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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Statistical estimation of stratospheric particle size distributionby combining optical modelling and lidar scattering measurements" *by* J. Jumelet et al.

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#The retrieval of the size distribution function of aerosols in the stratosphere and the determination of microphysical parameters from lidar signals is a very actual topic in nowadays. Most of the Raman lidar systems in networks have the possibility to measure at two or three wavelengths. They produce an enormous data base with those three backscatter profiles. But for climate model it is more important to have microphysical properties such as total number concentration and single scattering albedo. Therefore, this work addresses avery important topic. Moreover, the authors present a method to include lidar errors, a wavelength dependent refractive index and statistical aspects into the retrieval procedure of the aerosol size distribution function. The new method is very interesting and very worth full. The abstract, introduction and summary

are very fine. But the description of the methodology is poor and boringly. This section needs a major overhaul. After this revision the manuscript should be possible to publish.#

>> First of all we thank the reviewer for her/his efforts in reviewing the paper. Most of the comments have been integrated within the manuscript. We accept that the description of the methodology is a bit tedious. Nonetheless, this description has not been published in the past. Therefore, we think it is necessary to be as exhaustive as possible in order for other scientists to be able to reproduce the method. We will address further this issue in the specific point raised below.

#Now some details: Abstract: The authors should give a small explanation or at least a reference for the readers what a 1 sigma-filter is, which they apply to the solution cluster.#

>> The relevant sentence in the abstract has been modified: In order to discard model-simulated outliers resulting from the strong non-linearity of the model, solutions farther than one standard deviation of the median values of the solution cluster are filtered out, because the most probable solution is expected to be in the densest part of the cluster. Within the filtered solution cluster, the estimation algorithm minimizes a cost function of the misfit between measurements and model simulations.

#Page 8917, line 7: In the description what a regularization method is, it should be mentioned that regularization also includes lidar errors into the retrieval process. regularization method consists of two parts, namely, of the regularization operator and of the regularization parameter choice rule. Those parameter choice rules include the noise level of the lidar errors and the noisy data itself, e.g. the discrepancy principle, or an estimation of it, e.g. GCV, see Mueller, 1999.#

>> This comment has been integrated along with the reference: It is worth pointing out that the need to find a physical solution has led to added constraints on the form or properties of the solution. An example of such a constraint is the smoothness of the

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solution for vertical profile retrievals embedded in regularization techniques (Tikhonov and Arsenin, 1977 ; Tarantola, 1987 ; Müller et al., 1999, 2000). Regularization methods account for the lidar errors in the retrieval process when setting the regularization parameter choice rules (Müller et al., 1999).

#Using the two CRs additionally to the three BCs is a possible idea but it does not bring more additional information into the model since CR depends on BC.#

>> It is true that backscatter coefficients and color ratios are not independent sources of information. Nonetheless, all our tests showed that the use of color ratios on the top of the 3 BCs improves the quality of the retrieval. The mathematical dependancy of No in the expression of the backscatter coefficient is such that, when forming the Color Ratios, the median radius and standard deviation parameters are given more weight in the retrieval process, because the influence of No in CR only appears in the refractive index. This has to be connected to the low No sensitivity to the backscatter (as compared to rm and sigma), making it the most difficult parameter to retrieve.

#A strong limitation of the presented method is that one needs to know in advanced if a mono or bi-modal distribution is present. Furthermore, a second drawback of this method is that it is assumed that no absorbing particles are present since only a real part of the refractive index is regarded. But absorbing particles can also occur in PSCs.#

>> We agree with this comment. Both drawbacks are already highlited in the paper. As it stands, the method is only strictly valid for spherical particles, i.e. liquid (ternary solutions) PSCs. Beyer et al. (1996) showed that the absorption part can be neglected in scattering calculations. A comment has been added: In addition, the retrieval algorithm is only strictly valid for spherical particles (e.g. liquid ternary solution PSCs). For this type of PSCs, the absorption part of the refractive index can be neglected in optical scattering calculations (Beyer et al., 1996).

