Response to RC1 of egusphere-2023-2235

We want to thank the first referee of our paper for the review and comments. One major point of the review was the similarity of the results to the previously published results by Alexandrov et al. 2012, who studied the accuracy of the polarimetric cloud droplet size distribution retrieval applied to simulated measurements of the RSP instrument. To begin with, we think that it is a good result that we independently found a high accuracy of the polarimetric retrieval (for a different instrument) and that this also affirms the results of Alexandrov et al. 2012. Moreover, we want to highlight why our study is substantially different from the one published by Alexandrov et al. although the same retrieval approach is addressed:

- The specMACS measurements differ from the RSP measurements as we obtain 2-D polarized measurements which allows the retrieval of cloud droplets size distributions on 2-D images rather than in the principal plane only. The 2-D measurements also allow an accurate determination of cloud top heights from the stereographic retrieval which is also addressed in this work. Further, the accurate determination of the cloud top heights is important for the polarimetric retrieval and is considered in this work by evaluating the accuracy of the full retrieval procedure used for real measurements. This includes the initial identification of potential cloud targets, the geolocalization including the stereographic cloud top heights and the fit of the polarized phase functions to the aggregated signal. On the contrary, using RSP measurements, the simulated radiances can be aggregated to a defined point on the cloud surface. With regard to Fig. 15 in the paper, this is expressed by Alexandrov et al. as follows: “The horizontal position of a ‘pixel’ used for the comparison between 1D and 3D retrievals is depicted by the dashed line. The RSP reflectance simulated with the 3D RT model output was aggregated to the point where the dashed line crosses the cloud top boundary.”
- Providing 2-D measurements comes with the cost of broader spectral channels (three RGB channels), which might result in “smoothed” cloudbow signals and hence, the need to study the accuracy of the polarimetric retrieval applied to specMACS measurements. Therefore, obtaining similar results to the ones of Alexandrov et al. 2012 confirms that accurate cloud droplet size distributions can also be obtained from less spectrally resolved cameras.
- The MYSTIC simulations performed for Alexandrov et al. include only a single wavelength and did not consider the spectral response function of the RSP instrument.
- The clouds did not develop over time in their simulations while we also studied the impact of cloud evolution on the cloud top height and reff/veff retrievals.
- In Alexandrov et al. only a single point is compared to the effective radius expected from the LES input data. The statistics performed are mainly for potential biases in 1-D cloud assumptions.

The listed points are now addressed in the paper from line 97 onwards and are again discussed in line 467f.

General comments:

1. The results are largely consistent with those of Alexandrov et al. 2012, who used essentially the same retrieval approach and the same 3D radiative transfer model. In that sense the current paper does not add so much to the available literature. I would suggest to add a slightly deeper analysis of the cases where the retrievals substantially deviate from the truth. Are cases with large errors in Reff and Veff related? Do they correspond to low optical thickness cases? Do these retrievals exhibit a bad fit of the simulations to the data? Is there any way such cases could be identified in case of real retrievals?

   In addition to the above explained differences between the work of Alexandrov et al. 2012 and ours, we included a study of the retrieval results that substantially deviate from the truth in the paper. The results are shown in Fig. 7. Here, we show the correlations between the retrieved effective radius and variance (panel a), their differences (panel b) and the correlation between the differences and the vertical optical thickness of the observed cloud targets. However, there are no significant correlations between the different quantities, as explained in the paper between lines 419 and 436.

2. The paper refers to earlier paper for the details about the drop size distribution retrievals. However, I think it is crucial information to understand this paper and suggest that a short description of the retrieval procedure is included.

   We added a short description from line 69 onward.

3. In line 114 it is stated that k = 0.8 is assumed for the calculations of effective radius from the assumed number concentrations. However, in line 116 it is stated that an effective variance (veff) of 0.1 is assumed. This is inconsistent, as k and veff are related by k = (1-veff)*(1-2*veff) for the gamma distributions assumed here (see for example Grosvenor et al. 2020 Eq. 13; https://doi.org/10.1029/2017RG000593). For an assumed veff=0.1, k would be 0.72. I do not think this matters much for the analysis in the paper, so I will not ask to correct this. It should be noted in the paper, however.

   Yes, thanks for noticing. We noted the inconsistency from line 150 onward and explained why this should not affect the results of the paper.

4. It is not clear to me if “evolution” of the cloud also includes movement of these clouds. If so, please make this clear and mention the windspeed (profile) assumed in the paper and also indicate how much the clouds generally move during the cloudbow observations.

   The realistic simulation with cloud “evolution” includes the movement of the clouds within the LES model domain. We added the associated horizontal wind profile in Fig. 1. We used the wind profile to explain why an underestimation of the cloud top heights in

the stereographic retrieval is possible (l. 278f.) and calculated the horizontal displacement of the cloud targets during the cloudbow observations in l. 399f. to 70-105m.

Specific comments:

Line 133: For clarity, please change to “acquisition time of 8Hz of SpecMACS.”

We added “of specMACS” to the manuscript, but did not change “frequency” to “time”.

Line 206: A flight time of 30 seconds is simulated. Please specify what area is covered by all viewing angles in such a time.

Thanks, our description was probably not clear enough. We simulated a total flight time of 60s (see Sect. 2) and tried to clarify this as well in line 255f. We added the information that a single camera of specMACS covers an approximate area of 32 x 21 km^2 within the simulated time over the LES field in l. 128.

Line 252: The accuracy of stereo heights retrievals can be compared to those estimated by Sinclair et al. 2017 (https://doi.org/10.5194/amt-10-2361-2017), who analyzed data with many different cloud types.

Thanks for the advice. We compared our results to the results of Sinclair et al. 2017 and further to the stereographic cloud top height retrievals for MISR and ASTER described by Moroney et al. 2002 and Seiz et al. 2006 from l. 318f.

Line 284: If the optical path length for each viewing angle is similar, won’t different viewing angles see slightly different physical vertical locations in the cloud top? Then each angle may see slightly different size distributions. I guess this effect is minor, but it might be good to estimate this. Also, which viewing angle is taken into account for the analysis here?

With the setup for the single scattering (reference) simulation, we get indeed only a particular viewing angle for the comparison. However, as explained now in Sec. 5, we performed two more reference simulations at different times (after 15 and 45s). The corresponding viewing angle of a specific cloud target is then also changed. We verified that the overall results obtained for all the reference simulations and their combination are similar. By comparing the results for different cloud targets, we found that the expected effective radius can deviate by 1-2µm between the different reference simulations with different viewing angles, but the total results hardly change.

Line 332: Please give the mean and standard deviation of the differences here. They are only given in the conclusions.

Thanks for noticing. We included the mean and standard deviations as suggested.

Figure 4, 5 and 6. In the scatterplots all the low values are hard to see. Please change the colorbar.

Since the second referee suggested to present the histograms of the differences instead of the scatterplots, we decided to do that instead of changing the colorbar as suggested here.