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Raindrop Shapes and Fall Velocities in “Turbulent Times”

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Raindrop shapes and their fall speeds have been examined by many researchers in the past several decades. More recently (i.e. in the last 15 years), measurements from 2D-video disdrometers have also contributed greatly to such studies. In 2004, an artificial rain experiment was conducted with an 80 m fall, which captured more than 115,000 drops, in the diameter range 1.5 mm to 9.5 mm. This experiment resulted in the most probable shapes being derived in terms of the equi-volume drop diameter (Deq) and their variations due to drop oscillations. Fall velocity distributions were also derived and their mean values versus Deq were found to be close to the laboratory measurements of Gunn and Kinzer (1949), with relatively narrow and symmetric Gaussian-shaped distributions around the mean.

Since then, drop shapes and fall velocities measurements have been made in numerous locations around the globe. They range from measurements at sea level (e.g. Okinawa, Japan) to 1.4 km above sea level (Greeley, Colorado). In vast majority of the cases, drop shape measurements show that they largely conform to low amplitude axisymmetric oscillations, and the velocity measurements show good agreement with the Gunn-Kinzer variation, with altitude adjustments in the appropriate cases.

Notable exceptions have been observed however. In this paper, we discuss four cases: (i) a widespread event with highly-organized embedded line convection; (ii) another line convection event (but not as well organized); (iii) a supercell event; (iv) outer bands of hurricane Irma. In all cases, 10 m height wind-sensor data were also recorded at the instrument site, which were used to derive proxy-indicators for turbulent intensities.

In all four cases, our results for Deq > 2 mm clearly show very strong gusts, directional wind shifts (i.e. shear) and/or inferred high turbulence intensity are correlated with significant broadening of the fall speed distributions with negative skewness. The mean fall speeds were found to decrease almost linearly with increasing turbulent intensity reaching values as low as 25–30% less than the expected values, i.e. sub-terminal fall speeds. Case (i) showed a significant percentage of asymmetric drops (> 2 mm) deviating from the most probable axisymmetric shapes. We will also illustrate examples of 3D-reconstructed asymmetric drop shapes during the high turbulent intensity time periods compared with other, more common, low and moderate wind conditions, and show how the drop horizontal velocities (magnitude and direction) derived from the 2DVD measurements show remarkable agreement with the 10 m wind sensor measurements.