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Atmospheric Measurement Techniques Discussions

Interactive comment on "A better understanding of POLDER's cloud droplet size retrieval: impact of cloud horizontal inhomogeneity and directional sampling" *by* H. Shang et al.

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Thank you very much for pointing out our misunderstanding of the size distribution of combined gamma distributions, and give detailed instruction on the way of calculation .In the revised version, we adopt the method you suggested to calculate the size distribution parameters (CDR and EV) for combined gamma distributions, and the revisions we made based on the AMTD version: #1. We add the description of the calculation of CDR and EV for combined gamma distributions in Section 3.1, and stressed that the mixture of a bi-mode and tri-mode gamma distributions is no longer a gamma distribution.

PAGE 6570, LINE 14: before "Retrievals from…" we add "It should be known that the mixture of two or more gamma size distributions (sub-regions) is not another gamma size distribution, and the mean droplet effective radius and variance of the combined distributions is not simply the average of the effective radii and variances of sub-regions, the mean droplet effective radius and variance in this study is calculated with the method of (Alexandrov et al., 2012;Alexandrov and Lacis, 2000)."

#2. The mean radii and variances for the three cases in Figure 2 are recalculated with the correct averaging procedure, and the conclusions are adapted. In the legend of Figure 2, we add the RMSE and correlation coefficient of the best fit.

PAGE 6570, LINE 21-25: the sentence "The examples…reflectance oscillations" is rewritten as "The mean effective radii and variances for the mixtures in Figs. 2(a), (b) and (c) are 17.07 μm, 0.06, 18.00 μm, 0.06, 15 μm, 0.03 respectively. The examples in Figs. 2(a) and (b) illustrate the retrieved CDRs based on mean reflectance of inhomogeneous pixels sub-regions are smaller ($\sim$ 1.5 μm) than the mean CDRs", while the EV estimates are close to the mean variances of the combined size distributions.

#3. In Table 2, we added two new columns: the mean CDR and EV values for the combined droplet size distributions. In order to eliminate retrievals with large biases, the CDR and EV estimates of both groups (using measurements of 137°-165°, 145°-165°) are restricted with T1>0.978 and T2<0.01. The discussion related to Table 2 is adapted accordingly.

PAGE 6571,LINE 1-10: this part (discussion of Table 2) is rewritten as followed, The scattering angle range used in the operational POLDER procedure is 145$\sim$165° and does not include the primary rainbow region of 137$\sim$145°. To further assess the information content of the primary rainbow structure for the retrieval, more cases were examined with respect to CDR variability. Each case was retrieved twice, either using the 137$\sim$165° or the 145$\sim$165° scattering angle ranges. The POLDER-like polarized reflectances used in each retrieval is with directional interval of 0.2°. As shown in Table

2, more valid retrievals are received from the former group (137∼165°) than the latter group (145∼165°), and the CDR is underestimated by 8.2 μm for the case of "15+20" in the latter group. This results demonstrate that the primary rainbow make the retrievals more reliable. In addition, The CDR estimates of former group are close to the mean radii with biases less than 1.5 μm. Regarding the EV estimates, both the retrievals of the two groups have considerable biases with no identifiable trends.

PAGE 6571, LINE 11-14: the conclusion of Section 3.1 is corrected as followed, In conclusion, the heterogeneity in the cloud field CDR significantly reduce valid droplet size distribution retrievals, and introduce uncertainties to its mean estimate when using the operational procedure. However, the impact of this variability is very much reduced when using information content of the primary rainbow (angular range 137-145°).

#4. Based on the discussion of Section 3.1, we made the following revisions to the Abstract and Conclusion.

PAGE 6560, LINE 8-10, the sentence is rewritten as "Case studies show that the sub-scale variability in droplet effective radius (CDR) can significantly reduce valid retrievals and introduce small biases to the CDR (∼1.5μm) and EV estimates."

PAGE 6577, LINE 26-PAGE 6578 LINE5: the part "The sub-scale variability.... . .horizontal inhomogeneity" is rewritten as "The sub-scale variability of the CDR distributions reshape the observed rainbow structures, which make a lot of retrievals inaccessible. On the other hand, the variability of the CDR distributions induce small uncertainties in the CDR and EV estimates. The uncertainties become large when the measurements of the primary rainbow are not included in the retrieval. However, the sub-scale variability in the EV and COT distributions affects the EV retrievals, but with exert discernable impact on the CDR estimates. Therefore, the Higher-resolution retrievals bring more successful cloud droplet size distribution estimates and reduce the biases introduced by the effects of cloud horizontal inhomogeneity."

#5. The mean CDR and EV for the case of Figure 9 are corrected as followed,

PAGE 6577, LINE 13-14: the sentence "The sub-scale average of the CDRs was 9.92 μm, which was less than the grid-scale retrieval result." is correct as "The mean effective radius and variance of the 24 sub-regions are 10.54 μm and 0.09 respectively, which is very close to the grid-scale retrieval result."

