AIRBORNE PHASE DOPPLER INTERFEROMETRY FOR CLOUD MICROPHYSICAL MEASUREMENTS

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1. ABSTRACT

Conducting accurate cloud microphysical measurements from airborne platforms poses a number of challenges. The technique of phase Doppler interferometry (PDI) confers numerous advantages relative to traditional light-scattering techniques for measurement of the cloud drop size distribution, and, in addition, yields drop velocity information. Here, we describe PDI for the purposes of aiding atmospheric scientists in understanding the technique fundamentals, advantages and limitations in measuring cloud microphysical properties. The performance of the Artium Flight PDI (**F/PDI**), an instrument specifically designed for airborne cloud measurements, is studied. Drop size distributions, liquid water content, and velocity distributions are compared with those measured by other airborne instruments.

2. PERFORMANCE

One of the critical instrument parameters that must be determined is the instrument view volume as a function of drop size. We use a new model for determining the view volume. We compare data from a stratocumulus cloud with the model prediction, where the model has two degrees of freedom, one of which can be compared against a known instrument characteristic (laser $1/e^2$ diameter), and the other which is not easily measured (the minimum signal-to-noise ratio for detecting drops), which makes the model essentially a one free-parameter fit. Figure 1 shows a comparison between model and data, showing excellent agreement. This gives us confidence that we know the view volume very well, and thus can infer drop concentrations and other size distribution moments with some accuracy.

3. INTERCOMPARISON

We have performed comparisons with the Gerber PVM-100A as well as a FSSP-100. Figure 2 shows the results from the latter intercomparison, specifically the 10th, 50th (or median) and 90th percentile diameters (hereafter d_{10}, d_{50} and d_{90}) for these distributions, as well as $d_{90} - d_{10}$, which is one measure of the distribution breadth. From these plots, it appears that there is a ~5 µm discrepancy between the measured distributions, which is reasonably consistent among all the distribution parameters, although the discrepancy is greater for d_{10} than it is for d_{90}. The discrepancy in the breadth of the distribution in linear space as measured by $d_{90} - d_{10}$ is ~2 µm (compared to a total width varying from 4 to 10 µm), with the FSSP tending to measure broader distributions by 20 to 50% than the F/PDI.

These parameters, however, do not address the absolute concentrations of the size distribution. An alternate and complementary way of comparing the F/PDI and FSSP is to look at the measured concentration in particular size ranges. Figure 3 shows such a comparison, where the entire FSSP size range (ignoring the first bin, which is generally considered unreliable) has been divided into 6 size bins, and the F/PDI measurements are sampled to match these size bins with a 5 μm shift in size, i.e. a 15 μm drop measured by the F/PDI will be considered a 10 μm drop for this comparison, as suggested by Figure 2. The F/PDI data were shifted to smaller sizes because this was much more convenient than doing the converse for the FSSP sizes, and is not intended to suggest that F/PDI size data are actually biased in this way. The same comparisons performed *without* such a size shift (not shown) yielded comparisons that were generally extremely poor.

For the five largest size bins shown in Fig. 3, there is a good *correlation* between FSSP and F/PDI concentrations. In general, the FSSP infers higher concentrations than the F/PDI, with typical differences on the order of a factor of 2, but as small as ~20%, depending on the size bin. The agreement between FSSP and F/PDI data does not appear to systematically depend on either drop size (e.g. it does not simply improve as drop size increases) or drop concentration (e.g. best agreement is not for the smallest or largest concentrations). For the smallest size bin (2.1 to 7.3 μm), the FSSP predicts drop concentrations about an order of magnitude higher than the PDI. One possible explanation for this discrepancy is that the FSSP was triggering on noise, yielding numerous false drops in the smallest size bin. This is a well-known problem of the FSSP, which is normally dealt with by ignoring the lowest FSSP channel, which we have also done here. This analysis perhaps indicates that the noise problems extend to higher FSSP channels, at least in this data set. Whether this problem can extend to the other size bins and lead to an FSSP overcounting in those comparisons as well is unknown. It is also possible that uncertainties in PDI counting or view volume are partly responsible for these discrepancies.

