Sampling Considerations Associated with the Interpretation of Disdrometric Data

Michael L. Larsen[1,2] , Katelyn O'Dell[3], and Joseph Niehaus[1]

[1]Department of Physics and Astronomy, College of Charleston, Charleston SC, 29424

[2]Department of Physics, Michigan Technological University, Houghton MI, 49931

[3]Department of Atmospheric Science, Colorado State University, Fort Collins CO, 80523

INTRODUCTION/CONTEXT

Rain drop disdrometers allow for the detection and characterization of rain on a drop by drop basis and are thus ideal instruments to explore rain variability on small spatial (<100 m) and short time (<5 minute) scales. In an effort to quantify rainfall's variability on these scales, a network of 25 disdrometers has been constructed near Hollywood, South Carolina, with all detectors within about 250 meters of each other, and most detectors within a 100 m x 50 m domain.

Examination of these data have revealed many interesting results, but taking the data from this disdrometer network and using them to quantify natural rainfall variability is complicated; different detectors can see different rain accumulations due to some (uknown) combination of natural spatio-temporal variability, detector imperfections, and sampling variability.

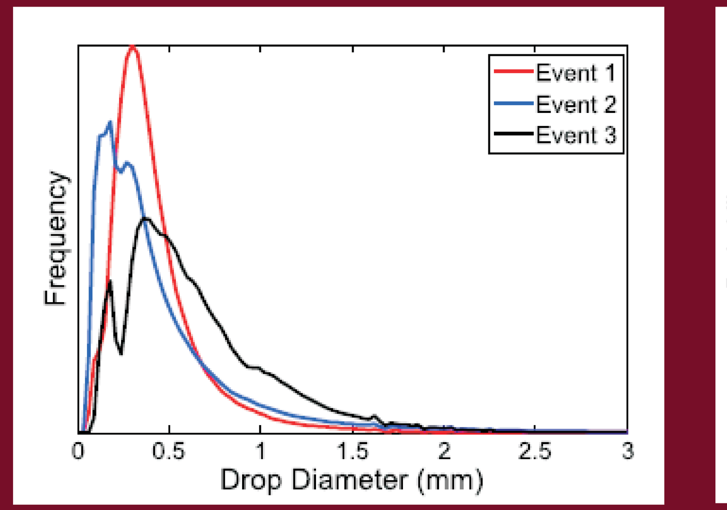
This work attempts to further quantify the possible effects of sampling variability alone in order to establish a reasonable working basis for the number of rain drops required to adequately estimate the natural rainfall properties. Although previous studies along these lines have been published, this work is novel in that it utilizes measured data to drive not only the underlying raindrop size distribution, but also utilizes measured rain drop arrival rate statistics to more fully quantify the sample-to-sample expected variability in observed raindrop number.

SIMULATION APPROACH

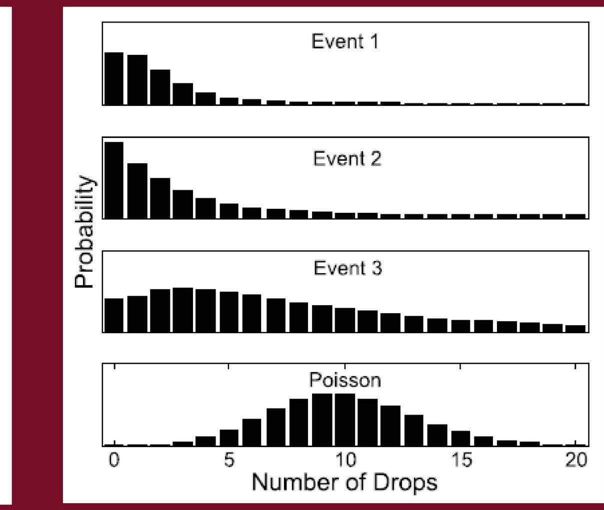
Data recorded by a 2-dimensional video disdrometer (Joanneum) from 3 different rain events was utilized; this instrument records rain drop sizes (to ~0.2 mm resolution) and drop arrival times (to ms resolution).

For each rain event, the event-averaged pdf of observed drop sizes was tabulated. Although for real rain events this pdf evolves over time, the simulations presented here (artificially) kept this underlying pdf constant. Each "sample" of N_i drops randomly assigns sizes by using N_i independent draws (with replacement) from these homogenized probability density functions. This approach is similar to other studies along these lines, except that rather than assuming a functional form for the underlying raindrop size distribution (e.g. Marshall-Palmer or Gamma distribution), the event-averaged distribution is used.