#6. As you pointed, we add the reference (Alexandrov et al., 2012) and another paper (Alexandrov et al., 2015) in the Introduction.

PAGE 6563, LINE 14-23: this part is rewritten as "Sensitivity studies based on simulated datasets demonstrate that the polarized technique is robust against uncertainties of 3D radiative transfer, solar-viewing geometry and aerosol layers above clouds (Alexandrov et al., 2012a). It is also found that the polarized technique can be applied to vertically multi-modal cloud size distributions by means of Rainbow Fourier Transform (Alexandrov et al., 2012;Alexandrov et al., 2015)."

Alexandrov, M. D., and Lacis, A. A.: A new three-parameter cloud/aerosol particle size distribution based on the generalized inverse Gaussian density function, Applied mathematics and computation, 116, 153-165, 2000. Alexandrov, M. D., Cairns, B., and Mishchenko, M. I.: Rainbow Fourier transform, Journal of Quantitative Spectroscopy and Radiative Transfer, 113, 2521-2535, 10.1016/j.jqsrt.2012.03.025, 2012. Alexandrov, M. D., Cairns, B., Wasilewski, A. P., Ackerman, A. S., McGill, M. J., Yorks, J. E., Hlavka, D. L., Platnick, S. E., Thomas Arnold, G., van Diedenhoven, B., Chowdhary, J., Ottaviani, M., and Knobelspiesse, K. D.: Liquid water cloud properties during the Polarimeter Definition Experiment (PODEX), Remote Sensing of Environment, 169, 20-36, 10.1016/j.rse.2015.07.029, 2015.

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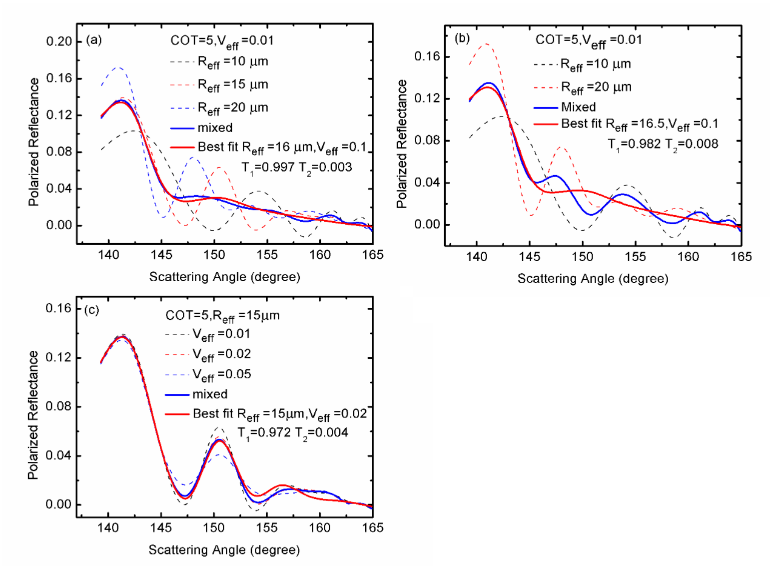

Fig. 2. The retrievals from a heterogeneous cloud field with constant COT=5 and variable CDR and EV values. The dashed lines indicate the separate rainbow structures for sub-scale cloud fields. Three equal-area sub-parts with CDR=10, 15 and 20 μm were considered in (a); two equal-area sub-parts with CDR=10 and 20 μm were considered in (b); three equal-area sub-parts with EV=0.01, 0.02 and 0.05 were considered in (c); the blue line represents the rainbow structure for the heterogeneous cloud field; the red line depicts the best fit.

Fig. 1.

Table 2. Retrievals from a heterogeneous cloud field with variable CDRs using POLDER-like polarized reflectances (865 nm) in 137~165° and 145~165° ranges, respectively. In all cases, the EV in the sub-scale cloud and the COT were assumed to be 0.01 and 5, respectively. The "+" indicates the equal share of the CDRs in the cloud fields. The mean CDR and EV indicate the effective radii and variances for the combined droplet size distributions. The CDR and EV estimates are restricted with T_1>0.978 and T_2<0.01.

Combined CDRs (μm)	Su-scale EV	Mean CDR (μm)	Mean EV	Retrievals of 137°-165°		Retrievals of 145°-165°	
				CDR (μm)	EV	CDR (μm)	EV
5+10	0.01	9.00	0.06	-	-	-	-
5+15	0.01	14.00	0.06	-	-	-	-
5+20	0.01	19.12	0.04	-	-	-	-
10+15	0.01	13.46	0.04	13.0	0.1	-	-
10+20	0.01	18.00	0.06	16.5	0.1	-	-
15+20	0.01	18.20	0.03	17.5	0.05	10.0	0.02
5+10+15	0.01	12.70	0.11	12.0	0.1	-	-
5+10+20	0.01	16.92	0.13	-	-	-	-
5+15+20	0.01	17.35	0.08	17.5	0.05	-	-
10+15+20	0.01	17.07	0.06	16.0	0.1	16.5	0.01

Fig. 2.