Overall, we find the correlation in the size-dependent concentration measurements encouraging, but acknowledge that the differences in performance between these instruments are substantial. Without a controlled experiment with known size distribution, and in the absence of an accepted standard instrument for size distribution measurements, it is not possible to determine which instrument measures more realistic size distributions. The results of this intercomparison clearly indicate that further instrument evaluation under controlled conditions with a known size distribution or an accepted standard is necessary to draw further conclusions.

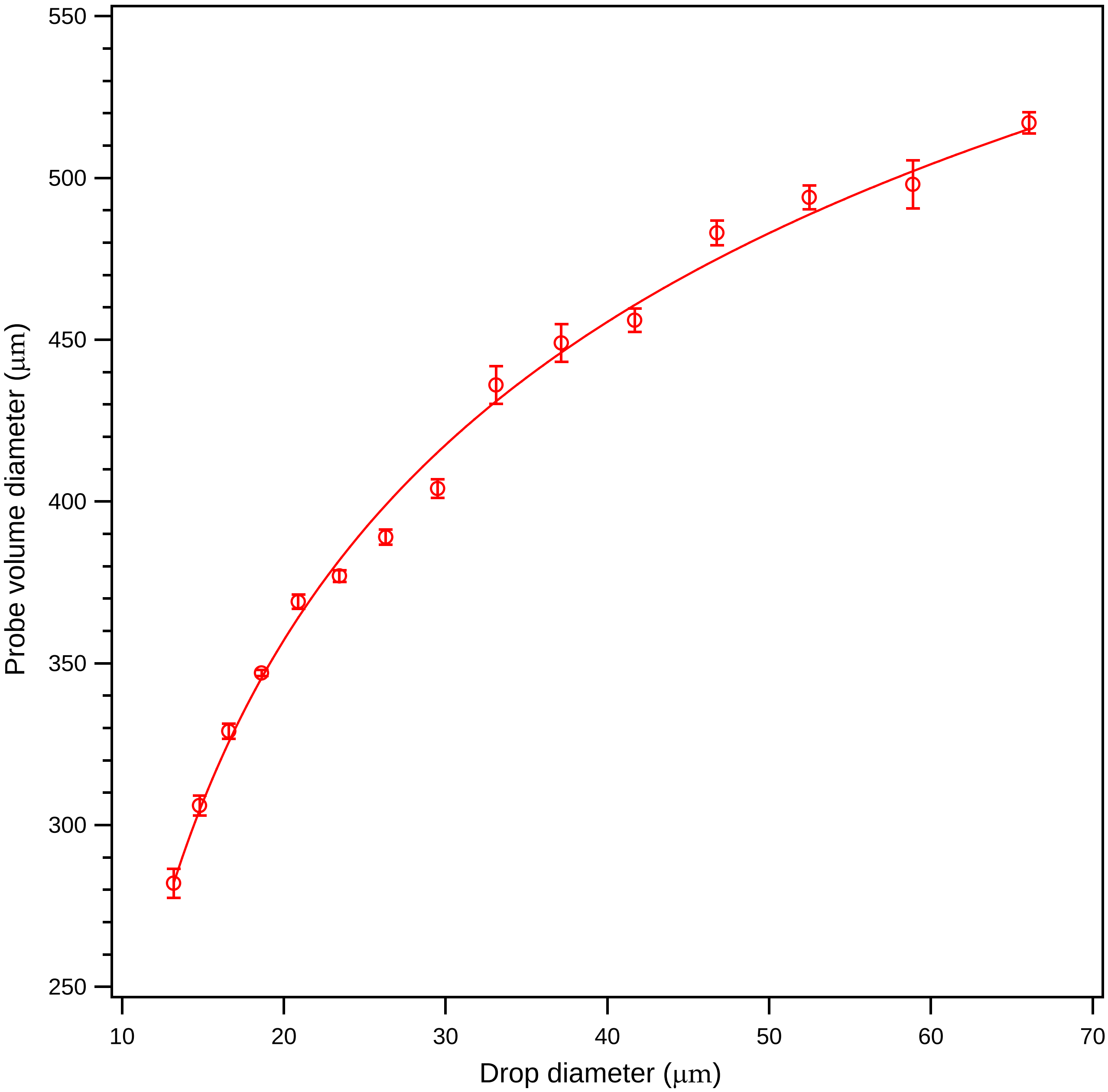

Figure 1: Comparison of modeled probe volume diameter (line) fitted to data (circles) as a function of drop size.

