Response to Reviewer 1
Thank you for your positive comments and your suggestions for improving the manuscript. Your time and effort are appreciated. Responses to your individual suggestions are given below in blue.

Reviewer 1 states:

The article describes an algorithm for an improved extinction retrieval from high spectral resolution lidar (HSRL) measurements. An analytical solution exists for the extinction coefficient derived from HSRL measurements, which often suffers from low signal to noise ratios. The presented optimal estimation solution has the benefit of less noisy extinction coefficient and lidar ratio profiles, which is desirable for aerosol research with lidar. Similar approaches were already reported for Raman lidar measurements and spaceborne HSRL observations. Here, the approach is developed for the airborne HSRL of NASA Langley Research Center. Another highlight is the characterisation of measurement uncertainties. The article is clearly written and describes the algorithm and applies it to simulated and real measurement data. The topic fits in the scope of AMT and should be published after minor revisions which mostly concern the figures.

Minor comments:

1. While the article focusses on the application to airborne HSRL systems, the possibility of the application to ground-based HSR lidars should be considered. New ground-based HSRL systems were developed, e.g., Jin et al., 2020. Jin, Y.; Nishizawa, T.; Sugimoto, N.; Takakura, S.; Aoki, M.; Ishii, S.; Yamazaki, A.; Kudo, R.; Yumimoto, K.; Sato, K. & Okamoto, H.: Demonstration of aerosol profile measurement with a dual-wavelength high-spectral-resolution lidar using a scanning interferometer, Appl. Opt., Optica Publishing Group, 2022, 61, 3523-3532

Several of the included references are papers about ground-based lidars, and the one you suggest is also a good addition. It has been added in the revision.

2. P4L20: Here, you call the lidar system HSRL-2, later just HSRL2. It is up to you to decide how to name your lidar system.

In the revision, this is made more consistent, with HSRL-2 used instead of HSRL2 in all cases.

3. Eq 11 is not really an equation (no =). Furthermore, the journal standards expect a vector to be in bold italic.

It's true that it's an expression and not an equation. I don't think that's disallowed by journal standards, and I somewhat prefer not to introduce a new symbol for the left-hand side that isn't required elsewhere in the text. As for the typesetting of variables, in the revision, the formatting of scalar, vector and matrix variables has been made more consistent with journal standards.

4. In nearly all figures, the units of the optical properties are missing.

Units have been added to Figures 1-3, 6, 12, and 14-15 for the revision.

5. Furthermore, the figures are often quite small. Sometimes, the minor ticks are not resolved well.

The overcrowded minor ticks were removed. These were part of multi-panel figures that I don't think are practical to split, since other reviewers are already concerned that there are too many figures. I hope the publisher's layout will allow the figures to be a little larger than how I set them in the review copy.

6. Fig 2 + 12: The perpendicular signal (in green) is multiplied by a factor of 10, not the particle signal. The label inside the figure is wrong.

True, that was a mistake. It's been fixed in the revision.

7. Fig 2: There are no pink circles as mentioned in the caption.

Fair enough, pink is not a very good descriptor word for this color. The colors were chosen to be distinguishable to viewers with color-vision deficiencies as well as viewers with typical vision, but the minor tradeoff is that they are not well described by the most common color words. The caption is revised to use "orange" as a better description for this color.

8. You use the terms "particle/particulate" and "aerosol" synonymously in the description of the optical properties and signals, e.g., particulate depolarization ratio and aerosol depolarization ratio or particle(-dominated) signal or aerosol signal. It is ok, if you focus on aerosol and exclude clouds. However, it would be nice to harmonize the terms throughout the manuscript and especially the axis labels in the figures. Sometimes, the particle dominated channel is referred to as "para" – parallel in the axis labels (e.g., Fig 5+18).

In the revision, more care has been taken to use the labels aerosol and particulate consistently. At the beginning of the manuscript, the descriptions of the measurement signals are general as to whether they involve aerosol or cloud, so "particulate" is used in the discussion almost exclusively at first. However, when it comes to describing our particular retrieval, it seems important to remind readers that we are focusing only on aerosol, since solving for cloud particles would require a solution for multiple scattering that we have not included. Therefore, where we begin to describe specifics of the methodology, we make the vocabulary more specific and replace "particulate" with "aerosol" when referring to backscatter, extinction, and lidar ratio quantities, while keeping "particulate" when referring to measurement channels. To make the intent more clear, this sentence was also added at the start of the discussion of the solution vector:

> ***The use of "aerosol" hereafter instead of "particulate" is meant as a reminder that we focus only on aerosol and have not included multiple scattering as would be required for solving for cloud properties.***

"Para" was removed from Figures 5 and 18. The captions use the full descriptive text for clarity.

9. The green lines in all your figures look almost blue to me. Maybe you find a different type of green to be clear.

The color has been changed to be better visible to people with red-green color vision deficiency and now the color is even more blue, so the description word has also been changed from green to blue in all the captions.

10. P12L16-17 Why the systematic uncertainties are not included in the analytic retrieval?

The ability to propagate systematic uncertainties in a complete and consistent manner is one of the strengths of this new retrieval. Although there have been published accounts describing and analyzing sources of systematic uncertainties for the analytic retrieval (e.g. Burton et al. 2015 and Burton et al. 2018), propagating them through the analytic retrieval has never been part of the standard processing.

11. P14L13-14: Probably, this is the reason why the analytic retrieval has the lowest residual in the topmost kilometer for all three signals.

By "this" do you mean the statement at lines 13-14? Yes, you are correct. The residual is small at the top of the profile and the accumulation effect means the error is larger below that. I added a few words to incorporate your idea. The sentence now says "Therefore, even though the residual is small at the highest altitude, random errors in the derived state contribute to accumulating errors in the attenuated backscatter at lower altitudes."

12. P14L17 Fig 1 does not contain uncertainty estimates. Probably, you want to refer to a different figure here. *?*

You are correct. It should have been Figure 3. It has been changed in the revision.

13. Fig 6 + 15: I would add a, b, c … to the subplots.
Added

14. Please estimate how important are Fig 7+8 and Fig 16 + 17. Maybe a description in the text is sufficient. It is up to you to decide.

OK, given that two reviewers thought there were too many figures, this suggestion of which figures to replace with text is a good solution. That has been done in the revision. Figures 7 and 8 are replaced with this paragraph:

> ***Figure 6 shows correlation between profile quantities, but the covariance matrix also includes rows that indicate correlation between the uncertainty in the profile quantities and the scalar quantities, K' and χ. There is significant negative correlation (not shown) between the uncertainty in the overall scaling factor, K', and the backscatter uncertainty profile, as expected. Correlations of the overall scaling factor uncertainty with lidar ratio and aerosol depolarization ratio uncertainties are near zero. Likewise, there is predictably significant correlation between the uncertainty in the depolarization cross-talk parameter, χ, and the aerosol depolarization ratio uncertainties, whereas correlations between uncertainties in this parameter and the aerosol backscatter and lidar ratio are near zero. All of these patterns are expected and reflect that errors (although small) in the backscatter profile are partially systematic and correlated with the calibration constant and likewise that the errors in the depolarization ratio profile are partially systematic and correlated with the depolarization cross-talk parameter.***

Figures 16 and 17 are replaced with similar but shorter summary text.

15. May I suggest, furthermore, to combine Fig 10 and 11 as Fig 10a and 10b?

OK, they have been combined in the revision

16. Fig 18: The exponents 10^x are hard to read.

These have been made bigger.

17.   Please add a section about the code availability.

The following statement has been added: Code used to create the results in this study is available on request from Johnathan.W.Hair@NASA.gov.