

Response to reviewer comments

We are sincerely grateful to the editor and reviewers for their valuable time spent on reviewing our manuscript. The comments are very helpful and valuable, and we have addressed the issues raised by the reviewers in the revised manuscript. Please find our point-by-point response (in blue font) to the comments (in black font) raised by the editor and reviewers.

COMMENTS TO THE AUTHOR(S)

Introduction:

The introduction requires restructuring, a more thorough literature review of LiDAR techniques and a revision for English. The current description of LiDAR systems by platform, without addressing the underlying techniques, does not reflect the state-of-the-art in LiDAR technology for mobile aerosol monitoring. For instance, studies were performed with HSRL LiDARs aboard aircraft (Tesché et al., 2009; Burton et al., 2013; Müller et al., 2014; Dmitrovic et al., 2024) and satellite (Donovan et al., 2024; Sato et al., 2025), with both elastic and Raman LiDAR systems deployed aboard ships (Duflo et al., 2011; Yin et al., 2019; Floutsi et al., 2023; Sanchez-Barrero et al., 2026) and vehicles (Dieudonné et al., 2015; Popovici et al., 2018, 2022; Chazette and Totems, 2023; Sanchez Barrero et al., 2024). Each technique has its limitations and the reasons for selecting the elastic LiDAR (specifically a micropulse LiDAR or ceilometer type, as inferred from Table 1) for this work remain unclear. The current manuscript does not clearly place the study within the current advancements in ground-based mobile platforms, weakening the motivation.

Response: We appreciate your comments on our manuscript. Your suggestions have greatly helped improve the rigor of the paper and the presentation of the research motivation. We have comprehensively revised the introduction section following your guidance.

We have supplemented the motivation for adopting LiDAR in the revised manuscript and comprehensively elaborated on the mobile LiDAR technology for aerosol monitoring. The modified parts can also be found in lines 41-47 of the revised manuscript.

Our aerosol monitoring system is mainly designed for industrial parks and does not require ship-based deployment. Therefore, we have clarified the rationale for adopting an unmanned vehicle platform. For detailed revisions, please refer to Chapter 1 Introduction. The modified parts can also be found in lines 52-55, 57-65, 82-95 and 102-106 of the revised manuscript.

Methodology:

The methodology briefly outlines the elastic LiDAR equation and claims the system quantifies aerosol and cloud optical properties, stating that Rayleigh scattering can be neglected within the boundary layer. This is problematic for several reasons:

- The elastic LiDAR system described in the manuscript do not directly measure optical properties, it requires inversion methods (e.g., the widely used Klett method) to derive backscatter and extinction coefficients (Klett, 1986; Weitkamp, 2005; Speidel and Vogelmann, 2023).

Response: Thank you for pointing out that there are some inaccuracies in our description of the problem. This greatly helped improve our manuscript. We have carefully reviewed the literature and made corresponding modifications, as follows:

We fully agree with the accurate point. We hereby clarify that the LiDAR equation is a rigorous fundamental physical relationship, which establishes a definitive quantitative correlation between the received echo signal power, LiDAR system parameters, and the optical characteristic parameters of the detected targets, rather than being limited solely to qualitative characterization.

We have revised the description of Rayleigh scattering and the methodology adopted in this study in the revised manuscript. The modified parts can also be found in lines 137-142、152-157 and 163-165 of the revised manuscript.

- To my knowledge, neglecting Rayleigh scattering within the boundary layer is not supported by the literature. Rayleigh scattering is primarily due to molecules, whose concentration varies with altitude as pressure and temperature change. Molecular density is higher at lower altitudes, making Rayleigh scattering significant. The authors may be referring to a weaker effect due to wavelength dependency, but this needs clarification.

Response: Dear Reviewer, we sincerely appreciate your insightful comments on the methodology section. We fully agree with your comment that Rayleigh scattering cannot be neglected within the boundary layer, and the original expression in the manuscript was indeed inaccurate.

