ERROR IN THE SAMPLING AREA OF AN OPTICAL DISDROMETER: CONSEQUENCES IN COMPUTING OTHER VARIABLES

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I. INTRODUCTION

The study of convective phenomena always involves a knowledge of the physical characteristics of the precipitation they cause. For example, the data on drop size distributions can either serve as a starting point for certain cloud formation models, or as an element for verifying the goodness of a model. Since the initial studies of Wiesner (1895), the measurement of raindrop sizes has been one of the goals sought by scientists who work with cloud and precipitation models.

Optical disdrometers have proved to be excellent instruments for determining some of the physical properties of raindrops, such as their size and fall velocity (Brawn and Upton, 2008).

Based on the size of the raindrop, it is possible to calculate a number of other properties, if we accept certain premises as being valid. For example, a raindrop of a given size may be associated with a shape, volume or terminal fall velocity. It is even possible to attempt to calculate the reflectivity of the drops that are precipitated, based on the previous variables.

However, some of the measurements provided by the disdrometers are affected by errors due to a series of causes, which generally depend on the measurement procedure of the disdrometer. In the case of optical disdrometers, the measurement process consists mainly in the interruption or obscuration of a laser beam when raindrops cross this beam. No problems arise when the raindrop falls perfectly within the sampling area. However, on the edges the error may be considerable and will depend on the geometric characteristics of the laser beam and on the drop size

In this paper we will attempt to quantify the sampling area of a disdrometer, and study how this influences the calculation of other parameters.

FIG. 1: Ground Based Precipitation Probe (PMI Model GBPP-100) installed at the University of León.

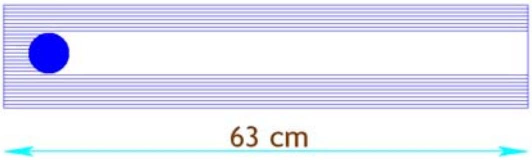

FIG. 2: Illustration showing the measurement system of the GBPP-100, representing a raindrop intercepted by a laser beam.

II. DISDROMETER SAMPLING AREA

The measurement equipment considered (Fig. 1) is the Ground Based Precipitation Probe (PMI Model GBPP-100). It emits a helium and neon laser beam with 64 rays (Fig. 2) with a separation of 0.2 mm. A receiver positioned 63 cm from the emitter detects how many rays are intercepted by a body (a raindrop or other object) that crosses the sampling area of 63×1.26 cm. The number of rays intercepted corresponds to the channel in which the drop is included. In summary, the GBPP measures the spectrum of drop sizes from 0.2 mm, of 63 channels. The channels correspond to a given precipitation size of between 0.2 and 12.4 mm. Another channel is used to include the drops that intersect either of the two rays on the edge of the beam. In this case, the drop size is unknown.

If the nominal area of the sampling (shown in Fig. 2) is a rectangle with dimensions $a \times b$ and we are measuring a hailstone with a diameter d, only hailstones that enter a rectangle with an area of $(a\text{-}d)\ (b\text{-}d) = ab + d^2 - d\ (a+b)$ will be counted. As a result, if we suppose that the sampling area is ab then we are committing an error of $d^2 - d\ (a+b)$.

It would perhaps be of interest to try and quantify this error for the case we are concerned with. Figure 3 shows the

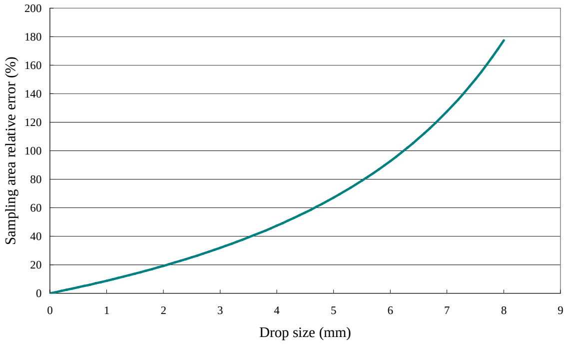

FIG. 3: Relative error of the sampling area $[100\ d\ (a+b) - 100\ d^2]/[(a\text{-}d)\ (b\text{-}d)]$ depending on the drop size.

relative error based on the drop size. Here we see that for large drops (a little over 6 mm), the effective sampling area is half of the area indicated by the manufacturer.