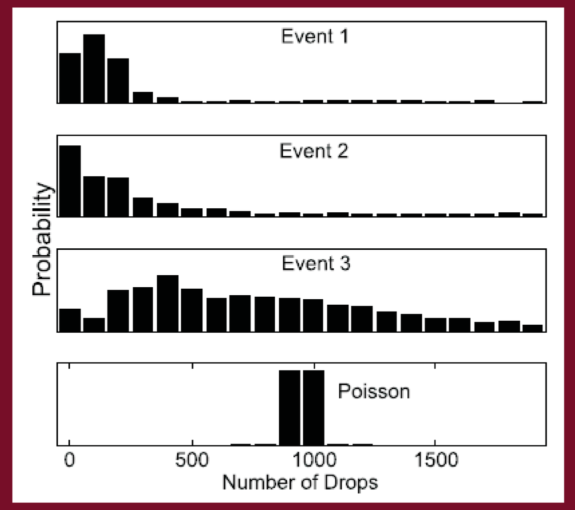
Previous studies determined the number of drops in each sample (N_i) by either assigning it to be the same for each sample or drawing it from a probability distribution (Poisson or Uniform). Here, we mimic the approach for drop sizes described above and use the data itself to dictate the probability distribution governing N_i. Each event had its own event-averaged drop arrival rate $\lambda=N_{tot}/T_{tot}$. To examine samples with mean drop number <N>, the real observational data was divided into temporal intervals of duration $\tau_{<N>}=<N>/\lambda$. After partitioning into intervals of duration $\tau_{<N>}$, the pdf of $N(\tau_{<N>})$ was used to drive the numerical simulations presented here. It is in this step – through the data-motivated introduction of more realistically broad pdfs for N_i – that this study significantly deviates from prior similar numerical studies.



