{10}$ ratio during dust events, with daily means that ranged from 0.22 to 0.24 during dust events (Tong et al., 2012).

The dust storm of 26 February 2023 was one the strongest and significant dust storms that occurred in this region over the last two decades. This study aimed to understand the meteorological conditions that initiated this dust storm and those measured during it using multiple meteorological stations across New Mexico and Texas, capturing its Spatial and Temporal changes. The impact this dust storm had on air quality over the two states was of interest to understand if and how significant its impact on PM concentrations in the region was and to evaluate its similarity to previous dust events in this region.

2. It would be great to add some discussion about the uncertainties of the datasets used in the study, especially the ground measurements, if possible, and how those may affect the analysis and results.

Limitation information was added to the different methodology sections:
It should be noted that there are some limitations to the use of ASOS stations, as there were only four stations with full-time weather observed, while the remaining were semi-/fully automated. In a recent study (Robinson and Ardon-Dryer, 2024), it was found that there could be mistakes in dust identifications. To make sure such will not happen, this study follows the guidance provided by Robinson and Ardon-Dryer (2024) to remove such cases. Another related issue is the fact that the automated stations can stop operating due to outages and in some cases, cannot be backed up, which has happened to some of the stations in this study limiting the ability to use the data. Regardless of these limitations, the usage of the ASOS with the spatial and temporal coverage allowed examination into the development and movement of the dust event.

It should be noted (as shown in Fig. 1B) that there is a wide spatial gap between the PM sensors, as these are the only active sensors in the area. Also, most of the PM sensors in Texas (except those in El Paso) only provide $PM_{2.5}$ meaning the impact of PM_{10} in West Texas will not be provided in this study.

3. I think Figs. S1-S4 contain information that helps better understand the analysis and should be moved to the main text, given that currently only four figures are in the main text.

These figures were moved from the supplements into the main manuscript. We decided to leave only one figure in the supplement as with decided its contribution was not crucial to the paper.

4. It would be interesting to add some analysis or discussion about the physical mechanisms and unique aspects of this dust storm, for instance, what caused the strong winds? Lines 131-133 provide some discussion, but it would be interesting to show more if possible.

We believe the original manuscript provided all the possible information on the physical mechanisms that describe why the dust event was initiated. The stacked jets and mixing of winds to the surface were the main physical meteorological reasoning as to why there were strong winds. This meteorological setup was not unique to this area, but it was rare to see these intense stacked lows and mixing of strong winds to the surface during the morning hours, which started to loft dust particles before the Pacific front which just intensified the dust.

Per the reviewer's comment, we added more information to the revised manuscript:
The fact that some of the locations had both synoptic and convective disturbances (also known as combinations) is a rare aspect of this region, as only a handful of the dust events were caused by such conditions, for the case of Lubbock Texas, ~15% of the past DS (2000-2021) were caused by a combination of disturbances (Robinson and Ardon-Dryer, 2024).

5. Line 49, airports over certain regions, or the whole U.S.?
Information was added to the revised manuscript, these are airports across the whole U.S.
Automatic surface observation systems (ASOS) are meteorological stations located at most airports across the United States that provide meteorological measurements….

6. Lines 57-58, a severe storm with heavy precipitation can also reduce visibility and increase surface wind but without any dust storms.

We agree with the reviewer that precipitation will reduce visibility. However, information on Precipitation is measured by the ASOS and provided in the METAR report, and it is easy to see it. We do not include such cases in our analysis as the reduction of visibility might be caused by the precipitation and not the dust particles. When precipitation occurs during dust events, the first observation of precipitation will be the end of the dust event. The precipitation will end up increasing the visibility as it clears the dust. Per the reviewer's comment, we added the aspect of precipitation to the sentence to clarify that we did not use that as part of our analysis. In this dust storm, none of the meteorological stations used in this study had precipitation during or after the dust.

This information was added to the revised manuscript:
The classification of the dust event in this study was based on the combination of present weather codes such as BLDU (blowing dust), VCBLDU (vicinity blowing dust), DU (widespread dust), DS (dust storm), and HZ (haze), with the reduction of horizontal visibility (< 10 km) and increase of wind speed (> 6 m s^{-1}) but without precipitation, similar to the method used in Ardon-Dryer et al. (2023b) and Robinson and Ardon-Dryer (2024).

7. Section 2.3, why is the RAPv3 selected for the analysis? What variables are used?

The RAPv3 was selected to illustrate meteorology due to its one-hour assimilation frequency and ability to provide one of the best forecasts in the rapidly changing atmosphere. Information on the variables used was also added to the revised manuscript.

