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Atmospheric Measurement Techniques Discussions

Interactive comment on "Applicability of the VisiSize D30 shadowgraph system for cloud microphysical measurements" *by* Jakub L. Nowak et al.

Anonymous Referee #1

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This paper introduces the commercial shadowgraph system VisiSize D30 and assesses its applicability for microphysical measurements of cloud properties (e.g. droplet number concentration and size distribution). The depth of field and sample volume of the instrument were characterized using a dense stream of poly-disperse particles. Furthermore, laboratory experiments with mono-dispersed droplets were performed for particle sizing. Based on these experiments, the authors developed correction methods to improve estimations of number concentration and size distribution. Finally, the instrument was applied in real atmospheric clouds at a mountain observatory.

This paper highlights the advantages and limitations of the shadowgraph technique for cloud research and proposes methods, which are interesting for cloud probes with a size-dependent sample volume. I recommend publication after addressing the comments below.

General comments

It is challenging to characterize the sample volume of the shadowgraph system (Sect. 3) without accurate information regarding the properties of the plume (e.g. uniformity, size distribution of poly-dispersed droplets). Uncertainties in the calibration method can have large uncertainties on the droplet number concentration and size distribution. The assumptions and speculations in Sect. 3 are all justified, but some uncertainties remain. For example, the different lens systems show different dependencies of the number concentration on the horizontal, vertical and axial position (Fig. 8), some of which are attributed to the non-uniformity of the plume (x2, x4), whereas others are explained by instrumental flaws (x1). A better characterization of the plume would strengthen the interpretation.

Regarding the particle sizing, a FMAG was used to produce mono-dispersed droplets (in the range of 15 to 72 μm in diameter). For the size calibration experiments, droplet diameters of 20.13, 39.35 and 57.55 μm were chosen. Would it be possible to produce size calibration experiments with smaller sizes (e.g. by using a Vibrating Orifice Aerosol Generator (VOAG); or PMMA/PSL spheres with atomizer or fluidized bed)? Previous studies have shown that sizing uncertainties are largest for the smallest particles, so I would recommend performing sizing experiments for smaller sizes and if possible include additional instruments for better validation. Furthermore, cloud droplets are generally smaller than 20 μm. For example, the cloud droplet size observed in Sect. 5 all lie below the smallest calibration size applied in this study (20.13 μm).

Specific comments

1. Page 1 line 19: You mention that researchers have to tackle with intrinsic difficulties

when using in situ and remote sensing observations. You could consider giving some examples describing the main challenges of in situ and remote sensing observations.

2. Page 2 line 44: Holographic systems have also been applied on balloon-borne platforms; e.g. HoloBalloon Ramelli et al. 2020, https://amt.copernicus.org/articles/13/925/2020/

3. Page 2 line 48: Here you compare the sampling volume and frame rate of holographic and shadowgraph instruments. I would recommend to compare the sample volume rate as this is more meaningful (e.g. 15 cm3*5 fps = 75 cm3 s-1; 0.04 cm3*400 fps = 16 cm3 s-1).

4. Page 2 line 50: You write that the shadowgraph technique did not gain common use in cloud measurements. This is misleading, as CPI are frequently used on aircrafts. Here are some examples:

Lawson et al. 2001: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2000JD900789

Lawson et al. 2010 : https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2009JD013017

Stith et al. 2002: https://journals.ametsoc.org/jamc/article/41/2/97/16088

Woods et al. 2018: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2017JD028068

5. Page 7 line 146: In Fig. 1 the flow was vertically aligned. Did you use a different flow direction for the experiments? Please specify.

6. Page 9 Fig. 4: On page 7 line 142 you state that the poly-dispersed water droplets in the stream were in the size range 2-20 μm. Is there a way to verify this? Why do you observe a lot of droplets larger than 20 μm in Fig. 4?

7. Page 14 line 280: I only see the gradual decrease from the center to the sides for x1 in the horizontal direction. It seems like you have more particles on the left side compared to the right side (maximum is not at 0 μm). Is this relating to the non-uniformity of the plume or to instrumental flaws?

8. Page 14 line 284: You speculate that the decrease in concentration in vertical direction for x1 is due to instrumental reasons (e.g. non-uniform illumination). Can you verify/quantify that based on the images? The shadow images for x1 in Fig. 12 don't show indications for non-uniform illumination. Please comment on that.

9. Page 14 line 292: You explain that the axial dependence is more difficult to evaluate. Fig. 8.c shows a sharp decrease of the concentration with increasing z-distance, which you attribute to the miscounting of the smaller droplets. Would it be possible to perform a similar experiment as in Sect.4 where you generate a mono-dispersed particle distribution? Or are the concentrations produced by the FMAG to small?

10. Page 16 line 335: For the size calibration experiments, you produced droplet diameters of 20.13, 39.35 and 57.55 μm. Can you explain how these diameters were selected?

11. Page 18 line 353: You state that the left-side skewness of the tails in Fig. 11 implies partial evaporation. I only see a left-skewed tail for x2 and x1 for the diameters 39.25 and 57.55 μm, but not for x4 and the smaller size (20.13 μm). I would expect that the evaporation effect is largest for smaller particles, but this does not seem to be the case. How can you explain this pattern?

12. Page 21 Fig. 14: Why do you have multiple times the same symbol in a, b and c? Are these different experiments?

13. Page 22 Fig. 15: Were other cloud probes deployed at the measurement site? On page 20 line 381 you say " After laboratory tests, the shadowgraph VisiSize D30 has been used for the first time to measure droplets in atmospheric clouds [...] to compare it with other probes already in service in cloud physics studies [...]". If other cloud probes were deployed at the same time, I would add the size distribution of additional probes in Fig. 15 for validation of the VisiSize D30 shadowgraph system. Alternatively, I would recommend performing a comparison campaign with other cloud probes in the future.

Technical comments

1. Page 5 line 93: I would suggest to write "[. . .] a method compensating for the effects [. . .]"

2. Page 6 Fig. 2: Consider choosing different colors for Th and Tp for better distinction.

3. Page 6 line 120: 'z' should be written in italic

4. Page 8 line 165: 'z' should be written in italic

5. Page 8 line 167: 'z' should be written in italic

6. Page 15 line 308: capitalize 'D' in "2-dimensional (z, D) maps"

7. Page 19 Fig. 12: Consider adding different lines for single droplet/double collision/triple collision similar as in Figure 13 or at least of the FMAG diameter.

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