Items-by-items response to Reviewer #2

The authors greatly acknowledge the anonymous reviewer for carefully reading the manuscript and providing constructive comments. This document contains the authors' responses to comments from reviewer #2. Each comment is discussed separately with the following typesetting:

*****Reviewer's comment

Author's response

Changes in the manuscript.

We also would like to mention that those comments are the same that those the referee provided for the quick review before the manuscript were accepted for publishing in Atmospheric Measurement Techniques Discussions. Therefore, those comments were already addressed. Here we mostly provide the same answer to those comments.

*The topic is very important in nowadays since for the retrieval of optical and microphysical aerosol properties from lidar signals it is urgently necessary to have a complete error analysis.

*Therefore, I support this manuscript as a discussion paper.

*The paper reports about systematic and random errors on the retrieval of microphysical properties in a very long-winded style.

We thank the referee for that suggestion. It would be helpful to have specific examples of what the reviewer meant by long-winded. Lacking any, we have made no changes to address this comment.

*First systematic errors and second random errors are investigated. The first part seems to be new and is interesting.

In fact, the second is also quite new when compared with any work previously done and we so state in the manuscript.

*In equation 1 and 5 a couple of misprints are included.

We thank the reviewer for noticing these initial mistakes. They were already corrected for their publication in Atmospheric Measurement Techniques Discussion. Actually, equation 1 and 5 are given as:

$$g_j(\lambda_i) = \int_{r_{min}}^{r_{max}} K_{j,N}(m, r, \lambda_i) n(r) dr \quad (1)$$

$$\frac{dn(r)}{dln(r)} = \sum_{i=f,c} \frac{N_{t,i}}{(2\pi)^{1/2} ln\sigma_i} exp\left[\frac{(lnr - lnr_i^m)^2}{2(ln\sigma_i)^2}\right] \quad (4)$$

We apologized because in the first version the referee received when numbering the equations we passed from equation (3) to equation (5). This is now corrected in the current version of the manuscript. Equation (5) is now numbered as equation (4), and equations (6) and (7) as equations (5) and (6).

*It would be also very helpful for the reader to include two Figures of the used examples for the size distributions type I and II, in particular to decide or to discuss whether the values r_min and r_max are suitable or not.

We have added the following figure that includes the size distributions of aerosol types I and II, and also type III that has been added for answering referee 2 comments:

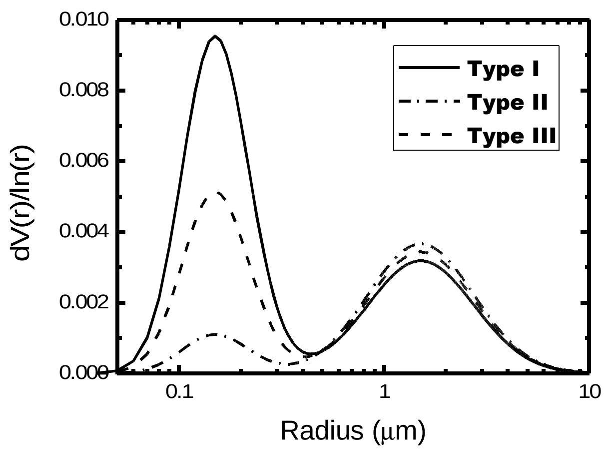

Figure 1: Normalized size distributions used for computing the simulated optical data. The ratio between the volume of fine and coarse mode, V_{tc}/V_{tc}, is 2 for type I, 0.2 for type II and 1 for type III.

And between lines 200-202 of the revised manuscript we have added:

"… Figure 1 illustrates the three size distributions used. For convenience, the size distributions of Figure 1 are normalized…"

And the discussion of the values of r_{min} and r_{max} established is now clearer in the text after including the following between lines 239-243 of the revised manuscript:

" … to stabilize the retrievals, the maximum radius of the retrieval interval was set to 5 µm. Additionally, the kernel functions for radius below 0.075 are very near to zero, and thus the minimum radius allowed was set to 0.075 µm. The behavior of the kernel functions versus wavelength can be consulted, for example, in Chapter 11 of Bohren and Huffman, 1983…."

*There is also a discussion in the paper (no page numbers are given) about the Mie kernel functions but neither a Figure nor a Reference is given. It is impossible for the reader to follow.

We are sorry for not including the page numbers in the initial version of the manuscript. This has been solved and we also include line number. The other referee also asked about that. It was a misunderstanding by the authors.

The largest discussion about the kernel functions was when we describe the sensitivities of r_{fine} and $V_{fine.}$ In the first manuscript that the referee received there were larger discussions about Mie kernel functions. We think that this is no a critical point to understand the manuscript and we have decided to skip it. The part skipped was:

" … Maximum values of Mie extinction kernel functions at 355 nm are found at 0.4 µm while for particles in the coarse mode (> 1 µm) these kernel functions reach very low values near zero. These dependencies of kernel functions to particle size imply that extinction of light at 355 nm strongly depends on the number of particle in the range of ~ 0.3-0.6 µm which explains the large dependence of both r_{fine} and V_{fine} to biases at α(355 nm). Moreover, for the range of submicron particles, a decrease in particle size yields a decrease in particle volume kernel functions, which implies positive slopes of V_{fine} as a function of biases at α(355 nm). On the other hand, at 532 nm the peak of the volume kernel functions is shifted to larger radii, that is, the maximum values are found for the range of particles of ~ 0.5-0.7 µm. But now the volume kernel functions for particles in the range of 1-2 µm, although very low, reach values different than zero. Thus, at 532 nm, extinction of light is sensitive to particles in the fine mode but also to changes between fine and coarse modes. This explains the sensitivities of both r_{fine} and V_{fine} to biases at α(532 nm)…."

