Review of "An iterative algorithm to simultaneously retrieve aerosol extinction and effective radius profiles using the CALIOP lidar" by Liang Chang et al.

Recommendation: Minor Revisions

The manuscript "An iterative algorithm to simultaneously retrieve aerosol extinction and effective radius profiles using the CALIOP lidar" provides a modified two-wavelength lidar inversion algorithm to retrieve the vertical distribution of both aerosol extinction and particle effective radius. The study built a look-up table to relate the lidar ratio with the Ångström exponent calculated using aerosol extinction at the two wavelengths. In order to verify the accuracy of the algorithm, two different lidar data (ground-based Raman lidar and CALIOP) were used for the application and the results showed good agreement.

In general, the paper presented in a logical way, but lightly lacking in English expression. The algorithm has some prospects of practical application. I therefore recommend publication of this paper in Atmospheric Measurement Techniques after minor revisions. My comments are listed as follows:

Response: We thank the reviewer very much for his/her encouraging comments, and we have revised the manuscript according to these specific comments and technical corrections.

Specific Comments:

1. Table 1 shows the aerosols parameters of the look-up table. How were these parameters obtained? If derived from experimental or simulation results, please

explain in the manuscript and provide references.

Response: Sorry for the confusion. These parameters are obtained from aerosol classification used in the operational algorithm of CALIOP, and we have added the references following this sentence.

2. In line 148 of the manuscript, it is mentioned "an initial guess". How did this initial guess work out? Does the selection of values for the initial guess affect the final results obtained.

Response: We guess the the initial value from the Look-up tables (Figure 1). For example, when AE is minimum, the lidar ratios are about 40 at 532 nm and 60 at 1064 nm. In the test of the inversion alagorithm with synthetic data, we test several sets of initial lidar ratios (e.g., 60 at 532 nm & 80 at 1064 nm, 80 at 532 nm & 60 at 1064 nm, 40 at 532 nm & 30 at 1064 nm, etc.), and find that using these initial value can all reach similar retrieval results. The only difference is the number of iterations. Therefore, the initial lidar ratios of 40 at 532 nm and 60 at 1064 nm are used in the following retrieval.

3. In line 18 How are these four types of aerosols distinguished and determined? Please explain in the manuscript.

Response: We are sorry for the confusion. On the test of the inversion alagorithm with synthetic data, we find that selection of aerosol type is critical as incorrect assumption of aerosol refractive index will result in divergence of the algorithm and fail to yield valid retrieval. Similar behavior is noted in the application to real lidar measurements. Thus, we determine the aerosol type by selecting the one that yields the best retrieval results. We added the following explanation in Lines 177-178:

"*This also helps us to determine the appropriate aerosol type, i.e., the type that yields the best retrieval results.*"

4. Figure 5(d) shows the results of the aerosol effective radius profiles obtained from the inversion, but without corresponding comparative validation results. How can the accuracy of the algorithm be demonstrated?

Response: We are sorry that we couldn't find the true values of the aerosol effective radius profiles to validate our retrieved results. As a result, we can only infer the validity of the retrieval empirically according to published results (Liu et al., 2009; Zhang et al., 2009; Yang et al., 2020; Cai et al., 2022; Li et al., 2022) and physical theory.

5. In Section 4, uncertainty analysis, the authors have only made a general analysis without giving specific values; various assumptions are used in the algorithm and the corresponding uncertainty analysis should be given.

Response: Thanks for your advice! We expanded the discussion about uncertainties associated assumptions, added more quantitative results in the uncertainty analysis, and used the MAPE (Mean Absolute Percentage Error) to quantify the error. The revised text in Lines 260-279 is cited as follows:

"*Uncertainties in aerosol extinction and effective radius profiles retrieved by our two-*

wavelength inversion algorithm are mainly due to measurement noise (e.g., the signal statistical error, the estimations of molecular optical properties, etc.), calibration errors, and assumption errors. In this section, we further examine the errors associated with the assumptions in the algorithm.

First, the single-scattering approximation is used in solving lidar equation, as multiple scattering effects in aerosol layers are generally small and are currently neglected for CALIOP (Winker et al., 2009). We limit the application of our algorithm to clear sky weather conditions to reduce this error, but this error is very difficult to quantify.

