Response to Reviewer #1's comments

This paper provides an examination of the evolution of downhill thunderstorms over Beijing by using a radar wind profiler (RWP) mesonet. The results elucidate the storm's dynamic structures with a focus on both enhanced and dissipated events. The usage of high-resolution horizontal divergence and vertical motion data from the RWP mesonet to characterize the pre-storm environment represents a significant advancement in understanding these meteorological phenomena. The detailed case study, along with statistical analyses spanning the warm seasons of 2018 to 2021, contribute to our understanding of the factors influencing thunderstorm intensity and evolution in this region. Thus, I recommend the publication of this paper in Atmospheric Chemistry and Physics after some minor corrections for clarification.

Response: We appreciated tremendously your positive and invaluable comments, which indeed help improving the quality of our manuscript. We have addressed the reviewers' concern one by one to the best of our abilities. For clarity purpose, here we have listed the reviewers' comments in plain font, followed by our response in bold italics, and the modifications to the manuscript are in italics.

Minor comments:

1. The discussion on the implications of these findings for weather forecasting and model improvements may be further strengthened. Expanding this discussion could enhance the practical relevance of the research, suggesting pathways for incorporating these observations and methodologies into weather forecast models.

Response: Thanks for your suggestion. In the previous work of our team, it has been confirmed that dynamical variables with higher temporal and spatial resolution derived from the RWP mesonet have great potential to improve the prediction skill of convection with the aid of a machine learning model. The results therein show that the usage of RWP observational data as the random forest model input tends to result in better performance in rainfall/non-rainfall forecast 30 min in advance of rainfall

onset than using the ERA-5 data as inputs. Per your kind suggestion, the reference has been cited and related discussion is further strengthened in section 5.2 as follows:

"In the previous work, it has been confirmed that these dynamical variables derived from the RWP mesonet in Beijing provide strong supports for machine-learning-based prediction of severe convection (Wu et al., 2023). The results therein show that the usage of RWP observational data as the random forest model input tends to result in better performance in the rainfall/non-rainfall forecast 30 min in advance of rainfall onset than using the ERA5 reanalysis data as inputs. In the future, these dynamic observations and methodologies need to be further incorporated into machine learning model for improving the prediction skill of downhill thunderstorms."

References:

Wu, Y., Guo, J., Chen, T., and Chen, A.: Forecasting Precipitation from Radar Wind Profiler Mesonet and Reanalysis Using the Random Forest Algorithm, Remote Sensing, 15, 1635. https://doi.org/10.3390/rs15061635, 2023.

2. As suggested by the statistical analysis, urbanization effects may play a potential role in the enhancement of downhill thunderstorms. The authors may include a more detailed discussion of the process-level mechanism due to the importance of this effect.

Response: Per your suggestion, we add a more detailed discussion of urbanization effects on downhill thunderstorms as follows:

Wind direction on the foothill is affected by both a mountain–valley-breeze circulation and urban heat island (UHI) effect (Dou et al.,2015). In the early morning, low-level westerly and northwesterly winds converged into the Beijing's plain area because of a combination of downslope mountain breezes and strong-UHI-induced convergence, which accelerate the speed of thunderstorms towards the plain. The weaker southeasterly upslope valley breezes in the late afternoon and evening make downhill storms slow down and contribute to the prolonged duration. This explanation correlates well with the results in statistical analysis that the downhill storms that reach plain areas in the late afternoon have prolonged duration.

In addition, the urban-barrier effect is essential when the storms have entered the plain (Changnon, 1981; Zhang, 2020), especially under weak-UHI conditions. Thunderstorms may be bifurcated to move around cities due to the urban blocking effects. The supply of moisture along south-southwesterly winds are also bypassed the urban center to produce minimum humidity. Thus, the storm may be suppressed by an urban building-barrier induced divergence as it approaches the urban center, just like the EDS event. We have added a relevant paragraph in section 3.3 of the manuscript as follows:

"Interestingly, as the squall line propagated eastward and approached the urban center after 1500 LST, it rapidly dissipated with the area of convective echo decreasing by four fifths until 1600 LST (not shown). This appears to result from the blocking of water supply by the high risings over the Beijing's built-up area, the so-called "urban bifurcation" effects on moving thunderstorms (Changnon, 1981; Zhang, 2020). In this case, deep convection in the urban center and northern suburban area were suppressed due to the urban blocking effects. It was consistent with the persistent low-level divergence over triangle 3 and 4 with the maximum value of $3\times10^{-4}\ s^{-1}$ *occurring near surface (not shown). Clearly, this result can help understand the urban building-barrier induced divergence and the dissipation of thunderstorm."*

References:

Changnon, S.A.: METROMEX: a review and summary, Meteor. Monogr., No. 40, American Meteorological Society ,181, 1981.

Zhang, D.-L.: Rapid urbanization and more extreme rainfall events, Science Bulletin, 65, 516–518, https://doi.org/10.1016/j.scib.2020.02.002, 2020.

Dou, J., Wang, Y., Bornstein, R., and Miao, S.: Observed spatial characteristics of Beijing urban climate impacts on summer thunderstorms. Journal of Applied Meteorology and Climatology, 54, 94–104, doi:10.1175/JAMC-D-13-0355.1., 2015.

3. The methodology for identifying downhill thunderstorms has been clearly described with a thorough explanation of its criteria. It may be beneficial to clarify on how this methodology compares or improves upon existing approaches.

Response: Thank you for your suggestion! How this methodology compares with or improves upon existing approaches has been added in section 2.1 as follows:

"Most of previous research, either case studies or small sample statistics analysis, lack an objective criterion used to determine downhill thunderstorms. They typically focus on EDS in the presence of high-impact weather and less consider DDS. Compared to the existing approaches in the literature, our methodology can discriminate between these two types of downhill thunderstorms for its capability in defining the timing and location of storms and tracking their corresponding evolution. Therefore, this methodology can be readily applied to other regions with similar topography as long as weather radar measurements are available."

4. The authors may strengthen the discussion regarding the pre-convective environment for the downhill thunderstorms. Some discussions for the statistical characterizations for the humidity and temperature profiles may be helpful.

Response: The radiosonde launches just twice a day at 0800 and 2000 Local Standard Time (LST) at the station of BWO. For the sake of improving the prediction skill of summertime storm, an additional radiosonde launch is performed at 1400 LST daily at the BWO for the period from June 1 to August 31. In the case study of an EDS event, the thermal stratification* is *just obtained by the sounding 6–7 hours prior to storm. Thus, it's a pity that we cannot obtain the real-time humidity and temperature profiles from radiosondes for the pre-convective environment of the downhill thunderstorms. In further study, we will perform the statistics analysis of some thermodynamic parameters derived from radiometer, such as CAPE, K index, precipitable water, to characterize the pre-storm environments in detail.