III. RAIN VARIABLES

The error committed in the sampling area is propagated to all of the variables that depend on this surface. Here we will refer to two of them.

The intensity is the precipitated volume of water per unit of time and surface, meaning that it will depend on the sampling surface. As a result, it is possible to calculate the intensity R once the sampling surface is corrected and the intensity R_0, supposing the sampling surface is constant (ab). On representing the two variables depending on the drop size, we obtain Figure 4.

In the Figure we can see that the error committed on taking the constant sampling area tends to undervalue the real intensity value: in reality, the intensities are higher than those we calculate with a constant area. And these rainfall intensity errors may be 50% for large drops, slightly more than 6 mm (larger sizes are infrequent, and drops larger than 8 mm are not registered).

Another variable that depends on the sampling area is the reflectivity factor Z of the rainfall (Fraile and Fernández-Raga, 2009). In this case, it is necessary to know the fall velocity of the drops. As the GBBP does not measure this parameter, we will suppose that the velocity varies with size, according to the equation:

$$v = 3.01145 + 1.0644\, D^{0.5}$$

proposed by Fernández-Raga et al (2009) based on the measurement of Gunn and Kinzer (1949).

In the same way as the previous case, we have used Z to refer to the reflectivity factor calculated with the different sampling areas, and Z0 for the reflectivity factor calculated with a constant sampling surface. Using these terms, Fig. 5 shows these two reflectivity factors based on the drop size. Once again we may see that supposing a constant sampling area means introducing an underestimation of the reflectivity. For example, for large drop sizes, such as 6 mm, the difference between these two reflectivities is approximately 3 dBZ. In these units the difference does not seem to be exaggerated, but we have to take into account the fact that these are logarithmic units: a difference of 3 dBZ between two reflectivities means that one is approximately twice the size of the other.

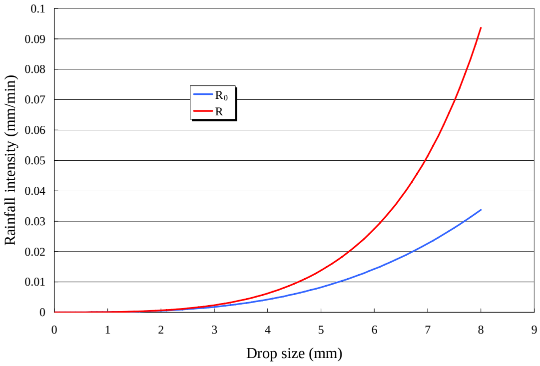

FIG. 4: Rainfall intensities calculated with the sampling area uncorrected (R_0) and corrected (R).

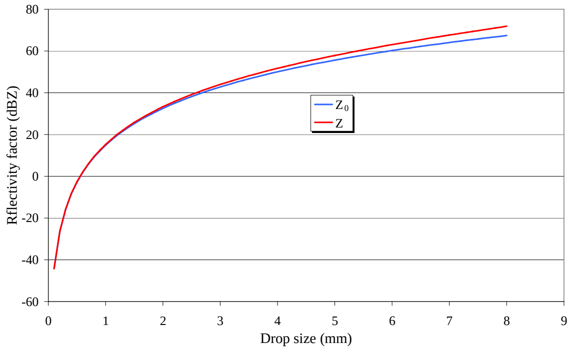

FIG. 5: Reflectivity factors calculated with the sampling area uncorrected (R_0) and corrected (R).

IV. CONCLUSIONS

As main conclusions, we may state the following:

- On calculating the variables based on the data from the disdrometer, it is necessary to take into account the real sampling area (variable for each drop size), and it is not enough to take a constant area, which may be that indicated by the manufacturer. Otherwise, this leads to major errors in the calculations.
- One of the major errors is that committed in calculating the rainfall intensity R, which may be as much as 50% of the rainfall for the largest sized drops.
- Another variable that can also be affected is the reflectivity factor Z, which can be as much as half of that calculated using a variable sampling area.

As a result, the nominal area of the sampling should not be considered as final, without previously calculating the possible error we may introduce into the calculations.

V. ACKNOWLEDGMENTS

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