Anonymous Referee #3

This study proposed an inversion method of atmosphere aerosol or cloud microphysical parameters based on dual wavelength lidar data. However, several comments below should be settled.

Response: Thank you very much for your nice comments. Your question and suggestion are very helpful for us to improve the quality of our paper. We appreciate the reviewer's thoughtful review and constructive comments. The following is our point-to-point replies.

1. Line 31: an5bd?

Answer: it is a clerical error. It should be "and". We will check and revise the manuscript sentence by sentence to avoid mistakes. Thanks.

2. Part 2.2: This section needs to be improved by expanding to include more supportive figures and detailed descriptions.

Answer: Thanks for your nice comments.

This section has been modified as

"In order to study the characteristics of APSDs and CDSDs in the vertical altitude, the APSDs and CDSDs obtained from aircraft observations by the Hebei Provincial Weather Modification Office were analyzed (from 2005 to 2006). APSDs were measured by the PCASP-100X probe, and CDSDs were obtained by the FSSP-100-ER probe [29]. The PCASP-100X is an optical particle counter for measuring aerosol size distribution from 0.10 μm to 3.00 μm in diameter in 15 different size bins with a frequency of 1 Hz. The sample flow volume in the PCASP-100X was set to 1 cm^3 s^{-1}. FSSP-100-ER is an instrument that measure cloud droplet size and concentration using light scattering, with the measurement range of 0.5-47 μm.

The obtained APSDs and CDSDs were fitted one by one using Gamma function. In order to minimize the error at all radius, the minimization problem is solved using the following equation

$$\int_0^{D_{max}} \left(\log\left(f_m(D)\right)-\log\left(f_{fitted}(D)\right)\right)^2 \mathrm{d}D \to \min \qquad (12)$$

here, $f_{\mathrm{m}}(D)$ is the actual particle size distribution measured by the PCASP-100X, $f_{\mathrm{fitted}}(D)$ is the fitted distribution, D is the aerosol particle diameter, D_{max} is the measured maximum particle diameter. The goodness of fit R^2 is used to represent the difference between the fitting function and the measured data. The definition of goodness of fit is as follows::

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i-\hat{y}_l)^2}{\sum_{i=1}^{n}(y_i-\bar{y})^2} \qquad (13)$$

where y_i is the measured value, $\hat{y}_l$ is the predictive value, $\bar{y}$ is the mean measured value. The numerator represents the sum of squared residuals, and the denominator represents the sum of squared total deviations.

~3500 sets of APSDs and 2221 sets of CDSDs were statistically analyzed. Over 95% of the data have a high goodness of fit in the Gamma distribution. The goodness of fit of CDSDs is higher than that of APSDs, with CDSDs of 0.983 and APSDs of 0.856. The parameters of CDSDs are significantly larger than that of APSDs, and there are obvious differences of b and c for cloud and aerosol. The literature suggests that there is a certain functional relationship between the Gamma parameters b and c of CDSDs [30]. Statistical analysis was conducted on the b and c parameters of APSDs and CDSDs, as shown in Fig. 1.

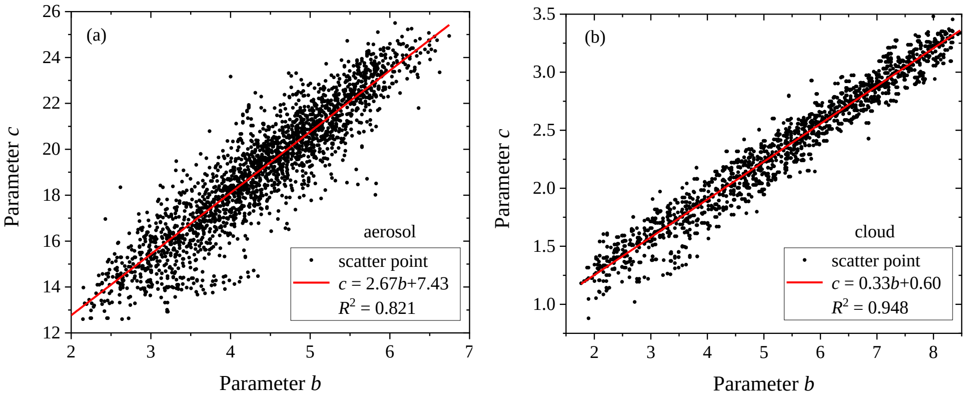

Fig. 1 Statistical Results of parameter *b* and *c* in aerial survey data. (a)Aerosol particles, (b)cloud droplets.