#Page 8929, line 4-5: I am wondering that the retrieval of the surface-area and volume

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concentration is such bad since in Mueller et al and Boeckmann et al it was shown that those parameters are very stable to retrieve and the errors were not so large. But indeed it was also noticed in both references that the retrieval of N0 is very difficult and sensitive. Please cite these references concerning the matter.#

>> Both references have been added. It is an interesting comment. We suppose the reviewer refers to Mueller et al. [1999] and Boeckmann et al. [2006]. It is true that both results presented in the aforementionned papers display lower errors on the retrieval parameters than ours. There are several reasons for this difference. First, we are considering stratospheric particles that are measured with higher lidar errors. Second, we only consider scattering coefficients whereas Mueller et al. and Boeckmann et al. also used two extinction coefficients. The extinction coefficient, if actually available, is not retrieved with sufficient accuracy at stratospheric altitudes. This limits the input parameters to 3, preventing us by the way from retrieving bimodal distributions. These differences limit our retrieval accuracy. If the retrieval is however theoretically possible, this leads to the relatively high errors on the particle surface area density and volume. Mueller et al. stated that: It is shown that both extinction channels are necessary for determining the abovementioned parameters within reasonable limits, i.e., effective radius, surface-area, and volume concentrations to an accuracy of +/-50%. Our results are consistent with this statement. The text has been modified: The overall errors on the integrated quantities A and V as well as the No parameter appear to be higher than errors derived theoretically for methodologies using regularization techniques (Mueller et al. 1999, Boeckmann and Kirsche, 2006). Mueller et al. (1999) and Boeckmann and Kirsche (2006) used extinction coefficients on the top of backscattering coefficients at tropospheric altitudes in their studies. In our case, the extinction coefficient is not retrieved with sufficient accuracy at stratospheric altitudes to be used as an additional constraint in the retrieval procedure, thus leading to higher errors on the final estimation. The total number of particles No still appears to be the most difficult parameter to retrieve accurately (Mueller et al. 1999, Boeckmann and Kirsche, 2006).

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#Concerning the methodology I would suggest the following: First of all, it is not a well known standard method (I do not know a reference) how to calculate the errors in the backscatter coefficient profiles from lidar signals via e.g. Monte Carlo method as the authors suggest. Please describe your method.#

>> We are not sure to have fully undertstood this point. The lidar errors are not estimated with a Monte Carlo approach as they are an input parameter to the size distribution retrieval method that is based on a Monte Carlo approach. There seems to be a confusion between the lidar inversion and the size distribution retrieval. The reviewer may be referring to the fact that we account for the uncertainty on the lidar errors by checking the stability of the final estimate on a local range (20%) around the value of the lidar error. The estimation of the lidar errors is actually independent and is not the point of the paper.

Please, give some references concerning the statistical estimation method.#

>> Our methodology is derived from works of Beyerle et al. (1996) and Mehrtens et al. (1999). Both references are already provided. The one sigma filtering is really a common statistics procedure.

The final method should be summarize in an Algorithm: Step 1: Step 2: Step 3 and so on.#

>> A simple and very visual figure has been added to summarize the algorithm.

Additionally, I feel it is urgently necessary to give an example in detail with synthetic data to describe the algorithm, to show how it works and to illustrate the method with some figures of the particular example. The reader must be able to recalculate this example. Otherwise, it is worthless for other readers.#

>> There is already a long and boring (as stated by the reviewer) description of the methodology. Now we are asked to add an example of application on synthetic data, probably based on what had been done in Mueller et al. The most valuable application

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is the comparison with independent size distribution measurements. We do not know any other way of validating the approach. In addition, to say the least, it would make the description of the methodology even more tedious. The overall low complexity level of our approach (still compared to more theoretical approaches like the regularization technique) makes it easy to reproduce the methodology and apply it to the real case considered here. A simple schematic has however been added for clarity purposes.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 8913, 2008.

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