In the revised manuscript, we have supplemented the relevant paragraphs to more accurately describe the data processing methods adopted in this study.

We have removed the absolute statement that "Rayleigh scattering can be neglected". Meanwhile, we clarify that within the boundary layer with high aerosol loading, the intensity

of Mie scattering signals from aerosols is generally much stronger than the molecular Rayleigh scattering.

This reflects the preliminary nature of this study, and complete inversion methods (e.g., the Klett/Fernald method) will be introduced in future work.

- The "Rayleigh fit" is a standard quality control criterion for LiDAR data, further emphasizing the importance of accounting for Rayleigh scattering (EARLINET guidelines; Freudenthaler et al., 2018). Moreover, authors may use existing standard methods for LiDAR data quality control for the in-movement operation.

Response: Thank you for your further clarification regarding the treatment of Rayleigh scattering. In response to your comments, we have revised the manuscript accordingly. Our detailed response is provided below:

“The 1064 nm Mie-scattering LiDAR, developed for aerosol monitoring, excels at high-precision detection of the vertical fine structure of aerosols and clouds. Its echo signals include Mie scattering from aerosol particles and Rayleigh scattering from atmospheric molecules, with Rayleigh scattering generally weaker in the atmospheric boundary layer, where Mie scattering dominates under high aerosol loading(Freudenthaler et al., 2018).”

The modified parts can also be found in lines 137-142 of the revised manuscript.

The description of the intelligent driving platform can be substantially reduced and improved before publication. The selection of the method lacks justification and comparison with existing approaches, which would also considerably improve the introduction. Authors should justify why this method was chosen over others. Moreover, it is unclear whether this method is widely adopted or validated. If the methodology follows Qiu et al. (2023), is it necessary to include all the equations?

Response: Thank you for the suggestions you provided.

This path planning method is adopted because it is an existing approach developed by our research group and has been validated with published academic papers (refer to the literature below for details). The manuscript mainly focuses on the aerosol detection system, with the intelligent driving platform serving as an auxiliary component. Therefore, this part is not elaborated emphatically in the introduction. However, to better explain the solution of optimal control problems using the Gaussian pseudospectral method, we have added an

appendix after the references.

Qiu, D.; Qiu, D.; Wu, B.; Gu, M.; Zhu, M. Hierarchical Control of Trajectory Planning and Trajectory Tracking for Autonomous Parallel Parking. *IEEE Access*, 9, 94845–94861. doi:10.1109/ACCESS.2021.3093930., 2021.

Results:

The results section presents LiDAR measurements but several areas could be improved:

- Vertical Detection: The use of range-corrected signals (RCS) to indicate changes in aerosol concentration as a quantitative parameter can lead to erroneous interpretations. Though we can qualitatively infer higher or lower aerosol concentration, this is not straightforward. To discuss aerosol concentration, inversion methods and assumptions about aerosol types are essential (Bedoya-Velázquez et al., 2022; Popovici et al., 2022). The analysis at RCS level can focus on atmospheric structure (e.g., boundary layer height, aerosol layer altitude) rather than concentration claims. Figure 4 could be better utilized to study boundary layer development and aerosol layers. Including available sun-photometer AOD to provide inversion results for the same day (Mortier et al., 2016; Cazorla et al., 2017; López-Cayuela et al., 2022) would strengthen the analysis and comparisons with in-situ PM measurements.

Response: We fully agree with the reviewer's rigorous point.

We hereby provide a supplementary clarification: The LiDAR equation is a rigorous, fundamental quantitative physical relationship for atmospheric LiDAR detection. It establishes a clear quantitative correlation between the echo signal, LiDAR system parameters, and the optical characteristic parameters of aerosols. Range-corrected signals (RCS) are standardized signals obtained by preprocessing the raw echo signal based on this equation. They are not limited to qualitative description only.