And instead we introduced in lines 385-387 of the revised manuscript:

These dependencies of the sensitivities of rfine and Vfine to biased input data are associated with the different dependencies of the kernel functions on wavelength and particle radius (e.g. Chapter 11 of Bohren and Huffman, 1983).

*A second main discussion point is the following: " We will show that the results obtained can also be used to assesthe sensitivity of the retrievals to random errors in a new way" … " But random error in a set of optical data can be considered simply as a particular set of systematic biases in the input data shwere those systematic biases vary randomly from on measurement to the next"

*Is that a common and well-known tool? Then the authors should give a few References. Otherwise, this needs carefully and exhaustive explanations, shy a random error can be simulated in this way.

The method we proposed just assumes that random errors in the optical data can be considered as a random distribution of bias in the optical data. We clarify have done a better clarification in the revised paper. Now, for answering also to referee 1 comments, between lines 437-450 we have:

Up to this point, we have concerned ourselves only with the effects of systematic biases in the input optical data on the retrieved quantities. But in lidar systems, random errors are also present due just to the measurement process itself. Any specific set of 3+2 data affected by random errors can be considered as a set of biased measurements where the individual biases for each of the data follow a normal distribution. Given the additive property of the systematic errors that we have shown, we can assess the effects of random errors in the optical data by generating random biases in the optical data and computing their deviations in the microphysical parameters from the values given in table 1. The sensitivities of the regularization technique to those random errors computed using the procedure just outlined will be compared with previously published ones [e.g. Müller et al., 1999a,b; Veselovskii et al., 2002, 2004].

To assess the sensitivity of the retrievals to random errors we use the additive properties of the systematic biases just described. The procedure used consists of generating random numbers distributed in a Gaussian way centered at zero with width according to the value of the random error to study. These random errors are applied to each optical channel of the $3\beta + 2\alpha$ configuration. This procedure was repeated 50,000 times for each parameter studied. Also, the initiation of the random number generation is different for each channel to avoid the situation where all the random numbers are the same in every channel. Finally, we introduced for every optical data this random number and computed the corresponding error in the retrieved microphysical parameter using the slopes provided in Table 1. For every set of $3\beta + 2\alpha$ values, the final error obtained in the microphysical parameter is the sum of the error obtained for each channel. The study of the frequency distributions of the final errors for this large number of simulations yields the effects of random errors. If the frequency distribution is a normal one, the standard deviation (Full-Width-at-Half-Maximum) provides the final error in the microphysical parameter. Moreover, if the normal distribution is not centered at zero it demonstrates an interesting property; that the presence of systematic errors in the retrieved microphysical property can be induced by random errors in the input optical data. As an illustration, Figure 5 shows the frequency distribution of the differences in the microphysical parameters studied here, for all aerosol size distributions type I, II and III, where 15% random error is assumed in all the optical data. Those differences are in percentages and denoted as 'deviation' in the 'x' axis of the histograms.

*The achieved sensitivity results to microphysical aerosol parameters are more or less already known.

We guess that the referee refers to the sensitivities to random errors as he said before that the part about systematic errors is new and interesting.

In the text, we mentioned that preliminary results of the effects of random errors in the optical were already done by Muller et al., (1999a,b) and Veselovskii et al., (2002,2004) only for 10% random errors in the optical data. What we propose here allows the retrieval of the sensitivity to random errors in a straightforward way and extended the results to other random errors in the optical data as for example 15%. We agree that the results obtained previously in the literature and those reported here for 10% in the text are very similar. However, the way that we have arrived at these conclusions is quite unique and very robust. It permits the straightforward assessment of the influence of any magnitude of random error up to 20%, on whatever subset of optical data desired, without running any retrievals. We believe this is a valuable addition to the literature and quite new. Some of these things are discussed in the manuscript between lines 565 and 575:

"…Müller et al., [1999a,b] and Veselovskii et al., [2002, 2004] studied 10% random uncertainties in the optical data in the 3β + 2α lidar configurations by introducing random errors in the optical data and running the regularization code repeatedly. These studies reported that the retrieved uncertainties were on the order of 25% for reff, V and S, 30% for rmean and 70% for N. These values are quite similar to those reported in Table 2 for our computations of 10% random errors. No evaluations for rfine and Vfine were done in the studies of Müller et al., [1999a,b] and Veselovskii et al., [2002, 2004]. The method shown here for assessing the sensitivity of retrievals to random errors is generally consistent with these earlier results but permits the influence of varying amounts of random error to be studied. It also permits the influence of random errors in different input optical channels to be quantified. We will now apply this capability to the problem of instrument specification…"

*Finally, a lot of self-citations are given.

The use of self-citations are for clarify that the technique is already published and well-tested. Otherwise we should make the manuscript longer. Therefore, we think that they are appropriate. To avoid misunderstandings, we have added some more references, as shown in the version of Atmospheric Measurement Techniques Discussions and in the answers to referee 1.