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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Benefit of depolarization ratio at $\lambda = 1064$ nm for the retrieval of the aerosol microphysics from lidar measurements" *by* J. Gasteiger and V. Freudenthaler

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We thank the reviewer for thoughful comments which helped us to improve our manuscript.

1) To which size range was the T-matrix method applied before the geometrics optics approach was used? What is the maximum radius of the particles that could be considered in the computations? The authors point out that parameters are given in one of their previous publications. I consider it helpful if an overview (table) is given in this paper, too.

In the revised manuscript, we have added a reference to an illustration of the size coverage of the T-matrix method and give examples for the size coverage of the T-matrix method at a wavelength of 532 nm. We also mention the size integration range (minimum and maximum radius) for the calculations. Furthermore, we have added a table with the ranges of the microphysical parameters of the model ensembles used for the Monte Carlo sampling.

2) The paper reports on one measurement of volcanic ash. To my opinion, the merit of the paper could be increased if the authors also show one example of dust measurements. Volcanic ash certainly is important in view of the impact the Iceland volcanic eruption had. The decision on measuring depolarization at two or three wavelength however will be mainly driven by the question: how much do we gain in regard of observations of mineral dust?

We agree that adding a dust measurement case would be useful. The main issue with the available dust measurements is that mineral dust is often mixed with a mode of comparatively small and spherical particles (e.g. sulphate particles during SAMUM, corresponding to the WASO component of OPAC), affecting mainly the depolarization ratio at 355 nm. Such measurements can not be used in retrievals in which only non-spherical particles (pure ash or dust) are assumed, like in our paper. An extension of the aerosol model with a second mode of spherical particles would be required for the application to available dust measurements. This is, however, beyond the scope of our study.

It can be shown that depolarization is weak for particles smaller than the wavelength and strong for particles larger than the wavelength (see Fig. 1 of revised paper). This is the main reason for the improved effective radius retrieval we found in our study (also discussed below and in the introduction of the revised paper). Due to the quite similar properties, e.g. depolarization ratios, effective radii, refractive indices, of pure mineral dust and pure volcanic ash, we expect that our findings are also valid for mineral dust aerosols. However we can not strictly verify that as suggested by the reviewer.

3) I am not sure if I understand the simulations in the results section/statistical verification. Did you use one particular size distribution as "truth" for your tests?

In Section 3 we use as "truth" one (of many possible) aerosol ensemble that match our Maisach volcanic ash measurements in April 2010, whereas in Section 4 we use 100 "truth" ensembles that match our Maisach volcanic ash measurement. See added a flow chart illustrating our approach.

4) What happens if the volcanic size distribution, i.e. effective radius is a factor two lower or a factor two higher? Are depolarization measurements at 1064 nm still that important?

The effective radii of the truth ensembles in Section 4 vary between 0.70 and 2.05 micrometer. Thus variable input effective radii are already considered, but the results from Section 4 may not be representative for volcanic ash in general because the selection of the refractive index and shape distributions of these input ensembles is not free; they were selected to match the ash measurements in 2010 at Maisach.

The primary depolarization-related criterion for the selection of solutions of the retrieval is the wavelength dependence of the linear depolarization ratio which results mainly from low depolarization ratios for small size parameters (x<2) and high depolarization ratios for larger size parameters (x>6), as indicated above and in new Fig. 1. For our input ensemble in Sect. 3, the depolarization at 1064nm is affected by small size parameters whereas the depolarization at 532nm is less affected (see optical data in Tab. 2). When the effective radii of the ensembles decrease, more particles are in the strongly selective size parameter range (x=2 to 6); when effective radii increase, the size parameter range of the size distribution shifts to larger values where the depolarization is hardly sensitive to size parameter. Thus it can be expected that the benfit of the additional depolarization channel increases if the effective radius is halfed with respect to the considered "truth" ensemble in this study, and decreases if the effective radius is doubled.

5) What is the impact of the quality of the retrievals if the real part of the refractive index is different for another type of volcanic ash, or in other words: is it possible to generalize the results of your study so that the lidar community can use these results for a future volcanic ash even if the composition of the particles differs?

We expect that the quality of the results will not be much different if the real part of the ash refractive index varies within its natural variability, which we assume to be in the order of 0.05. The new Figure 1a shows that the transition region between weak and strong depolarization is shifted slightly when the real part changes. A variability of 0.05 for the real part of the refractive index results in a variability of the position of the transition region in the order of 10%, equivalent to a variability of 10% of the sensitive size range, which has only minor effects on the quality of the retrievals.

6) Figure 3 shows the results for m-real versus effective radius. Can you show the same plot for the imaginary part? Can you explain why the "correlation" shown in Figure 3 fans out, becomes wider with increasing effective radius?

As suggested, we added a plot for the imaginary part. No fan out is found for the imaginary part at large effective radii. As can be seen in Fig 1a and b and as explained now in the introduction, the refractive index has a stronger impact on the linear depolarization ratio in the transition region between about 0.15 and 1 μm particle radii than above and below. Above, the selectivity of the linear depolarization ratio regarding the size parameter is very low, and the "fan out" is probably determined by the particle size selectivity of the other measured lidar parameters. However, the explanation of this multi-parameter dependency would require more investigations.

7) You assumed a wavelength independent refractive index in your simulations and also in your assumption of the "true value". Can you corroborate this assumption, or in other words: do you have information in how much real and imaginary parts could vary across the three measurement wavelengths?

We assumed a wavelength independent refractive index also for the "truth". The assessment of the effect of the realistic wavelength-dependence of the refractive index on the benefit of the additional depolarization channel has to be postponed to future studies. Of course, this study should be part of a more general study on the effects of refractive index assumptions on retrieval results. These studies should consider the important effects of the variability of refractive indices within the ensembles, too.

8) I am missing a brief overview on results by other authors who reported on this volcanic ash event. Did they find results that could either influence the conclusions of our study or point toward parameter values you would need to consider in a follow up study? What would be the impact on the quality of your results? This question is also important if these results are to be applied to observations of ash in other regions where volcanic activity and thus the impact on air traffic is high. Your study in that regard would potentially contribute to discussions if a next generation space lidar should be equipped with one, two, or three depolarization channels. A respective comment on this would be very helpful in the abstract and the conclusions section.

This paper is aiming at illustrating the effect of additional depolarization channels at 1064nm using the example of Eyjafjallajökull ash measurements. We did not find results by other authors that may influence conclusions from our sensitivity study. As discussed above, we have added a more general discussion that our results should be transferable to other volcanic ash compositions and dust.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 5095, 2014.