Reply to (late) Reviewer 3 D. Winker.

Reviewer comments are in Black while our response is in Blue.

General Comments

This manuscript describes retrieval algorithms which will be used to process data from the ATLID lidar,to be launched soon on the EarthCARE satellite. Thus this is an important paper which will draw considerable interest. The manuscript gives a good summary of how the retrievals are performed but is unclear in places. There is some necessary context that is missing and some discussion of why key algorithm design choices were made would be helpful.

Noted: We will try to add more context and the rational behind our choices.

This paper is one of a large set of EarthCARE algorithm papers and the algorithm described here uses results from several algorithms described in other papers. The current manuscript seems to assume the reader is familiar with these other algorithms. To avoid the need to refer to other papers to understand the A-PRO processor the authors should add brief descriptions of the other algorithms and the parameters which are used as inputs to A-PRO. For example, the paper needs a paragraph or so describing the A-TC algorithm and the classification information it provides to the A-PRO processor, perhaps in the form of a table listing the target categories

Perhaps the balance between not repeating what is in the other papers and making the paper more self-contained indeed needs to be adjusted. More information about A-TC will be included and how it interacts with the other A-PRO components will be added.

To make it easier for the reader to understand the three ATLID signals used in these retrievals, the authors should include a schematic of the optical layout of ATLID, which isn't described well by the layout in do Carmo et al. A lidar expert can derive the optical layout from Eqns 1-3, but this requires expertise and some effort. Including a layout schematic would avoid confusion and mis-interpretation.

Noted: A simple sketch and discussion will be added.

Retrievals are performed at different horizontal resolutions. It's not clear to me how the signal averaging and retrievals are related or how results are reported in the data products. In CALIOP data processing, layers in a given scene have likely been detected at different resolutions, following a detect- remove-reaverage approach. It looks like ATLID takes the approach of averaging the entire scene at a uniform resolution, except that certain features are excluded from averaging. Some discussion of how the averaging scheme is similar or different from the one used for CALIOP would be helpful.

The averaging strategies are described in quite some detail within the algorithm flowcharts and the associated discussion. However, we can see how the presentation is perhaps too detailed, such that the reader can miss the forest-for-the-trees (so to speak). A higher-level more accessible discussion addressing the points the reviewer raised will be included.

Retrievals are performed at 1-km and 50km scales. What was the thinking behind two, and only two,

different scales vs. the CALIOP approach which uses five different averaging scales?

A-AER (the direct HSRL based algorithm) retrievals are applied at the 1-km scale but use input signals that have been "strong-feature" screened and smoothed to between 10 and 100 km or so. A-EBD (the optimal estimation based retrieval) always uses unsmoothed 1-km resolution signals as input. High, Medium, and Low-resolution EBD output products are provided. Nominally, this corresponds to 1-km, 50 km and 100 km. They are constructed by averaging the "strong-feature" screened 1-km EBD outputs and then superimposing the "strong-feature" results. We will attempt to clarify this in the manuscript.

The feature detection algorithm A-FM, in a sense, fills the role played by the multi-scale approach used by CALIPSO. But in a "continuous" rather than "discrete" fashion. The role of A-FM and how it is used by the A-PRO processor will be discussed more in the text.

It is not entirely clear to me how smearing of aerosol and cirrus together is avoided in this multi-resolution scheme. Dense cloud is easily separated from aerosol (using information from A-TC?) but aerosol and cirrus can have similar scattering strengths, and sometimes even similar volume depolarization. A little description of the information coming from A-TC would be helpful – a table listing the different feature categories? Are A-TC classifications provided at the resolution of the JSG grid?

A-TC classifications are indeed provided at the resolution of the JSG grid. Aerosol and thin cirrus separation will be challenging and likely can not be entirely avoided. Ultimately, If the signals strengths are similar, the depol ratios similar, and the lidar-ratios are similar, then the lidar-only approach is problematic.

I was confused by the choice of math symbols in Sections 2.2-2.3. They are different from what I am used to and involve a variety of confusing sub- and super-scripts. Adding a table defining each symbol would be helpful.

Noted. We will consider adding a table.

Several times it is mentioned that an algorithm parameter is configurable or can be set to one of two or more options. Will one of these options be selected for all operational processing, or is one option or another selected by the operational processor depending on which is better for a given scene?

For operational processing the configuration options will be fixed. For off-line studies different configuration options will be investigated. Operational values will only be fixed during the course of the commissioning phase.

Specific Comments

Line 43 – Please cite the papers which describe calibrations and cross-talk corrections. Maybe add a few sentences on the general approaches for calibration and cross-talk corrections?

Noted. More information will be added.

Parts of Section 2 read like a bulleted list rather than a narrative. Some additional context is needed to understand the details provided. See next comments.

Noted.

Line 83 – Describe the JSG a little bit – why is there a JSG? Explain why the L1 ATBs need to be rebinned to the JSG grid. What is the resolution of the JSG?