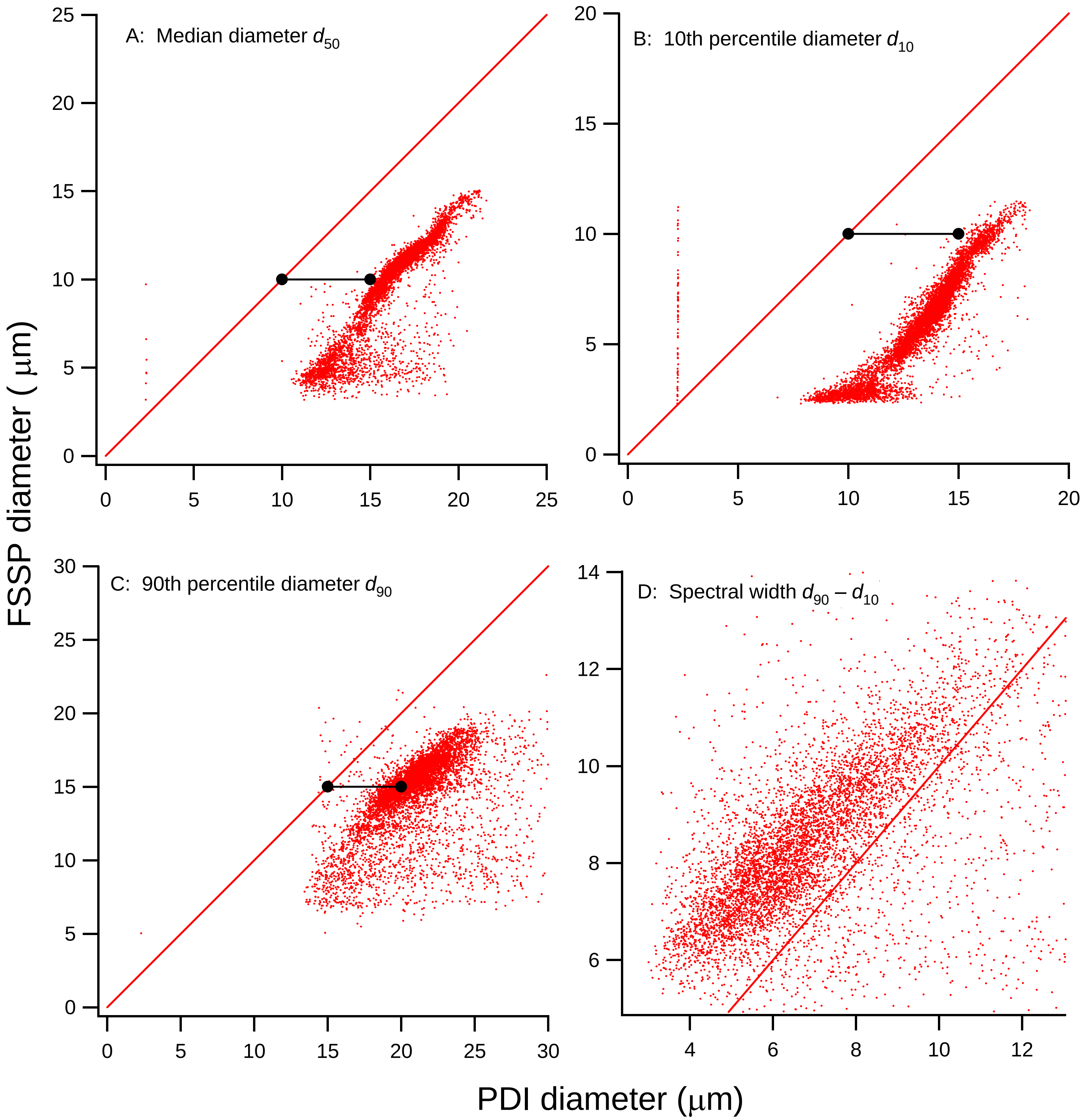

Figure 2: Comparisons of drop size distribution shape as measured by the F/PDI and a FSSP-100. Panels A, B and C represent the d_{50}, d_{10} and d_{90}, respectively for the measured size distributions. In each of these panels, the line terminated by two circles represents 5 μm. Panel D represents $d_{90} - d_{10}$. In all panels, a 1:1 line is drawn. Each dot represents 1 s of data. Approximately 7000 s worth of data is shown.

