On-demand raindrop generator with photogrammetric drop size and fall velocity validation

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The precipitation process is made of an ensemble of a wide variety of hydrometeors, that derive from the complex atmospheric processes of nucleation, accretion, melting and interactions. Microphysical properties of precipitation are often measured using dedicated instruments called disdrometers. Calibration of such gauges is, however, still an open challenge, since the hydrometeor characteristics like particle size, shape and fall velocity must be carefully reproduced to provide a traceable reference precipitation. Instrument calibration is usually declared by the manufacturer, using undisclosed internal procedures, since no standard calibration methodology exists (Lanza et al. 2021).

To meet the need for disdrometer calibration, a device is presented in this work to achieve individual drop generation on demand and in-flight measurement of the released drops. Water drops in the range from 0.6 to 5 mm in diameter are generated to mimic natural raindrops. A high-precision syringe pump, mostly 3D printed, is used to form the drop of the desired volume at the tip of a calibrated nozzle. A high-voltage power supply is then used to apply a large potential difference between the nozzle and a metallic ring positioned just below it, so that the resulting electric field would release the drop. A precision motorized gantry moves the generator across the horizontal plane, to cover different releasing positions within the instrument sensing area. By varying the release height, different fractions of the terminal velocity can be achieved, depending on the drop size. A second gantry, just above the gauge under test, aligns the plane of focus of a high-resolution digital camera with the fall trajectory of the drop. The release of the drop and the camera shutter are synchronized so that three images of the same drop are captured in a single picture, using speedlights triggered at a 4.2 ms fixed interval. The picture is then post-processed by means of photogrammetric techniques, providing the shape, size and fall velocity of the drop. Each released drop is therefore characterized to a traceable standard before it reaches the instrument sensing area (Baire et al., 2022). By comparison with the disdrometer measurement, the instrumental bias is then obtained. Performance of the calibration device are validated, in terms of the drop size, by comparing the output of the photogrammetric procedure with direct measurements of the drop mass from a high-resolution scale.

This calibration device is used to evaluate the performance of the Thies LPM, a laser disdrometer commonly deployed in the field. Tests are conducted considering six different drop diameters, and two different telegrams as provided by the instrument. At least 50 drops are released for each diameter, from a height of 1.2m. Results show a general underestimation of the drop size, with the smallest drops reporting, on average, larger errors. The dispersion of the results in terms of the drop size is similar for all diameters, except for the smallest one showing a higher value. The instrumental bias on the drop velocity is on average more limited, meaning that the instrument provides a better measure of fall velocity than of the drop size. A strong variability in the results is however observed for both small and large diameters.

The difference between results obtained for the two output telegrams is quite large in terms of the drop diameter, while it is more limited for the fall velocity. This fact suggests that the instrument firmware applies different forms of correction on the drop size, depending on the telegram settings. Differences in the drop velocity are instead compatible with the error introduced by the binning operation performed by the instrument when computing the drop size and fall velocity distribution matrix.

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References:

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