- Cone-Scanning Detection: The purpose and potential applications of horizontal observations are unclear. The analysis lacks depth and fails to demonstrate the utility of this capability.

Response: We appreciate the reviewer's valuable comments, which have prompted us to more clearly clarify the limitations and future potential of scanning detection in the present study. We fully agree with your comment that the analysis depth and application value are insufficient.

We acknowledge that the advantages and effectiveness of the conical scanning mode have not been fully illustrated in the present study. This is mainly attributed to the limitations of

the experimental site: when performing horizontal scanning in the current campus environment, the laser path is easily blocked by buildings, resulting in the failure to obtain valid and atmospherically representative echo signals. Therefore, the relevant analysis in the original manuscript is indeed limited to the preliminary verification stage and fails to fully explore the practical application value of the system. Based on this, we will revise and clarify the content in the Discussion or Future Work section of the manuscript as follows.

1、 In this experiment, constrained by the experimental site, the conical scan data were mainly used to verify the basic capability of the system to operate in this mode, rather than for in-depth scientific retrieval.

2、 The conical scan mainly enables three-dimensional scanning and positioning tracking of atmospheric aerosols. Compared with vertical detection, its unique advantage lies in the ability to resolve pollutant transport pathways and monitor the spatial diffusion dynamics of specific pollution sources.

3、 Future experiments will be conducted at open sites (e.g., high-rise rooftops, mountain-top observatories) to ensure an unobstructed laser path, thereby obtaining high-quality data for wind field retrieval and horizontal diffusion analysis.

- In-Movement Measurements: This section is brief and does not convincingly show how the system enables real-time regional pollution monitoring or control.

Response: We appreciate your comments on this section. We agree that the elaboration was insufficient and failed to effectively demonstrate how the system realizes real-time regional pollution monitoring and control. To address this issue, we have revised the manuscript accordingly. The modified parts can also be found in lines 328-330 of the revised manuscript.

Due to the limitations of experimental conditions, additional cruise experiments cannot be conducted. However, the mobile cruise routes completed in previous experiments demonstrate that the system can acquire spatially continuous aerosol distribution data. Moreover, these results can intuitively present the variations in aerosol signals captured during movement, thereby effectively reflecting the dynamic characteristics of the system. Although real-time pollution intervention measures were not implemented during the experiment, we will focus on monitoring areas with high aerosol pollution in subsequent

studies to provide a scientific basis for the precise control of pollution sources.

Discussion:

While the discussion acknowledges potential failures or performance degradation, it lacks a rigorous analysis of the LiDAR's limitations during in-movement operation. Critical issues such as opto-mechanical stability under extreme temperatures or induced vibrations, and performance under high aerosol loads or increased background noise during daylight are not addressed. These factors are essential for evaluating the system's robustness and practical applicability.

Response: We appreciate your insightful comments. The issue you raised is critical—the practical limitations of LiDAR during mobile operation, which directly determine the practical value of the system. This will also be a key focus of our future improvements.

Vibrations occurring during unmanned intelligent cruise experiments may affect the stability of the LiDAR system. Such vibrations can cause slight misalignment between the transmitting and receiving optical paths, thereby inducing non-aerosol fluctuations in the Range-Corrected Signal (RCS), and may even lead to detection blind zones or a sharp drop in the signal-to-noise ratio. Therefore, to eliminate the influence of vibration, the moving speed was controlled within 1.0 m/s in the experiments of this study. In future work, an active vibration damping platform will be installed to improve the data reliability of mobile measurements.

The issue that the detection capability of a Mie-scattering LiDAR may be affected by signal saturation or nonlinear attenuation under high aerosol load conditions was already taken into consideration when we selected the LiDAR. Details of the lidar system used in this study can be found in the references listed below. The modified parts can also be found in lines 354-369 of the revised manuscript.

