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Atmospheric Measurement Techniques Discussions

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Interactive Comment

Interactive comment on "A video precipitation sensor for imaging and velocimetry of hydrometeors" *by* X. C. Liu et al.

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We thank the reviewer for the thoughtful comments, which enables us to further improve the quality of our manuscript. Specific responses are as follows.

a) the instrument is based on a double exposure principle, where a software algorithm then identifies two images to stem from the same individual particle. Since particles have different fall velocities, such algorithm may not be trivial. Fig. 10 (a) 'Fall velocity' and (b) 'Axis Ratio' show results partly significantly deviating from literature expectations. The authors should explain the algorithm, how images are paired, and if the outliers in Fig. (a) and (b) might be caused by failure of such algorithm.

Response: The pair algorithm is based on the assumption that the same particle have the same gray scale, area, horizontal size, and vertical size. If two images have the same gray scale, area, horizontal size, and vertical size, it can be identified as the same particle; otherwise it can be identified that they are from the different particles. However, if the different particles have the same size, their images might have the same gray scale, area, horizontal size, and vertical size, on this occasion, such algorithm might cause the mismatch of image pair, it is the possible explanation of outliers of fall velocity and axis ratio in Fig. 10. We have added this algorithm and explanation in the manuscript.

b) In 10170 line 4 states: 'Each particle is exposed twice in a single frame'. For an imaging height of 30 mm and an exposure repetition time of 2 ms, (area-less) points with fall speeds of more than 7.5 m/s may be photographed just once, depending on their location relative to the height of the image. For objects with vertical extensions (as hydrometeors are) an even lower fall speed is required, to have two full images of EACH particle photographed. Fall speeds of 7.5 m/s are expected already for rain drops of only 2.8 mm and bigger. The authors should present an analysis, what hydrometeors in fact are expected to be fully photographed twice (e.g. percentage over rain drops' diameter or similar) and should derive the impact on the figures of merit (rain rate etc.). Potentially this analysis might be extended to the horizontal dimension (wind speeds and actual trajectory, rain drops' actual full stay within the imaging section of 30 mm x 40 mm).

Response: Thank you for your suggestion, we have added the discussions and figures about the capture probability in the vertical dimension and horizontal dimension in the Sec 3.2 of the revised manuscript. It should be noted that the limitation of capture probability can be complemented by the long-time sampling.

c) 10171 line 21 reports on sizes of calibration targets, ranging from 1 to 4.5 mm. This range does not cover the size range of rain drops. Why not use calibration targets covering the full size range of rain drops? The authors should either do that, or inform on the reason why not doing so.

Response: The calibration of VPS requires that the targets should have the similar opacity with the water drops, therefore we choose the glass ball. However, the glass balls have relative poor sphericity, especially for the tiny balls and very large balls, and the irregular balls have great effect on the sizing of balls and calibration results, therefore we choose glass balls with good sphericity ranging from 1 to 4.5 mm. In the revised manuscript, we addressed that "Limited by the samples of ideal spherical glass ball, the calibration glass ball does not cover the size range of rain drops, therefore we create a look up table of threshold by using the linear least square fitting method, which ranges from 0 mm to 10 mm, the results are shown in Figure 10." We believe that the fitted curve of threshold can meet the requirement of binarization of rain drops with full size range.

d) 10172 line 7 presents a probability function that a certain particle with a certain size and fall velocity can be captured. Such instrument characteristics is often rated as the sampling area (e.g. 50 cm2 for the impact type disdrometer, etc.). It would be very helpful for the reader, if the authors would express the probability function in an EQUIVALENT sampling area (potentially as function of raindrop size).

Response: Thank you for your suggestion, we have added the discussion about the equivalent sampling area in the Sec 3.2, the equivalent sampling area is 300 mm $\times$ (40 mm - DH/2) $\times$ (30 mm - DV/2), which is a function of the vertical size and horizontal size of raindrop.

e) the algorithms used by the authors to derive axis ratio and canting angles should be explained. The effects of rain drops' orientation in three dimensional space being photographed in a two-dimensional image should be addressed.

Response: Thank you for your comment, we have added detail descriptions about the calculation of axis ratio and canting angle. The long axis and short axis of each drop can be obtained according to the minimal bounding rectangle of its image, by which the axis ratio can be calculated, and the orientation can be calculated according to

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the included angle between the short axis (rotational symmetry axis) and the vertical direction. Also we addressed that the VPS only has two-dimensional measurement in the X-Z plane, the information in the Y-Z plane can not be observed, hence the VPS has its own limitations on axis ratio and oscillation measurement. we will refine our instrument by two orthogonal cameras and three-dimensional measurements in the future.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 10165, 2013.

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