Empirical pdfs of Droplet Sizes



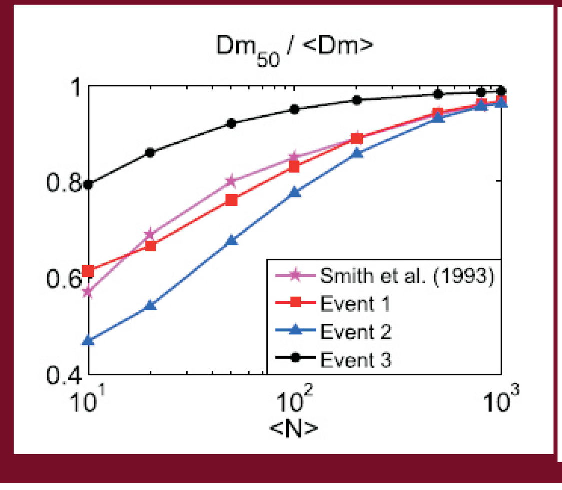
Empirical pdfs of $N(\tau_{<N>=10})$

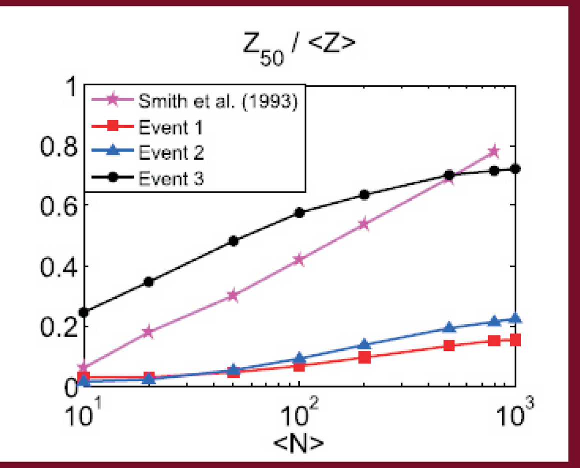


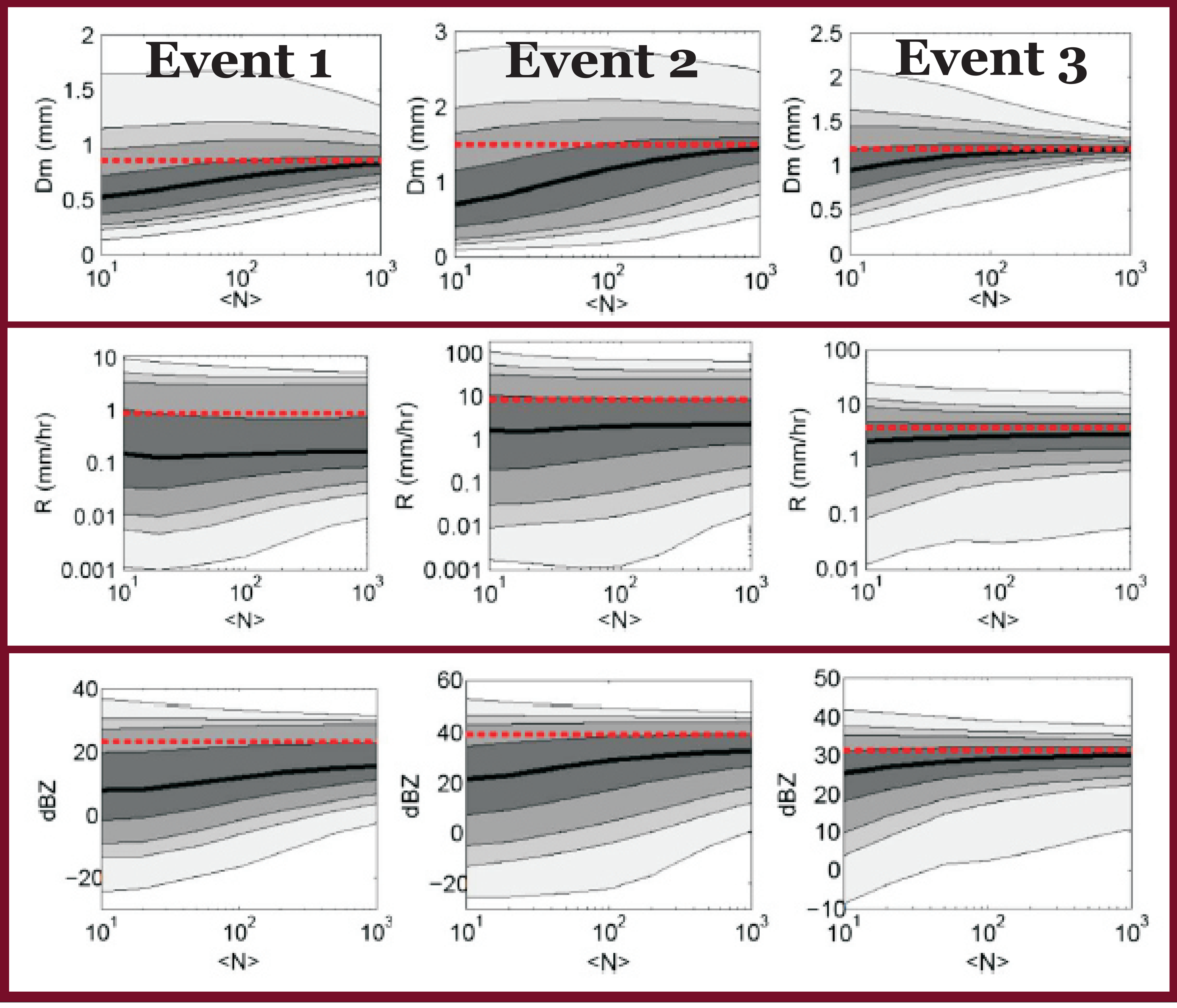
Empirical pdfs of $N(\tau_{<N>=1000})$

DSD MOMENT ESTIMATION

Previous studies used similar numerical approaches to determine how many drops must be in an average sample so that the median sample was an acceptably reliable estimator of the intrinsic event-averaged moment of the drop size distribution. Given the skewness of the underlying drop size distribution, median underestimation for samples with low drop numbers is expected (and observed) though use of realistic sampling statistics result in even slower convergence to the intrinsic event-averaged moments; especially for higher order moments of the drop size distribution like rain rate and radar reflectivity factor. In fact, our simulations reveal that the median sample can frequently underestimate rain rates or reflectivity factors by orders of magnitude (see figures on right; the intrinsic event-averaged values are marked with dotted red lines while shading encloses 50% (dark gray), 80%, 90%, and 98% (light gray) of all simulated samples).

