Response to Reviewer # 2

We thank the reviewer for his review and valuable comments. The manuscript has been modified according to the suggestions proposed by the reviewer. The remainder is devoted to the specific response item-by-item of the reviewer's comments.

RC=Reviewer Comments
AR=Author response
TC=Text Changes

General Comments

Some time ago now, I reviewed an earlier version of this paper for another journal. Now, I find the work and presentation to be much improved! I have only a few mainly minor comments/concerns.

We thank the referee for all comments on the early version of this paper, which allowed us to progress and improve the content of this new version.

Specific Comments

1) Aeolus carries a Fizeau spectrometer, which measures the spectrum of the return +/- 0.33 pm around the emitted laser wavelength using 16 different frequency bins. Thus, Aeolus provides spectrally resolved data in the normal sense of the phrase. ATLID separates the pure so-called "Mie" and Rayleigh backscatter returns. This is not the same as measuring the full spectrum. Please adjust the text accordingly.

We thank the reviewer for this comment. In the revised paper, and according to suggestions of the first reviewer, we have changed the sentence "The Atmospheric LAser Doppler INstrument (ALADIN) of the ADM-Aeolus, the ATmospheric LIDar (ATLID) and the Cloud Profiling Radar (CPR) of the EarthCARE mission will provide spectrally resolved data." by :

The Atmospheric LAser Doppler INstrument (ALADIN) of the ADM-Aeolus provides spectrally resolved data. Indeed, the Mie receiver is a Fizeau spectrometer combined with a charge-coupled detector that measures the spectrum of the return around the emitted laser wavelength using 16 different frequency bins (Stoffelen et al., 2005; Reitebuch, 2018). The ATmospheric LIDar (ATLID) signals of the EarthCARE mission will be optically filtered in such a way that the atmospheric Mie and Rayleigh scattering contributions are separated and independently measured (Pereira do Carmo et al., 2019).The radar echoes of the Cloud Profiling Radar (CPR) of the EarthCARE mission will be input to autocovariance analysis by means of the pulse-pair processing technique for the estimation of the Doppler properties (Zrnic, 1977 , Kollias et al., 2013; Kollias et al., 2018). Note however that ATLID and CPR will not provide the spectrally resolved data.

2) Page 2: Line 20: Simulation tools are steadily advancing thus allowing the exploration of the direct...way. Lidar and/or radar simulators are no exception.

In the revised paper, we have changed "Simulation tools are steadily advancing thus allowing the exploration of the direct...way. Lidar and/or radar simulators are no exception" by

"Lidar and/or radar simulators are steadily advancing hence allowing to explore direct and inverse problems in a cost-effective way".

3) Page 3: Line 5. This text is not clear. Is DOMUS part of ECSIM or something separate ?

DOMUS is not a part of ECSIM. In the revised paper, we have added in page 3 :

"Note that DOMUS is not a part of ECSIM."

4) Section 2.2: The modelling of Doppler shifts is well described, however, the treatment of polarization is not described at all (despite the section title of " Modelling of idealized polarized backscattered power spectrum profiles") ! At least short description with references should be given.

This remark of reviewer 2 joins the comment of reviewer 1 which asks for results on polarization.
We used the McRALI code to simulate profiles of the volume depolarization ratio measured by the CALIOP/CALIPSO lidar in our previous work (see Figs. 7-8, Alkasem et al., 2017). In the same work, we demonstrated that our simulation of the linear and circular depolarization profiles in a C1 cloud are in good agreement with the published data (see Appendix A.3, Alkasem et al., 2017). The later result was confirmed by other authors that cited our work (see, e.g., Sato et al, 2019; Wang et al, 2019).
We prefer not to present our new results on polarization in this work because they would make the paper under reviewing too long. Those results will be a subject of a separated publication.

We modified the last sentence of the revised paper as following:
"Real detailed cloud case studies and statistical analysis of representative fine-structure 3-D cloud field effects on lidar and radar observables, while taking into account the polarization of the light, will be the topic of future papers."
Moreover, in the revised paper, we have modified the title of section 2.2 by deleting the word "polarized".

5) Page 14: Lines 10-15. The cross-talk coefficient used in this paper have been apparently derived assuming ideal behavior of the EarthCARE FP element. In practice, the Airy function will be "blurred" due to the effects of non-ideal collimation of the beam, frequency jiter, surface roughness etc.. These factor all act to decrease the peak transmission and lower the FWHM. For a more realistic view on these parameters you should take into account the information in CEAS Space Journal (2019) 11:423–435 https://doi.org/10.1007/s12567-019-00284-6 (See Fig 9).