The synoptic maps were made using the North American Rapid Refresh version 3 (RAPv3) with a horizontal grid spacing of 13 km and 51 vertical levels (Benjamin et al., 2016). The RAPv3 was selected to illustrate the meteorology due to its one-hour assimilation frequency and ability to provide one of the best forecasts in the rapidly changing atmosphere. Only the initialization hours and no forecast hours were used in this study. Each synoptic map was made using the Metpy python package (May et al., 2023), with several meteorological variables layered. The following variables were chosen to analyze the meteorology; geopotential heights (mid-level and surface), wind speed and direction (mid-level and surface), temperatures (mid-level), and dewpoint temperatures (surface).

8. Lines 129-130, which figure do you refer to?

Information on the figure was added to the revised manuscript

9. Line 142, can you please provide definitions for 'blowing dust,' 'vicinity blowing dust,' and 'dust storm'?

Information on these weather codes was added to the revised manuscript:
The classification of the dust event in this study was based on the combination of present weather codes such as BLDU (blowing dust), VCBLDU (vicinity blowing dust), DU (widespread dust), DS (dust storm), and HZ (haze), with the reduction of horizontal visibility (< 10 km) and increase of wind speed (> 6 m s^{-1}) but without precipitation, similar to the method used in Ardon-Dryer et al. (2023b) and Robinson and Ardon-Dryer (2024). The different present weather codes for dust are defined by the World Meteorological Organization (WMO) and the Federal Aviation Administration (FAA). BLDU represents a case when the dust is present in the atmosphere and visibility drops below 11 km, DU indicates that dust is present and gives distant objects a tan or gray tinge, DS represents when dust drops the visibility to 1 km or less, and VCBLDU refers to that the dust is present within 8 to 16 km away from the station. Each of these codes can only be entered manually by a weather observer (WHO, 2019; FAA,2021). It should be noted that 16.1 km is the maximum visibility that should be reported by the ASOS (ASOS User's Guide, 1998). Many studies have used the present weather codes to identify dust events in this region (Kandakji et al., 2020; Herrera-Molina et al., 2021; Kelley and Ardon-Dryer, 2021; Robinson and Ardon-Dryer, 2024).

10. Line 216, is there an upper limit of PM10 measurement?

Yes, there is an upper limit to the instrument, and each might have a different one. Some of the $PM_{2.5}$ units had an upper limit of 5,000 µg m^{-3} or 10,000 µg m^{-3}, and many of the PM10 units had an upper limit of 10,000 µg m^{-3}. it should be noted that we did not have control over these as each start air quality agency decided which unit to use and where. Information on the matter was added to the revised manuscript:

All of the PM sensors are Federal Equivalent Methods (FEMs). Each FEM instrument had a different resolution depending on the operated unit (See Table S2), some units ranged from 0.1 up to 10,0000 µg m^{-3} (T640, 2024), or -15 up to 10,0000 µg m^{-3} (BAM 1022, 2024), other had an upper limit of 5,0000 µg m^{-3} (R & P Model 2025; EPA, 2024).

11. Line 265, is it the daily average of 26 Feb. 2023?

We added information in the revised manuscript and in the supplement to clarify that the daily average refers to Feb 26th. Per comments from reviewer 2, we performed daily calculations every day from February 2023 for each PM sensor.

12. Line 280, how are correlations calculated? Do you use hourly data of the day? Are autocorrelations considered?

The regression used were linear and polynomials, both were based on hourly values of wind and PM from the stations used in this study. No autocorrelations were used in this study. Information was added to the revised manuscript and to Table S4.

Calculations of regression (linear and polynomial) were made based on hourly PM concentrations and wind speeds for all stations with measurements from February 26.

13. Line 285, are the correlations significant?

Some were significant but others were not, this information was provided in detail in the manuscripts as well as in Table S4 for each of the stations.

14. The current title indicates that meteorological conditions are affected by the dust storm. However, the text suggests the other way around. Please consider rewording to avoid confusion.

The title of the manuscript was modified per the comments from both reviewers, this is the title of the revised manuscript:
The Spatial, Temporal, and Meteorological Impact of the 26 February 2023 Dust Storm, Increase of Particulate Matter Concentrations Across New Mexico and West Texas

15. In Figure 2, please consider reducing the density of contours. In Fig. 2a-b, is the shading total wind speed? Also, can you please add labels for temperature and geopotential height? Similarly, for Fig. 2c, please add labels for surface height. And why are these time snapshots, i.e., 18UTC on 26 Feb. and 00UTC on 27 Feb., selected? When did the storm start?