The JSG exists to facilitate ``synergy'' with the other EarthCARE instruments. A common approach is used for co-lcating the lidar,radar and nadir msi pixels. This is done via the JSG. The JSG has a nominal resolution of 1-km along track.

Lines 85-90 – It's not clear if cloud phase and aerosol type information are determined in A-FM or in A-PRO. Add a table listing the feature mask classifications provided in A-FM?

A-FM only provides a target mask, not a classification ! Phase, aerosol type etc is done with A-PRO (using A-FM as one of the inputs). This will be clarified within the text.

Line 125-126 – Expand a little on what the A-FM feature probability indices are. I can guess what is going on here, but the reader shouldn't be forced to go to another paper to understand this.

Noted. More information will be provided in the manuscript.

Line 129 – How is the "strong feature" mask created by thresholding? A little more detail please. Is a constant threshold used, is it adapted depending on signal SNR?

Noted. More information will be provided in the manuscript.

Line 134 – The threshold is set to "8" – 8 what? Is this a 355 nm scattering ratio threshold?

No. It is the A-FM target probability index. More explanation will be added.

Line 141 – It is not clear what is meant by "layering structure" and how this is determined. Is this just feature detection or does it include identifying cloud and aerosol, or determining composition differences? What makes this preliminary?

This is just feature detection. More explanation will be added.

Line 141-142 – Incomplete sentence (The scattering ratio calculations performed … )

Noted

This text should read…"….is determined using the scattering ratio…"

Line 145 and following – It would be nice to have some detail and a figure describing Step 3

We will consider this.

Line 151 – Does “e.g. 5” refer to a scattering ratio? If so, this should be made clear, and remind the reader that this is a scattering ratio at 355 nm as some of us think of 532 nm by default.

Yes. This will be made clearer in the text.

Lines 152-160 – Understanding what is going on here involves a lot of guesswork. A figure might help

We will consider this.

Line 185 – Is there a definition of fine and coarse layers? It is not clear what the difference is, or why this is done in two steps.

Fine layers have a higher vertical resolution than the coarse layers and are determined using more information (which is available at this point in the algorithm flow e.g. the lidar-ratio). The fine-layer structure is important input to the optimal estimation process. More explanation will be added in the text.

Line 201 – Explain what the ‘classification priors’ are and where they come from. I think this is the first mention

Noted. This is explained in the A-TC paper but more info will be added here.

Starting around line 243 – does ‘a priori errors’ refer only to random errors or both random and bias errors?

Random and bias. This will be made clearer in the text.

Lines 225-226 – Is there a subscript missing? Eqn 9 has x^l_a and x^l_r. x^l_a is discussed in the following text but there is no discussion of x^l_r, only of x^l.

Noted: There are several typos to be fixed in this section. The use of x^l will be eliminated (see our response to point 4 of Reviewer 2).

Line 243-250 – I don’t quite understand how errors are treated in the O-E retrieval. In A-EBD, errors are assumed to be uncorrelated. A constant value of lidar ratio and particle size is retrieved for each layer, but there is still an error which may be different in every range bin. Wouldn’t bias errors be highly correlated within an aerosol or cloud layer? Is this just ignored? A little more discussion would be helpful.

For the lidar-ratio and particle size A-EBD operates on a per (fine) layer-by-layer basis. So only the correlations between different layer averages are important. Moreover, the lidar-ratio and Reff are layer averages, no sub-fine-layer information is supplied in the output product (so it does not make sense to talk about bias errors within a fine-layer) this is one of the reasons the fine layer structure is important. This point however, should be made clearer to potential end-users of the data.

Line 288 – The algorithm seems to estimate both IWC and effective ice particle size using one of two parameterizations from Heymsfield et al. The particle size from this approach is just a parameterized climatological average based on temperature and should not be thought of as a retrieval. This should be made clear to data users.

Noted. This will be made clear.

Line 289 – Why are there two options for estimating IWC? Are both options available to the data user or will a final selection made by the algorithm developers after launch. Please explain

A final selection will be made during after launch. The data users can always make their own IWC estimates using the retrieved extinctions (after all the IWC product is only a parametrization). However, A-PRO used the Re estimates in the MS correction procedures. So the decision will likely hand on this aspect.

Line 353: Last paragraph of Section 3.1 – Many people are familiar with CALIOP, which uses the simpler Platt method for correction of multiple scattering effects from cirrus. This is mentioned (very briefly) in Appendix B, but it would be helpful to point out here that the small footprint of ATLID enhances the multiple scattering tail effects relative to CALIOP, which has a larger footprint. From the discussion here, it appears to be much easier to characterize errors due to incorrect MS correction for HSRL than for a backscatter lidar.

Noted. The suggestion will be adopted.

Color bars: Some of the color bars used in the figures should be improved. Copernicus journals are now making color-vision deficiency (CVD) accessibility a priority. The color bars used in Fig 7 and 8 are probably good for CVD. The rainbow color bars used in Figs 5 and 6, and others, mix red and green and may be difficult or impossible for those with non-standard color vision to interpret.

Noted.