Kuang, Z.; Liu, D.; Wu, D.; Wang, Z.; Li, C.; Deng, Q. Parameter Optimization and Development of Mini Infrared Lidar for Atmospheric Three-Dimensional Detection. *Sensors*, 23 (2), 892. <https://doi.org/10.3390/s23020892>, 2023.

Conclusions:

The conclusions are not adequately supported by the results presented in the current manuscript.

Response: Dear reviewer, thank you for your comments. We promptly addressed them in our revisions. We acknowledge that the system, in its current form, cannot perform real-time pollution warning, and this is indeed a key direction for future improvements. However, the system already possesses the capability for unmanned intelligent cruising and can provide spatially resolved data essential for pollution warning analysis. The modified parts can also be found in lines 386-388 of the revised manuscript.

Response to reviewer comments

We are sincerely grateful to the editor and reviewers for their valuable time spent on reviewing our manuscript. The comments are very helpful and valuable, and we have addressed the issues raised by the reviewers in the revised manuscript. Please find our point-by-point response (in blue font) to the comments (in black font) raised by the editor and reviewers.

COMMENTS TO THE AUTHOR(S)

Please incorporate some comments in the paper regarding Mie-scattering lidar (as you provided in the author's response document) in a short paragraph motivating its use in the paper. The same for the second comment regarding the discussion of autonomous driving versus alternative platforms. This should be discussed in the main-body text.

Response: We appreciate your valuable comments. Following your suggestions, we have supplemented the manuscript with content on Mie-scattering LiDAR and autonomous driving platforms, which can be found in Section 2.1 of the revised manuscript. The modified parts can also be found in lines 114-115 and 134-142 of the revised manuscript.

Table 1. It is not clear the meaning of the new fields: is “vehicle lidar measurement accuracy” the mean distance measurement error? Is the “vehicle lidar distance measurement” the minimum distance that the vehicle lidar can measure, or is it its resolution?

Response: Thank you for the suggestions you provided.

This discrepancy might arise from our insufficiently clear description. For greater clarity, we have added detailed descriptions of the vehicle-mounted lidar and binocular camera hardware in the revised manuscript. The modified parts can also be found in lines 117-123 of the revised manuscript.

Please include in the text a brief summary of the lidar model characteristics or cite the corresponding reference when the lidar model is discussed. Please include in the text the models of the main parts of the hardware. All are not necessary, but at least the Lidar, the computing platform, the vehicle lidar, etc.

Response: We greatly appreciate your valuable suggestions, which are crucial for improving

the rigor and reproducibility of this paper. We have supplemented the relevant content in the main text in accordance with your comments. These details can be found in Section 2.1 of the revised version.

Mie-scattering LiDAR: The overall dimensions of the Mie-scattering LiDAR are controlled within $200\text{mm} \times 200\text{mm} \times 420\text{mm}$, with a total weight of 13.5kg and a power consumption of less than 100W(Kuang et al., 2023). The 1064 nm Mie-scattering LiDAR, developed for aerosol monitoring, excels at high-precision detection of the vertical fine structure of aerosols and clouds. Its echo signals include Mie scattering from aerosol particles and Rayleigh scattering from atmospheric molecules, with Rayleigh scattering generally weaker in the atmospheric boundary layer, where Mie scattering dominates under high aerosol loading(Freudenthaler et al., 2018).

Computing Platform: The selected computing platform hosts the Baidu Apollo autonomous driving system.

Vehicle LiDAR: The vehicle LiDAR is a 16-line laser radar (RS-LiDAR-16), which integrates 16 laser emission channels. It has a maximum detection range exceeding 150 meters, a ranging accuracy of $\pm 2\text{ cm}$, a point cloud output rate of up to 320,000 points per second, and features a 360° horizontal field of view and a 30° vertical field of view.

The modified parts can also be found in lines 114-115、 117-123 and 134-142 of the revised manuscript.

