Reviewer 1

General Remarks

This paper provides a useful concise overview of the JAXA EarthCARE lidar products and will be a useful reference for the community. I recommend publication. There are, however, several mainly editorial issues that need to be addressed.

Title:

This paper describes several algorithms. I suggest changing "Algorithm" to "Algorithms" in the title.

=>Thank you for pointing this out. We have made the correction as noted.

Abstract:

The abstract is, in general, awkward to read. It should be re-written

For example:

-EarthCARE should be introduced. "ATLID (Atmospheric lidar)" does not mean much to many readers by itself without more context.

-"optimization method using the Gauss-Newton method combined.". The numerical methods used in the optimization procedure are not interesting enough to be included in the abstract ! It would be more suitable to mention what is being optimized (e.g. have you implemented an optimal estimation type procedure ?)

-"algorithm's performance". Since more than one algorithm is being treated, the phrase "The performance of the various algorithms was evaluated"

=>Thank you for your valuable comments. We have revised the abstract in line with your comments, focusing on introducing the description of EarthCARE, simplifying the description of optimization, and the description of algorithm performance. The revised abstract is as follows.

"The Earth Cloud Aerosol and Radiation Explorer (EarthCARE) is a joint Japanese-European satellite observation mission for understanding the interaction between cloud, aerosol, and radiation processes and improving the accuracy of climate change predictions. The EarthCARE satellite was equipped with four sensors, a 355 nm high-spectral-resolution lidar with depolarization measurement capability (ATLID) as well as a cloud profiling radar, a multi-spectral imager, and a broadband radiometer, to observe the global distribution of clouds, aerosols, and radiation. In this study, we have developed algorithms to produce ATLID Level 2 aerosol products using ATLID Level 1 data. The algorithms estimated the following four products: (1) Layer identifiers such as aerosols, clouds, clear-skies, or surfaces were estimated by the combined use of vertically variable criteria and spatial continuity methods developed for the CALIOP (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) analysis. (2) Aerosol optical properties such as extinction coefficient, backscatter coefficient, depolarization ratio, and lidar ratio at 355 nm were optimized to ATLID L1 data by the method of maximum likelihood. (3) Six aerosol types, namely smoke, pollution, marine, pristine, dusty-mixture, and dust were identified based on a two-dimensional diagram of the lidar ratio and depolarization ratio at 355 nm developed by cluster-analysis using the AERONET (AErosol RObotic NETwork) dataset with ground-based lidar data. (4) The planetary boundary layer height was determined using the improved wavelet covariance transform method for the ATLID analysis. The performance of various algorithms was evaluated using pseudo ATLID Level 1 data generated by Joint-Simulator (Joint Simulator for Satellite Sensors), which incorporates aerosol and cloud distributions simulated by numerical models. Results from applying the algorithms to the pseudo ATLID Level 1 data with realistic signal noise added for aerosol or cloud predominant cases revealed: (1) misidentification of aerosol and cloud layers was relatively low, approximately 10%; (2) the retrieval errors of aerosol optical properties were $0.08\times10^{-7} \pm 1.12\times10^{-7}$ $m^{-1}sr^{-1}$ (2 ± 34% in relative error) for backscatter coefficient and 0.01±0.07 (4 ± 27% in relative error) for depolarization ratio; (3) aerosol type classification was generally performed well. These results indicate that the algorithm's capability to provide valuable insights into the global distribution of aerosols and clouds, facilitating assessments of their climate impact through atmospheric radiation processes."

1 Introduction:

Line 53: "...extraction of the component parallel to the laser polarization (co-polar component)..."
Line 54 delete "published" == > "calibrated"
Line 55 "understandings" ==> "understanding"
Line 77: "...generate JAXA L2 products using.."
Line 79: "..cloud properly estimation.."
=> We have corrected it as noted.

2 Algorithm flow and products

Line 85 : "Initially, the algorithm" ... which algorithm ? I guess this is referring to the "signal smoothing" step in Fig 1. ? Please re-work this sentence.
=>The text has been revised and the corresponding section (smoothing) in Figure 1 has been corrected for greater clarity as follows.

"First, to improve signal quality, the algorithm reduces the signal noise using a discrete wavelet transform (DWT) (Fang and Huang, 2004)."

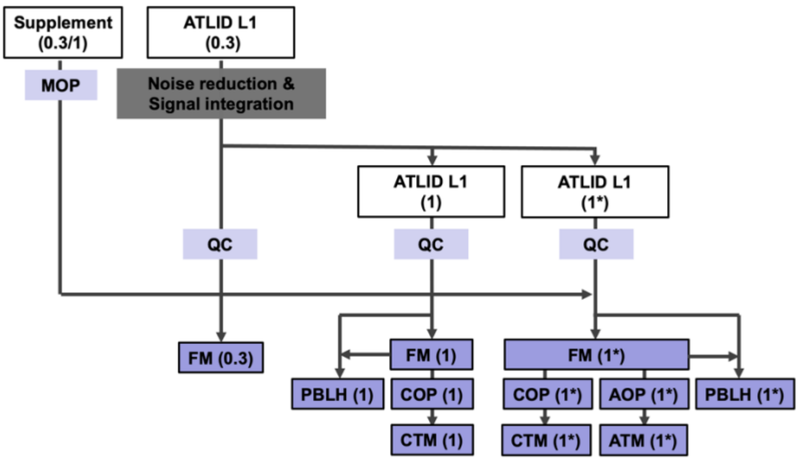

Figure 1. ATLID L2 products and the flow of algorithms.

Line 114 : "..ECMWF forecast model.."
=>We have corrected according to your comment.