According to Fig. 2, there are the remarkable linear relationships between parameter b and c. The fitting functions for CDSDs and APSDs are as follows:

$$\begin{cases} c_{\text{cloud}} = 0.33 b_{\text{cloud}} + 0.60 \\ c_{\text{aerosol}} = 2.67 b_{\text{aerosol}} + 7.43 \end{cases} \quad (14)$$

The linear relationship between the two parameters of CDSDs is better with a goodness of fit of 0.948, and a linear goodness of fit of 0.821 for APSDs. According to the statistical results, the parameter b of APSDs at vertical height is mainly distributed in the range of 2-7, and CDSDs is mainly distributed in the range of 2-8. “

3. Figure 2: Not clear, Add more details on the description of the algorithm. For example, the look-up-table, etc.

Answer: Thanks for your nice comments.

We have redrawed the flowchart of the algorithm, and shown as the following figure.

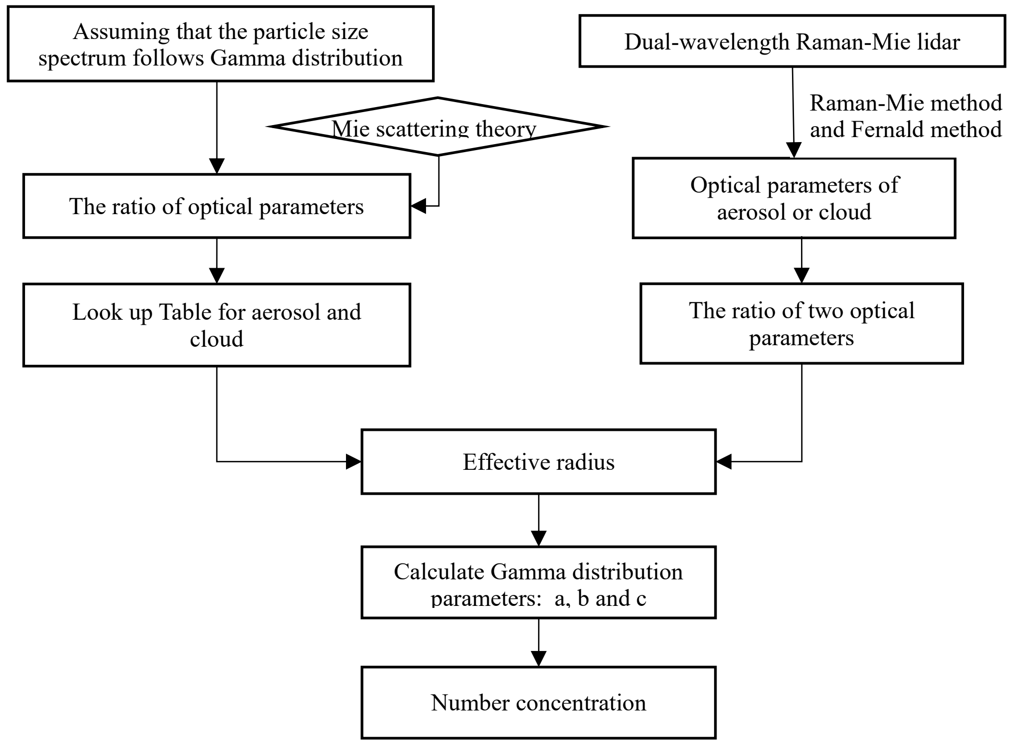

Figure I the algorithm flowchart for atmosphere particle microphysical parameters

And the descriptions of the algorithm are added.

"In this algorithm, the first step is to establish a lookup table between aerosol/cloud optical parameters and microphysical parameters. 1) Assuming that aerosol particles and cloud droplets follow the Gamma distributions, calculate the extinction coefficient and backscatter coefficient at different laser wavelengths (355nm and 1064nm in this paper) based on the Mie scattering theory; 2) Calculate the ratio of backscatter coefficients for two wavelengths, which is the backscatter color ratio, or calculate the ratio of extinction coefficient to backscatter coefficient, which is the radar ratio; 3) Change the parameters of the aerosol to obtain the gamma distributions with effective radius from 0.2 μm to 3 μm, calculate the optical parameters and corresponding optical parameter ratios (radar ratio or backscatter color ratio) for each Gamma distribution, and establish the lookup table for aerosol effective radius; 4) Similar to the step 3, establish the lookup table for cloud drops (effective radius are from 0.5 μm to 5 μm). After the lookup table is completed, the microphysical parameters of aerosols or clouds are calculated based on the lookup tables and LiDAR detection data. The specific steps are as follows: 1) the dual-wavelength (355 nm and 1064 nm) Raman LiDAR need be selected for the detection of atmosphere; 2) Raman and Fernald methods are used for the retrieval of optical parameters at multi-wavelengths, and the backscatter color ratio or lidar ratio can be obtained ; 3) aerosol and cloud layers are identified based on lidar echo signals; 4) Retrieve the effective radius of aerosols or cloud droplets at different heights based on optical parameters ratios and lookup tables; 5) Calculate the parameters b and c in the Gamma distribution according to formulas (11) and (14); 6) Calculate the value of a in the Gamma distribution according to formula 18; 7) Calculate the number concentration according to formulas (2) and (5). "