Regarding the editing of Sect. 2.4. in the previous review: “Unmanned Mobile Detection Path Planning Algorithm requires extensive editing. [...] In its current form, it feels disconnected from the rest of the manuscript. Many readers of this journal may not have a strong background in control theory; therefore, additional plain-language explanations are needed to bridge the mathematical formulation and its application to your path-planning problem.”, the is not reflected in sufficient changes of the manuscript. Please, either create an appendix with all detailed equations and explanations, or restructure Sect. 2.4. to be self-contained and understandable by non-experts in control theory.

Response: We sincerely appreciate your valuable and professional comments, which are

essential for enhancing the professionalism and rigor of this paper. We have added an appendix after the references to elaborate on the solution of optimal control problems using the Gauss pseudospectral method.

In section 3.1., the discussion regarding MERRA-2 is insufficient. Moreover, according to the data shown in Fig. 5 c), it seems that the high pollution episode is finished the 24/02/2025. You could provide the hourly evolution of MERRA-2 AOD for the 24/02/2025 and compare it against lidar RCS and PM10, PM2.5 measurements.

Response: We thank you for your specific suggestions regarding the discussion of MERRA-2 data in Section 3.1. In response to the issues you raised, we have revised the manuscript accordingly, supplementing the discussion of the MERRA-2 data. The discussion addresses the complementarity between MERRA-2 data and lidar data, highlighting the advantages of lidar for the detection of regional pollution. For details, please refer to Section 3.1.

In the revised manuscript, hourly MERRA-2 AOT data have been incorporated into Section 3.1. By supplementing this hourly evolution data, we are able to demonstrate that the lidar system accurately captures the relative variation process of pollution concentration, thereby validating its reliable pollution monitoring capability. The modified parts can also be found in lines 227-282 and 283-285 of the revised manuscript.

Lines 213-215: These analysis lines are difficult to understand. Please check the grammar and meaning and rephrase.

Response: Thank you for the suggestions you provided.

We have fully revised and rephrased Lines 213–215 to facilitate readers' understanding.

In section 3.2. please indicate the exact times “HH:MM UTC” of the cone measurements. Why use 1h? The measurement time is kind of long, and aerosol/cloud conditions can change extensively during a period of 1 hour (look at Fig.4 for example).

Response: We sincerely appreciate the important comments from the reviewer. Your concern regarding the measurement duration and the dynamic changes in aerosol conditions is highly

critical.

As for the specific measurement timestamps, we have supplemented and clarified the accurate starting and ending times of the conical scan experiment in Section 3.2. The modified parts can also be found in lines 297-302 of the revised manuscript. This arrangement facilitates the analysis of observational data within a specific meteorological and atmospheric environment context.

Explanation on the 1-hour measurement duration: The adoption of 1-hour continuous scanning is mainly based on the following technical considerations. Conical scanning is designed to retrieve the three-dimensional spatial distribution of pollutants. To obtain reliable retrieval results, sufficient independent laser pulse echoes must be accumulated at each azimuth angle to achieve the required statistical accuracy. Achieving a complete, uniformly sampled conical scan and meeting the minimum data requirements does necessitate a relatively long continuous observation period. We have provided supplementary explanations in the corresponding sections of the manuscript.

Section 3.2. is uncontextualized with the rest of the manuscript. Please motivate within Section 3.2. what is its purpose. For instance, would the system be used for unmanned conicals canning? What are its applications? Is there any reference that can be added to support this? Please add the changes in the main body text.

Response: We thank the reviewer for raising this important point.

There are three working modes for LiDAR to detect aerosols: fixed vertical detection, scanning detection, and mobile detection. Due to limitations of the experimental environment, the laser beam strikes high-rise buildings during horizontal scanning, resulting in the failure to collect valid echo signals. Accordingly, we adopted conical scanning, whose primary purpose is to obtain the three-dimensional spatial distribution of atmospheric targets (e.g., aerosols, clouds, and wind fields). This method enables four-dimensional (three spatial dimensions plus time) dynamic monitoring of atmospheric processes within the observation area, including pollutant dispersion, cloud formation and dissipation, and wind field evolution. It thus provides critical data for pollution source tracing, meteorological analysis, and climate

research. This can be referenced from the following article.