3 Algorithm
Layer Identification
Line 115: "Algorithm" ==> Algorithms
=> We have corrected "Algorithm" to "Algorithms"

Line 129 : "..and linear depolarization ratio.."
=> We have corrected as indicated

Line 133-134: Pm and Pr are not defined ! Or does e.g. Pm=beta_atn_M ? and Pr=beta_atn_R ? If this is the case, it is unnecessary and confusing in the description. Please adjust the subsequent description and Equations 3 and 4 to use beta_atn_M etc..
=> As you may have guessed, section 3.1 has been modified to remove PM and PR and write in βatn.M and βatn,R.

Line 168: "SN's" ? Do you mean "..are not identified separately using the SNR" ?
=> We modified "SN's" to "SNR's".

Aerosol optical properties
Can the authors give an indication of how computationally demanding their approach is ? i.e. how long (and on what type of computing system) does it take to profile a frame of Atlid data ?
=> The computational time for the retrieval of aerosol optical properties in a frame of ATLID L1 data (about 5000 profiles) is less than 15 minutes on Linux platform.

Line 193: If I understand correctly, the forward model being employed is described by Eq1 1a-1c. Is there any account of lidar multiple scattering ?
=> The multiple scattering is not considered in the retrieval of aerosols. However, the actual analysis (as described in the manuscript) estimates the optical properties of the cloud along with the aerosol, so the cloud estimation takes multiple scattering into account. The algorithm already implements the method using the η-factor, but since we are dealing with aerosols in this study, we performed various estimations assuming $\eta = 1$ (no multiple scattering).

Line 198: "...optimize the vertical profiles of the POP to the L1 data...". I am not sure what is meant here ? Maybe the authors mean to say that "...optimize the difference between the observed and forward modeled L1 profiles based on the POP profiles"
=> Thank you for your comment. The sentence was modified to "Therefore, we simultaneously estimated the vertical profiles of the POP from the L1 data by the method of maximum likelihood with a priori smoothness constraints for the vertical profiles of the POP. The state vector x, which comprises of alpha(zi), δ(zi), and S(zi) at altitudes zi, is optimized to the L1 data by minimizing the following cost function:".

Please describe how the w terms in Eq 5 are determined ? I guess they are the log uncertainties based on the (linear) error estimations in the alpha and beta determinations ?
=> the w terms are determined from the measurement error of the L1 data. An explanation has been added to the revised manuscript to clarify this point.

Are the w terms also adjusted to control the "smoothness" of the results ?
=> We added the w terms for the smoothness constraints to the Equation 5 in the revised manuscript. The smoothness constraints are controlled by the w values.

Esq. (5). It looks like there are extra "-" signs in the last three terms of the equation. e.g. -ln(-alpha_p(z_(i+1)).
=> Thank you for pointing that out. We have removed it.

Line 199: Is this really and "optimal estimation technique" ? The method looks like some sort of forward modeling approach coupled with smoothing constraints but I do not think it can be described as an "optimal estimation" technique. I.E. optimal estimation involve some sort of a prior constraint, not smoothness constraints.
=> Yes, we think the optimal estimation technique. In this study, the cost function is defined based on the method of maximum likelihood, and the state vector is optimized by minimizing the cost function.

Line 217-220: Here the authors (finally) introduce the state-vector (x). The discussion would be much easier to follow if this was done explicitly at the beginning of this sub-section.
=> Thank you for your comment. We moved the introduction of the state vector to the beginning of this subsection in the revised manuscript.

Line 219 : Provide a reference for the "Armijo" rule.
=>The reference was added to the revised manuscript.
Nocedal, J. and Wright, S. J.: Numerical optimization, 2nd edition, Springer Series in Operations Research and Financial Engineering, 664 pp., Springer Science+Business Media, LCC, New York, 2006.

Aerosol type classification (Target mask).
Line 244: Please provide a reference for the "fuzzy c-means method"
=> The following reference has been added.
Bezdek, J. C.: Pattern recognition with fuzzy objective function algorithms, Plenum Press, 1981.
Dunn, J. C.: A fuzzy relative of the ISODATA process and its use in detecting compact well-separated clusters, J. of Cybernetics, 3, 3, 32-57, 1973.

PBL height
Line 264 : "...ratio are directly influenced...."
=> We have corrected as indicated.

Line 275 : "..results in a small;.." ? Small what ? This sentence seems corrupt.
=> To clarify this sentence, the following modifications have been made, including around the pertinent text. "Because the Rayleigh scattering at 355 nm is relatively large (approximately five times larger than that at 532 nm), the difference in the backscatter signals for the PBL and the free troposphere (FT) can be small. This larger Rayleigh scattering at 355nm also produces greater signal attenuation, resulting in the lower signal difference between the PBL and the FT. It should be noted that the signal attenuation due to Rayleigh scattering near the top of the PBL is larger for spaceborne lidar observations than for ground-based lidar observations. Thus, the detection of PBLH by spaceborne lidar observation at 355nm is more challenging than in the past, even when the WCT method is applied (Kim et al., 2021)."

Results and Discussion
Line 293 : "..algorithm,.." ==> "..algorithms,..".
=> We have corrected it as indicated.

Line 298 : Were lidar multiple-scattering (MS) effects included in the simulations ? MS is described later in lines 359-365 but it is unclear(to me) if these effects were incorporated into the simulations used in this paper.

=> Yes, they were. In this study, the pseudo ATLID L1 data were created by J-simulator. In that calculation, multiple scattering is taken into account by using the η-factor.

Line 311 : "..highliting.." ==> "..highlighting.."

=> We have corrected it as indicated.

Conclusion

Line 412 : "...will be released as JAXA's L2 ATLID standard products."

=> We have corrected it as indicated.

References

Check the references to the other special issue papers and update them if appropriate.

=>We reviewed the references and made corrections.