4. line 136: How to determine the boundary of the blue box?

Answer: The boundary of the blue box is determined by the common monotonic variation interval of multiple curves. Thanks.

5. line 143: you claimed that the larger the value of b, the more pronounced the Gamma function describes the characteristics of large particles. Why did you choose b=6 for cloud droplets, and b=3 for aerosols?

Answer：Because the particle size of cloud droplets is larger than that of aerosols, it is preferred to choose the b-value of cloud droplet as the larger value and the aerosol as the smaller value. On the other hand, according to Figures 4 and 5, we can also observe that the influence of b value on the results is not significant.

6. Figure 5: these figures do not match the description. The 3.2.2 part should be modified.

Answer：”when the complex refractive index of particles changes, the color ratio curves will fluctuate, but they always monotonically decreases at 0.3 μm to 1.7 μm.” has been modified to “when the complex refractive index of particles changes, the color ratio curves will fluctuate, but they always monotonically decreases at 0.3 μm to 1 μm.” Thanks.

7. Line 159-160: It is claimed that “According to Fig. 5, when the complex refractive index of particles changes, the color ratio curves will fluctuate, but they always monotonically decrease at 0.3 μm to 1.7 μm.”. However, the content displayed in some figures does not align with the aforementioned description. Furthermore, why is there a need to emphasize “0.3 μm to 1.7 μm”? How do the authors determine these two boundary values?

Answer：This question is the same as the previous one. There is an error in the manuscript，and it should be “they always monotonically decrease at 0.3 μm to 1 μm. ” this error will be modified in the revised manuscript. Thanks.

8. Figure 6: The text of the legend of Figure6(a) and 6(b) such as Inversion value and True value should be modified.

Answer：Thanks

“True value” has been modified to “the initial values” , and “Inversion value” has been modified to “the retrieved values”. And the Figure 6 are shown as:

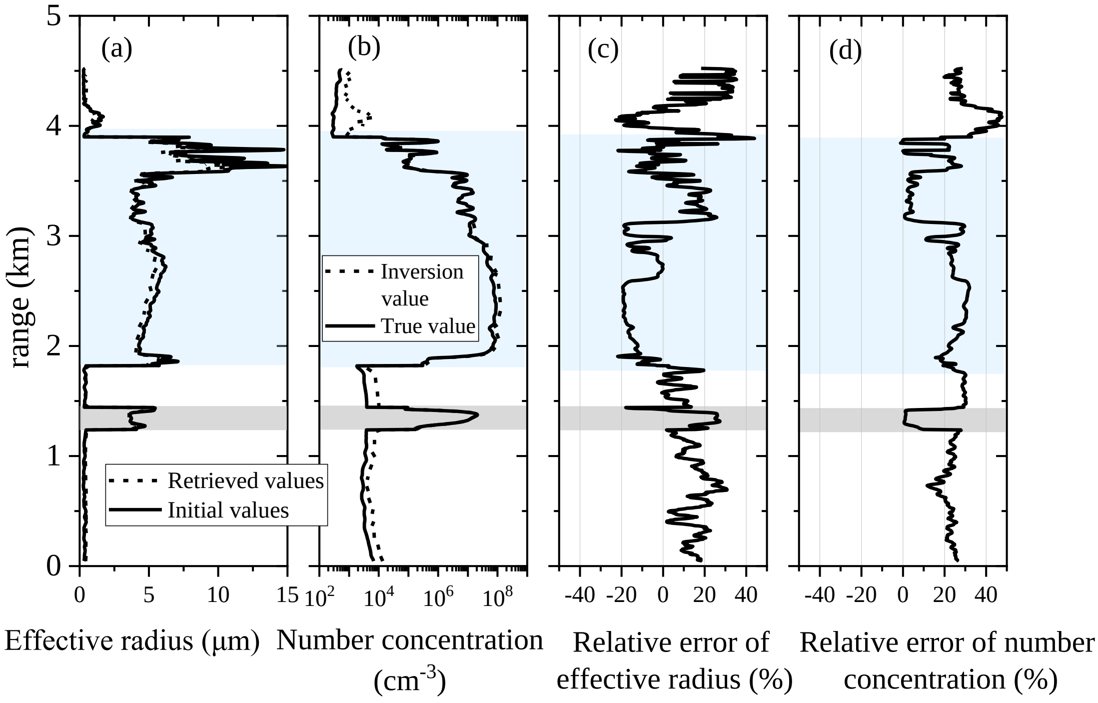

Figure 6

9. Part 3.3, line 182-183: It is claimed that the first three factors have been discussed earlier and this section focuses on the inversion error introduced by optical parameters. As the error analysis of the algorithm, the all factors which affected the inversion algorithm should be discussed.

Answer: Yes, the opinion of reviewer is right that "all factors which affected the inversion algorithm should be discussed". More discussions and explanations about error analysis of the algorithm will be added to the revised draft.

For urban aerosols and water clouds, their particles are spherical, so the error caused by non-spherical particles can be ignored.

The error introduced by the assumption of Gamm distribution is relatively complex and difficult to accurately calculate. This study evaluates this error by numerical simulation based on APSDs and CDSDs data by aircraft observations. Actually, the error presented in Figure 7 is mainly caused by the assumption of Gamm distribution. Calculate optical parameters of over 5000 sets of APSDs and CDSDs data, and retrieve the microphysical parameters using our algorithm. The calculated standard deviations between the inversion results and the actual data are: for aerosols, the standard deviation of the effective radius is ~10%, and the standard deviation of numerical concentration is 20%; For clouds, the standard deviation of the effective radius is 15%, and the standard deviation of numerical concentration is 20%.

The deviation introduced by improper assumption of complex refractive index may be the largest term in this technique. For water clouds, the complex refractive index is stable and the deviation caused by it can be ignored. It is difficult to accurately obtain the complex refractive index of aerosols, and the deviation caused by the complex refractive index may reach over 100%. Figure 6 shows the effect of complex refractive

index variation on the optical parameter ratio. From Figure 6, it can be seen that when the real part of the complex refractive index changes within the range of 0.03 and the imaginary part changes within 0.01, the effective radius deviation caused by the complex refractive index is within a controllable range. After calculation, the deviation does not exceed 40%. And it can be seen that although complex refractive index can lead to the significant change of the effective radius value, when the aerosol is constant, its monotonic characteristics remain unchanged, which means that the evaluation of particle size changes is reliable.

The above three errors are independent of each other. Considering the actual inversion ability of LiDAR, the deviation of color ratio will reach 10%. The final evaluation shows that the mean square deviation of the inversion error of aerosol effective radius is less than 45%, and the standard deviation of the inversion error of cloud droplet effective radius is 25%.

10. Part 4.2: the experimental observation of a cloud generation process was provided in this part. How can the experiment be confirmed as a test of the cloud generation process, rather than clouds drifting in from other locations?

Answer：

When using LiDAR for vertical detection at fixed points, it often detects clouds floating over from other places. However, we believe that Figure 9 shows a process of cloud generation, as we can see from Figure 9 that the aerosol gradually thickens and the cloud gradually thickens, so it should be the generation process of cloud. Clouds drifting from other places usually do not have such clear signal growth process, and the boundaries are usually very clear.

11. Figure 8: The description of the Figure 8 should be modified. Figure 8(b) is not the lidar observations.

Answer：Thanks，Figure 8(b) is not the lidar observations， and it is the temperature and relative humidity profiles obtained from the sounding balloon at 7:15 am (BJT).

12. Figure 9 and Figure 10: What the error bars stand for?

Answer：The error bar represents the uncertainty of the inversion result. The error of backscattering coefficient and backscatter color ratio is determined by the signal-to-noise ratio of the LiDAR system and the error of the optical parameter inversion algorithm. The error bar of the effective radius represents the uncertainty of the results caused by optical parameter errors and gamma distribution assumption errors.

13. Only one experimental observation was provided. Could you provide more experiments?

Answer：Our experimental observation data has other cases, as shown in the following figures, which is another case of observed cloud formation process. The variation process of effective radius and numerical concentration can be clearly displayed. However, this article focuses on the research of data inversion methods, so one case in

the article is sufficient. Thanks!