Xie, C.; Zhao, M.; Wang, B.; Zhong, Z.; Wang, L.; Liu, D.; Wang, Y. Study of the Scanning Lidar on the Atmospheric Detection. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 150, 114–120. doi:[10.1016/j.jqsrt.2014.08.023](https://doi.org/10.1016/j.jqsrt.2014.08.023)., 2015.

Extensive revision of the document English is required. There are some paragraphs which are difficult to understand by an external reader. I suggest using a grammar revision software or contact an English native editor.

Response: Thank you for the suggestions you provided.

We have revised the manuscript accordingly.

I appreciate the addition of Sect. 4 discussion. However, some improvements are still needed. Apart from the limitations, consider adding the advantages of it: how it is able to measure the aerosol conditions in a controlled environment (your testing site), etc. A more profound explanation of the method limitations is required. For example (don't limit it to this) elaborate a bit more on harsh weather conditions such as rain or snow.

Response: We thank the reviewer for raising this important point. We acknowledge that, as correctly noted, the performance of the currently used Mie-scattering lidar indeed faces challenges when operating in precipitation conditions such as rain or snow. This is primarily due to two main reasons:

1. Signal Attenuation and Scattering Distortion: Raindrops and snowflakes induce intense Mie scattering and absorption of the laser pulses. This results in severe attenuation of the effective backscattered signal and introduces significant background noise. This results in a degradation of the raw signal-to-noise ratio, thereby compromising the accuracy of aerosol optical parameter retrieval and reducing the effective detection range.

2. Limitations in Environmental Adaptability: The prototype developed in this study is currently positioned primarily as an experimental verification system. Its design prioritized the realization of core functionality, a high degree of integration, and overall portability. Therefore, the entire system has indeed not yet undergone rigorous waterproof and dustproof

rating certification tests. Operation under continuous precipitation conditions entails certain operational risks.

In response to this concern, we have clearly stated in the experimental section of the manuscript that all field observations were conducted under precipitation-free conditions to ensure the reliability of the data obtained. We fully agree that if the system is to be deployed for all-weather operational observation in the future...

This includes applying a hydrophobic coating to the optical window and implementing a sealed enclosure design for the entire unit to achieve a protection rating of at least IP65. The modified parts can also be found in lines 354-369 of the revised manuscript.

We have incorporated this limitation and the aforementioned directions for improvement as prospects for future work into the Discussion section of the manuscript. Once again, thank you for your insightful comments, which are crucial for improving our work.

Response to editor comments

We are sincerely grateful to the editor and reviewers for their valuable time spent on reviewing our manuscript. The comments are very helpful and valuable, and we have addressed the issues raised by the reviewers in the revised manuscript. Please find our point-by-point response (in blue font) to the comments (in black font) raised by the editor and reviewers.

COMMENTS TO THE AUTHOR(S)

Dear authors, the changes made are not yet sufficient to meet the standards of Atmospheric Measurement Techniques. Both referees recommend major revisions. The authors are asked to:

(1) revise the introduction with a thorough literature review on lidar techniques for mobile platforms, justifying the choice of the elastic lidar system;

Response: Thank you for your valuable comments. We have substantially revised the introduction section of the manuscript. The revisions include a comprehensive literature review on lidar technology for mobile platforms and a discussion of the rationale for selecting the lidar system. The modified parts can also be found in lines 52-55、 57-65、 82-95 and 102-106 of the revised manuscript.