Changes were made to the figure as recommended by the reviewer. The density of contours has been reduced. The wind speed is shaded in Fig 2a-b and dewpoints are shaded in Fig 2c-d, which is now indicated in the caption. The time snapshots of 18UTC on 26 Feb. and 00UTC on 27 Feb. were chosen to show the evolution of the system the weather system that amplified the dust storm. The two times chosen are considered synoptic times and best represent the evolution through the afternoon and early evening hours, which is when the dust storm intensified across West Texas.

These changes were made in the revised manuscript:

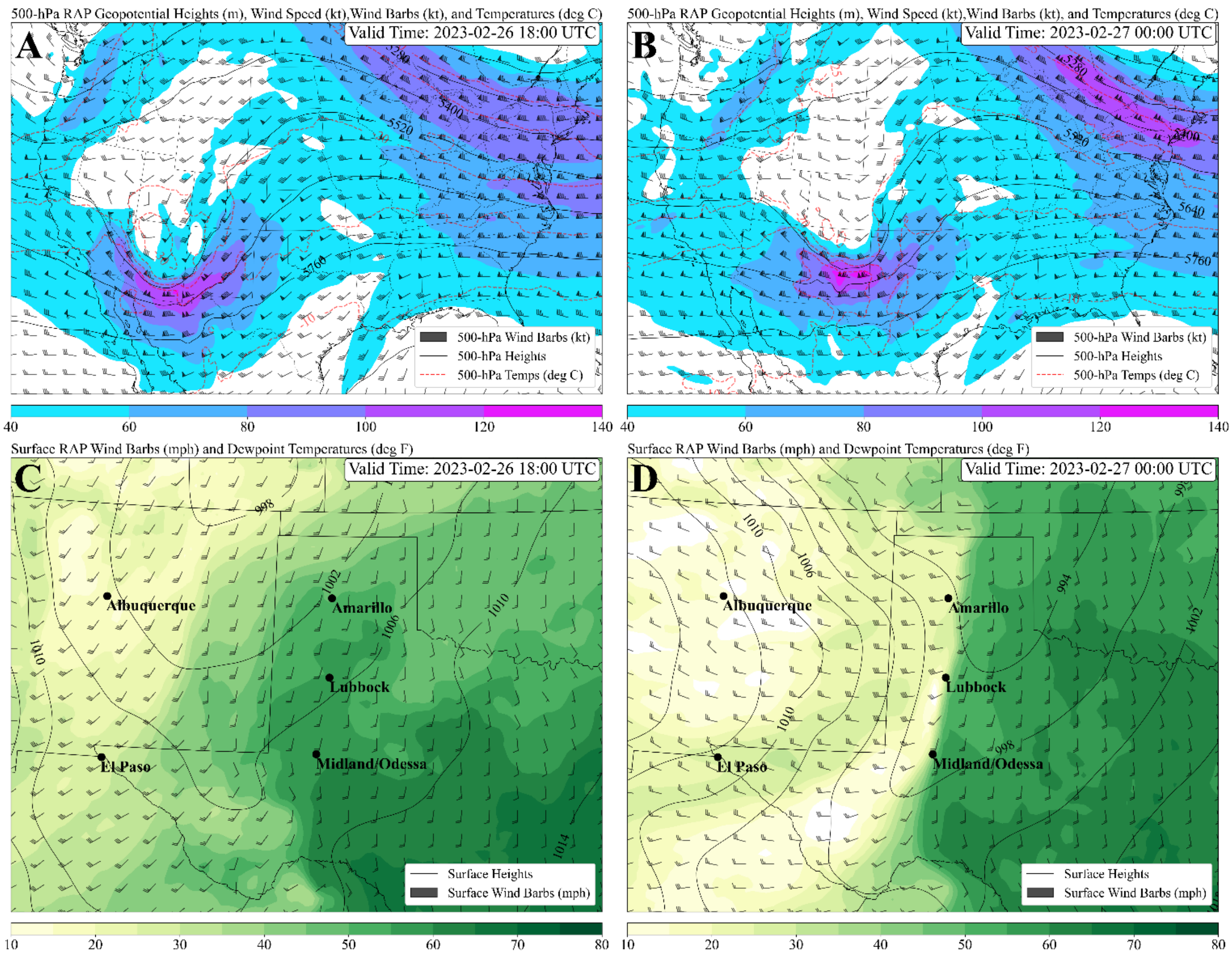

Figure 2. 500 mb geopotential heights (m), wind speed (kt, shaded), wind barbs (kt), and temperature (°C) for February 26 at 18:00 UTC, 12:00 central time, when the dust started (A) and 27 at 00:00 UTC, 18:00 central time, when the dust intensified across west Texas (B) and surface wind barbs (mph) and dew point temperature (°C, shaded) for February 26 at 18:00 UTC, 12:00 central time (C) and 27 at 00:00 UTC, 18:00 central time (D).