Looking at the FP characterization curve, it is certain that here will be substantially more Mie to Ray cross-talk than reflected by the present choice of coefficients. This fact will not alter any of the present papers conclusions (the increased X-talk will act mainly to reduce the SNR of the *cross-talk corrected observations). Rather than redo the "EarthCARE" cases (which would be ideal but may require too-much time/effort) the authors could instead make it clear that the calculations shown are merely "EarthCARE like" but with an idealized modeled FP etc...*

We thank the reviewer for the information, comments (and the publication reference) on cross-talk effects in ATLID which are not all taken into account in the McRALI simulator, the one using an idealized modeled FP interferometer. We also agree that this fact does not alter any of our conclusions. In order to clarify the fact that our calculations are carried out under idealized conditions (idealized FP interferometer, as suggested by the reviewer), we have added in the revised paper, page 15, this sentence:

Note that the cross-talk coefficients used in this paper assume ideal behavior of the ATLID FP interferometer. In practice, the Airy function will be "blurred" due to the effects of non-ideal collimation of the beam, frequency jiter, surface roughness and so on. All these factors end to decrease the peak transmission and lower the full width at half maximum (see the Fig. 9 in Pereira do Carmo et al., 2019). It is important to keep in mind that all the calculations shown in this paper are merely "EarthCARE like" but with an idealized modeled FP interferometer.

Page 14: Line 21 "(named by abuse of language)" ==> "the so-called"

Corrected in the revised paper.

Page 14: Line 26 "..step a simulated FP interferometer separates the ..."

Corrected in the revised paper.

Page 15: Figure 5 and associated text. It is likely worth pointing out the quasi exponential decay of the below cloud molecular return towards single scattering return levels. This result is consistent with the cases shown by Donovan 2016.

We thank the reviewer for this remark. We have added these sentences in the revised paper (page 16, line 5-6 in the revised manuscript) :

It is likely worth pointing out the quasi exponential decay of the below cloud molecular return towards single scattering return levels. This result is consistent with the cases shown by Donovan (2016).

Page 25: Lines 10-15: Have the the variance reduction techniques described by Buras et al. been employed in these calculations ? If so, it is work some more discussion regarding why these spikes in the spectrum remain. If not, then why were they not used ?

The variance reduction techniques described by Buras et al. has not been employed in calculations of this work.
With reference to the variance reduction techniques (VRTs), the Monte-Carlo code McRALI has two separated sets of subroutines. With the first set (without VRTs), simulations are done only using the local estimate method. In the second set (with VRTs), the methods and equations of the work by Buras and Mayer (2011), hereafter BM2011, are implemented. A McRALI user

can choose to do simulations with or without the VRTs. The user must assign the set of parameters (see, Section 2.6 of BM20110) when simulations with the VRTs are performed.

We consider a set of VRTs parameters to be acceptable when there is good amelioration in the computing time and there are no biases between simulations with and without VRTs. For instance, our simulations of the MUSCLE cases are in very good agreement with the MUSCLE community results (see, Section A.1, Alkasem et al. 2017). The difference between the ratios of multiple-to-single scattering, which were computed using the McRALI code with and without VRTs, is within ±5%. The VRTs computing time is 100 times faster. The important point of the MUSCLE cases is the extinction coefficient value that is of 17,25 km-1.

When the extinction coefficient value is rather low (1 km-1 or lower), it is especially difficult and time consuming to get an acceptable set of VRTs parameters. Unfortunately, we have not succeeded to find a unique set of VRTs parameters, which is acceptable for different lidar types and configurations, and different particles phase functions. Thus, we decided to perform simulations of that work without the VRTs.
Of course, the statement above has to be considered as only our personal experience. Thorough investigations are needed before it will be accepted or rejected.

We added to the revised manuscript (page 3 line 25) the following text.

“All simulations of this work were done without application of the variance reduction techniques.”

References

K. Sato, H. Okamoto, and H. Ishimoto, "Modeling the depolarization of space-borne lidar signals," Opt. Express 27, A117-A132 (2019) https://doi.org/10.1364/OE.27.00A117

Z. Wang, S. Cui, Z. Zhang, J. Yang, H. Gao, F. Zhang, Theoretical extension of universal forward and backward Monte Carlo radiative transfer modeling for passive and active polarization observation simulations, Journal of Quantitative Spectroscopy and Radiative Transfer, 235, 2019, p. 81-94, https://doi.org/10.1016/j.jqsrt.2019.06.025.