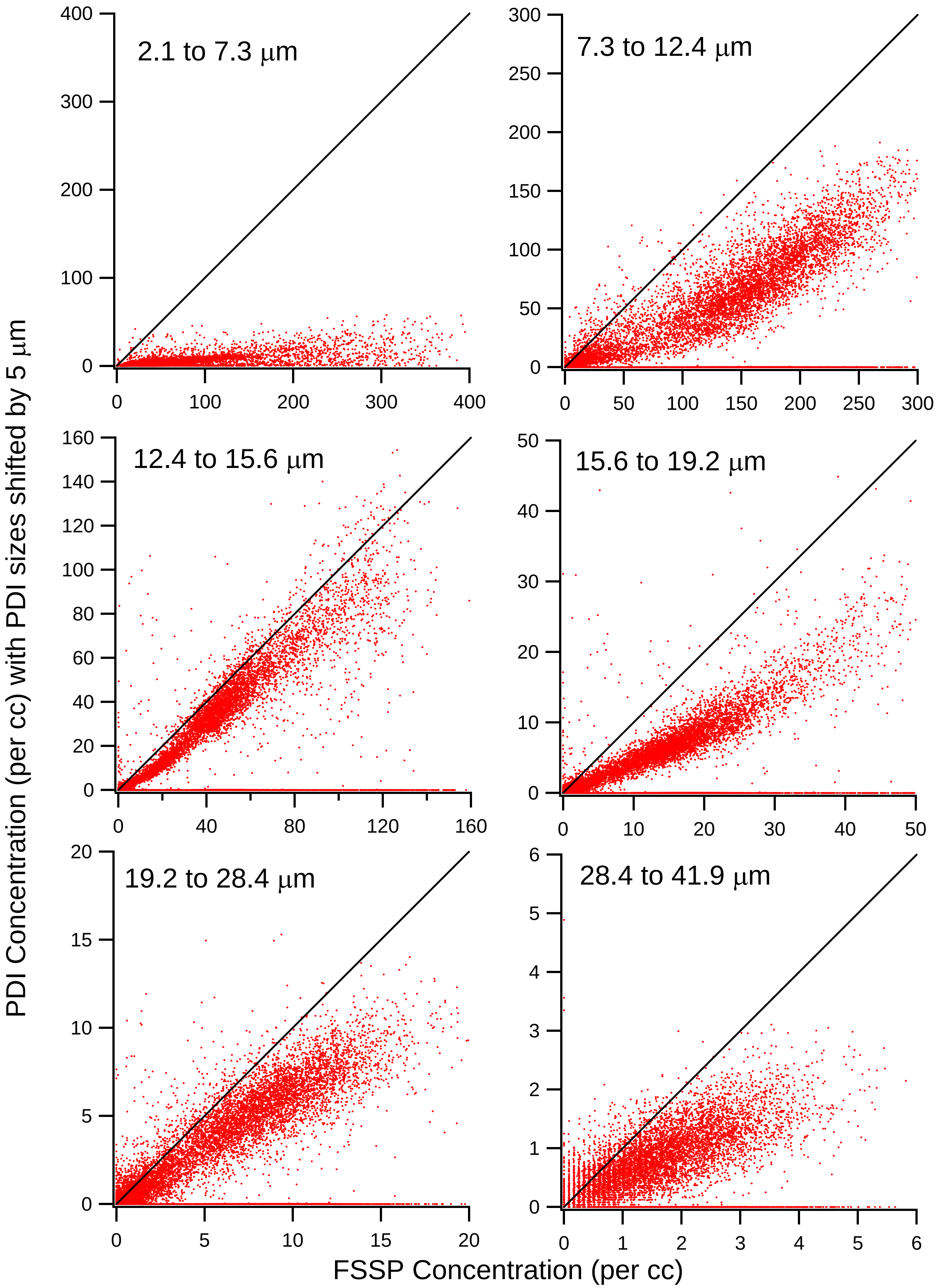

Figure 3: Comparison of the measured drop number concentration by the F/PDI and FSSP in six different nominal size bins. In all cases, the F/PDI distributions have been shifted towards smaller size by 5 μm to account for the sizing discrepancy shown in Fig. 2. This was more convenient than shifting the FSSP distributions upwards by the same amount, and is not meant to imply that these represent the actual drop sizes.