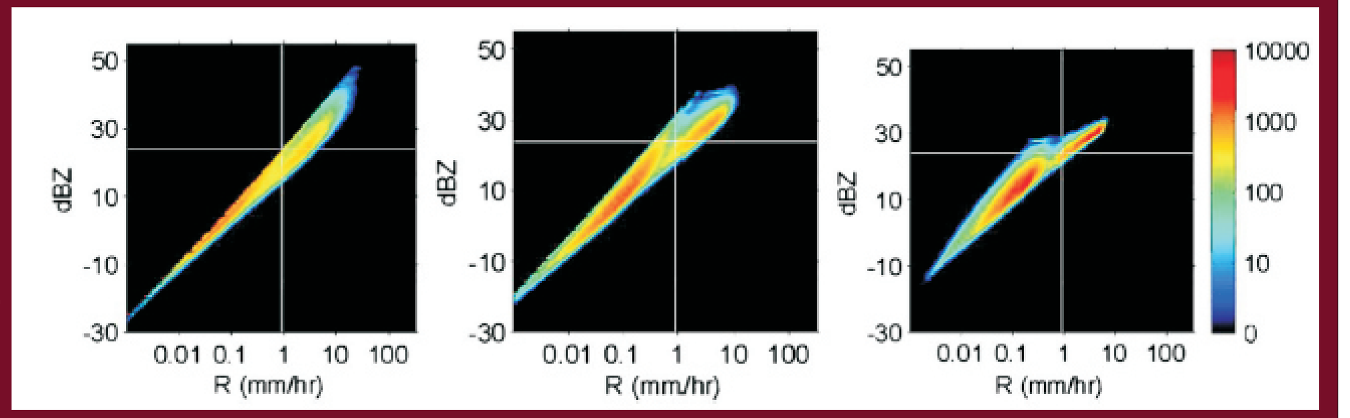


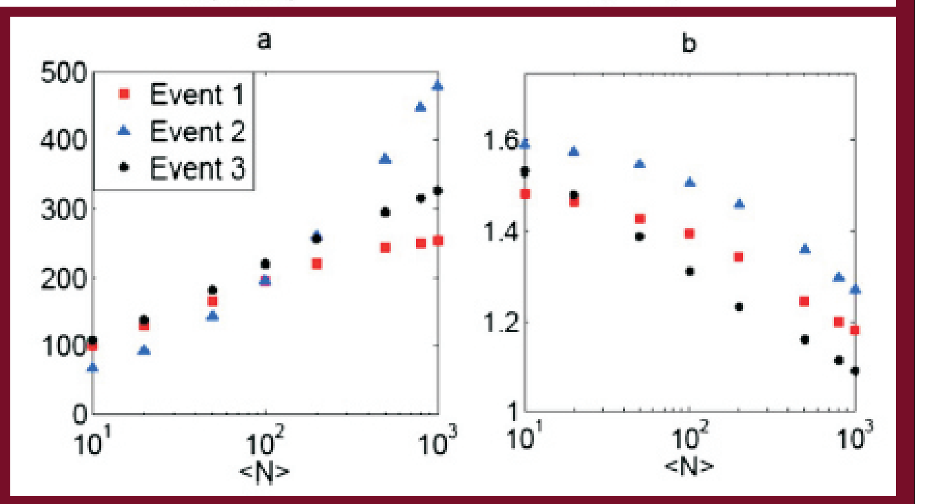




SPURIOUS Z-R RELATIONSHIPS

Since each simulated rain event has a single intrinsic value of both radar reflectivity and rainfall rate, the underlying Z-R relationship is actually a single point (where white lines intersect in the figure above right). The sampled Z-R pairs, however, give a "cloud" of points very reminiscent of traditional Z-R scatter-plots. In fact, realistic-looking power-law fits can be drawn through these data to reveal completely sampling-driven (and wholly unphysical) Z-R relationships.





CONCLUSIONS

The numerical study conducted here – which used disdrometric data to more realistically model the natural variability associated with changing raindrop arrival rates – helps to give insight about the possible effects of insufficient sampling on disdrometric estimation of rainfall parameters. We have confirmed the earlier numerical results that demonstrated the disdrometeric data usually underestimates moments of drop size distributions – though our results suggest that previous rules-of-thumb stating that several hundred to several thousand drops should be sufficient to reliably estimate rain distribution moments may be far too optimistic; our artificially homogeneized data still sometimes mis-estimated radar reflectivities by more than 20 dB even in samples expected to have a thousand drops, due to the much broader than previously modeled drop number distribution variability. We urge extreme caution when using disdrometers to estimate higher moments of raindrop size distributions.

FURTHER READING

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