(2) move key explanations from the rebuttal (Mie-scattering lidar motivation, autonomous driving vs. alternatives) into the main text;

Response: Thank you for your valuable comments. In the revised manuscript, we have supplemented the rationale for selecting the portable Mie-scattering LiDAR and discussed the considerations for adopting the autonomous driving platform. All corresponding revisions have been incorporated into the manuscript, and full details are available in the revised manuscript. The modified parts can also be found in lines 114-115 、 117-123 and 134-142 of the revised manuscript.

(3) clarify Table 1 and include hardware model details;

Response: Thank you for your comments. We have added detailed descriptions of the computing platform, the Mie-scattering lidar, and the onboard sensors in the main text. The manuscript has been revised accordingly as requested. For details, please refer to Section 2.1.

The modified parts can also be found in lines 117-123 of the revised manuscript.

(4) apply proper inversion methods (e.g., Klett) to derive aerosol optical properties instead of relying on range-corrected signals;

Response: Thank you for the suggestions you provided. In this study, the original signals are mainly processed by range-squared correction to obtain the Range-Corrected Signal (RCS), which is used to analyze the vertical distribution of aerosols. Within the boundary layer with high aerosol concentration, the contribution of Mie scattering usually dominates, and the Range-Corrected Signal (RCS), which is used to reflect the aerosol concentration and vertical distribution characteristics. The modified parts can also be found in lines 137-142 and 163-165 of the revised manuscript.

In the future, we will continue to optimize the system by adopting quantitative retrieval of aerosol concentration, thereby providing accurate data support for real-time regional pollution warning.

(5) justify the treatment of Rayleigh scattering;

Response: Thank you for your further clarification regarding the treatment of Rayleigh scattering. In response to your comments, we have revised the manuscript accordingly. Our detailed response is provided below: Regarding the discussion on Rayleigh scattering, we have added a relevant paragraph in Section 2.1. The modified parts can also be found in lines 137-142 of the revised manuscript.

(6) restructure Sect. 2.4 to be accessible to non-experts in control theory;

Response: We sincerely appreciate your valuable and professional comments. We have followed the suggestion from one of the reviewers and added an Appendix after the References section. In the revised manuscript, which elaborates in detail on the implementation of the Gauss Pseudospectral Method (GPM) for solving the optimal control problem.

(7) extend the MERRA-2 analysis in Sect. 3.1 and compare hourly AOD with lidar RCS and PM measurements;

Response: We thank you for your specific suggestions regarding the discussion of MERRA-2 data in Section 3.1. In response to the issues you raised, we have revised the manuscript accordingly, supplementing the discussion of the MERRA-2 data. In the revised manuscript, hourly MERRA-2 AOT data have been incorporated into Section 3.1. By supplementing this hourly evolution data, we are able to demonstrate that the lidar system accurately captures the relative variation process of pollution concentration, thereby validating its reliable pollution monitoring capability. The modified parts can also be found in lines 227-282 and 283-285 of the revised manuscript.

(8) add exact measurement times in Sect. 3.2 and better motivate the cone-scanning application;

Response: Thank you for your valuable comments. The timestamps labeled in the scanning figures correspond to the actual measurement times.

Explanation on the 1-hour measurement duration: The adoption of 1-hour continuous scanning is mainly based on the following technical considerations. Conical scanning is designed to retrieve the three-dimensional spatial distribution of pollutants. To obtain reliable retrieval results, sufficient independent laser pulse echoes must be accumulated at each azimuth angle to achieve the required statistical accuracy. Achieving a complete, uniformly sampled conical scan and meeting the minimum data requirements does necessitate a relatively long continuous observation period. We have provided supplementary explanations in the corresponding sections of the manuscript. The modified parts can also be found in lines 297-302 of the revised manuscript.

(9) expand the discussion with system advantages and more detailed limitations under harsh conditions. The authors are invited to address all comments in both referee reports before resubmission.

Response: Thank you for your comment. We have added a more detailed discussion of the constraints and limitations inherent in the system's current technical configuration. The modified parts can also be found in lines 354-369 of the revised manuscript.