Second, the errors in the aerosol refractive index, size distribution and spherity assumptions in look-up tables can also introduce errors in solving the lidar equation. The lognormal distribution assumption of aerosol volume-size distribution may make the algorithm fail to converge in other actual size distributions. For example, using data generated by Junge distribution (a simpler aerosol size distribution), the algorithm cannot yield valid retrieval results. Similar outcome is noted for non-spherical particles or aerosol types significantly different from the assumed type.

Finally, we consider assumption and retrieval unceratinties as a perturbation in the lidar ratio and attempt to quantify its effect on the retrieved profiles. We increase the lidar ratio profiles at 532 nm and 1064 nm from the look-up tables by ±10% before calculating the synthetic attenuated backscatter profiles, which makes the synthetic data do not entirely match the look-up table. The retrieved profiles exhibit mean MAPE less than 14% (lidar ratio increases by 10%) and 17% (lidar ratio decreases by 10%), *indicating that the algorithm is comparatively robust to noise.”*

Technical Corrections

1. Line 32: The literature (Ipcc,2023) should be changed to (IPCC, 2023).

Response: Thanks for your advice! We have revised the manuscript accordingly.

2. Line 43: There should be a space between the number and the unit (532 nm) and line 179 (53 m).

Response: Thanks for your advice! We have revised all the mistake units in manuscript accordingly.

3. In Section 3.1, the unit “nm” has different fonts, please standardize the format.

Response: Thanks for your advice! We have revised all the mistake in manuscript accordingly.

4. Line 125: “with some size distribution”, the word ‘some’ doesn't seem to fit here.

Response: Thanks for your advice! We have revised this sentence as:

“*By assuming spherical particles size distribution*”

5. Line 166: “To save space” can be removed. should be a space between the number and the unit (1 km).

Response: Thanks for your advice! We have removed “*To save space*” in the sentence, and revised all the mistake units in manuscript accordingly.

6. There is only one red line in figure 5(d), so the subtitle can be revised to “Particle radius profile”.

Response: Thanks for your advice! We have revised all the related figure titles.

References

Cai, Z., Li, Z., Li, P., Li, J., Sun, H., Yang, Y., Gao, X., Ren, G., Ren, R., and Wei, J.: Vertical distributions of aerosol microphysical and optical properties based on aircraft measurements made over the Loess Plateau in China, Atmospheric Environment, 270, 118888, https://doi.org/10.1016/j.atmosenv.2021.118888, 2022.

Li, Y., Guo, X., Jin, L., Li, P., Sun, H., Zhao, D., and Ma, X.: Aircraft Measurements of Summer Vertical Distributions of Aerosols and Transitions to Cloud Condensation Nuclei and Cloud Droplets in Central Northern China, Chinese Journal of Atmospheric Sciences, 46, 845, 10.3878/j.issn.1006-9895.2104.20255, 2022.

Liu, P., Zhao, C., Zhang, Q., Deng, Z., Huang, M., Ma, X., and Tie, X.: Aircraft study of aerosol vertical distributions over Beijing and their optical properties, Tellus B, 61, 756-767, https://doi.org/10.1111/j.1600-0889.2009.00440.x, 2009.

Winker, D. M., Vaughan, M. A., Omar, A., Hu, Y., Powell, K. A., Liu, Z., Hunt, W. H., and Young, S. A.: Overview of the CALIPSO Mission and CALIOP Data Processing Algorithms, Journal of Atmospheric and Oceanic Technology, 26, 2310-2323, 10.1175/2009jtecha1281.1, 2009.

Yang, J., Li, J., Li, P., Sun, G., Cai, Z., Yang, X., Cui, C., Dong, X., Xi, B., Wan, R., Wang, B., and Zhou, Z.: Spatial Distribution and Impacts of Aerosols on Clouds Under Meiyu Frontal Weather Background Over Central China Based on Aircraft Observations, Journal of Geophysical Research: Atmospheres, 125, e2019JD031915, https://doi.org/10.1029/2019JD031915, 2020.

Zhang, Q., Ma, X., Tie, X., Huang, M., and Zhao, C.: Vertical distributions of aerosols under different weather conditions: Analysis of in-situ aircraft measurements in Beijing, China, Atmospheric Environment, 43, 5526-5535, https://doi.org/10.1016/j.atmosenv.2009.05.037, 2009.