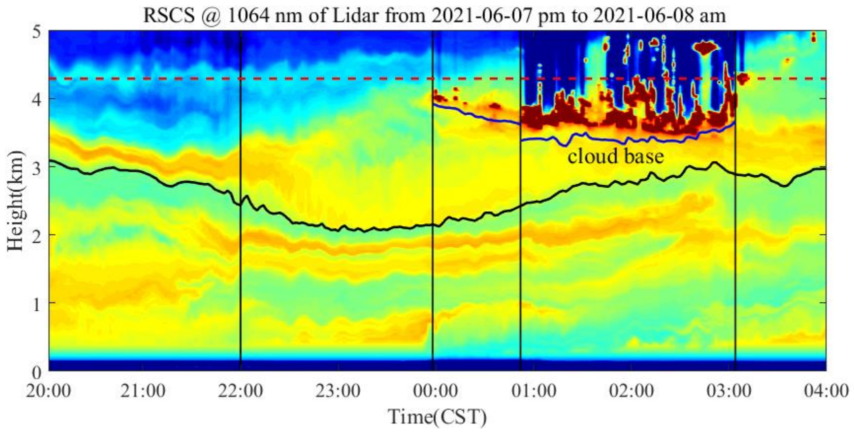

Fig. I Lidar observations at 20:00 June 7 to 4:00 June 8, 2022(CST) (THI diagram of RSCS at 1064 nm)

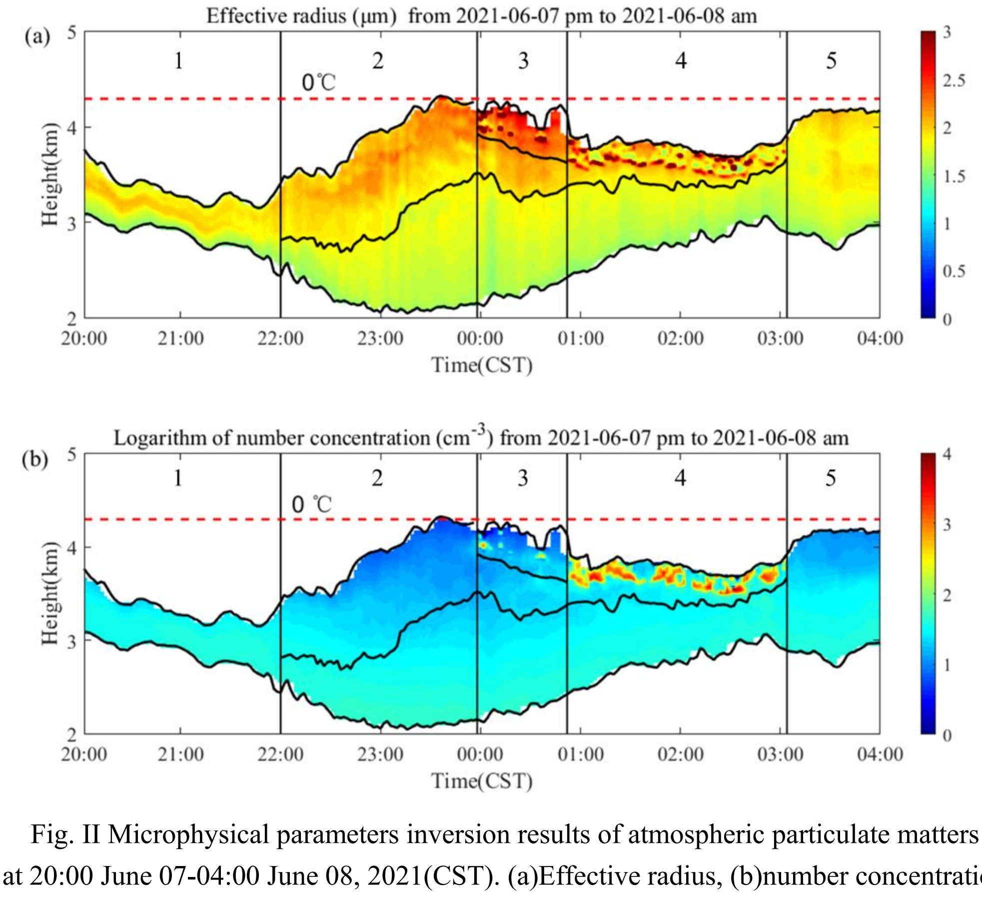

Fig. II Microphysical parameters inversion results of atmospheric particulate matters at 20:00 June 07-04:00 June 08, 2021(CST). (a)Effective radius, (b)number concentration