Analysis of pluviometric data collected in the Apennine environment through traditional sensors and laser disdrometer

Master di II livello in Meteorologia e Oceano grafia fisica
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1. Introduction

A detailed knowledge on rainfall properties is important in many fields and applications, such as soil erosion, agriculture and road conditions. This work aims to evaluate the performance of a Thies laser-optical disdrometer in a well-instrumented apenninic site of Southern Italy (Montevergine Observatory, Fig. 1).

An extensive comparison between the disdrometer and a reference tipping bucket rain gauge (the FAK010AA) is performed in terms of average rainfall rate and total rainfall. In the attempt to minimize sampling errors and remove spurious velocity-diameter classes (Kathiravelu et al. 2016), a filtering process on disdrometer data is introduced. Finally, wind effects are investigated using the anemometric data collected by an Automatic Weather Station.

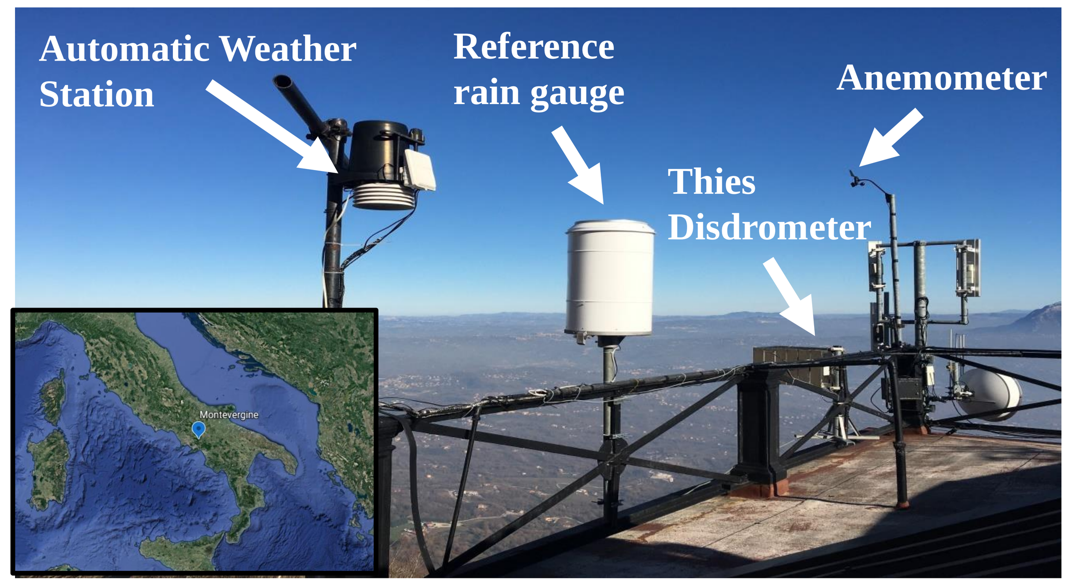

Fig. 1 The measurement devices placed on Montevergine Observatory terrace: automatic weather station (temperature and humidity), FAK010AA reference rain gauge, Thies disdrometer and three-cup anemometer. Inside panel shows a map of Italy and the location of Montevergine Observatory (LAT = 40.936502, LON = 14.72915, 1280 m asl).

2. Data and methods

The dataset includes 35 rainy events occurred between December 2019 and September 2020 in the experimental site of Montevergine Observatory.

- An "ad-hoc" filtering procedure has been applied to raw disdrometric data in order to remove spurious measurements due to wind, margin faller and splashing effects. As a result, a filtered version of the original disdrometric dataset has been obtained.
- Since Thies Clima manufacturer does not report the exact equation used to calculate the precipitation amount and the rain rate, the latter has been derived from raw and filtered spectrographs by equations suggested by the available literature (e.g. Angulo Martinez et al. 2018).
- To compare Thies disdrometer and gauge observations and bypass mismatches due to temporal shifts between measurements, both data have been aggregated on a 10-minutes period.
- The results have been discussed in terms of two essential variables, the rain rate and the rain amount, with the aid of some statistical scores, considering two different datasets of disdrometric measurements: a raw version, consisting of original data collected by device, and a filtered one.
- Finally, wind effects on raindrop size and velocity distribution recorded by disdrometers have been investigated, considering only light rain events. The Thies spectrum collected in a determined time instant has been associated to a certain wind speed threshold, ranging from 0 to 10 m s^{-1}. Subsequently, the spectrographs associated to each wind classes have been aggregated through a simple sum of the hydrometeors detected for each velocity-diameter class.

3. Results

- To remove spurious velocity-diameter classes, a filtering process has been designed. A nice comparison between raw and filtered data for a determined disdrometer acquisition is provided by **Fig. 2**.

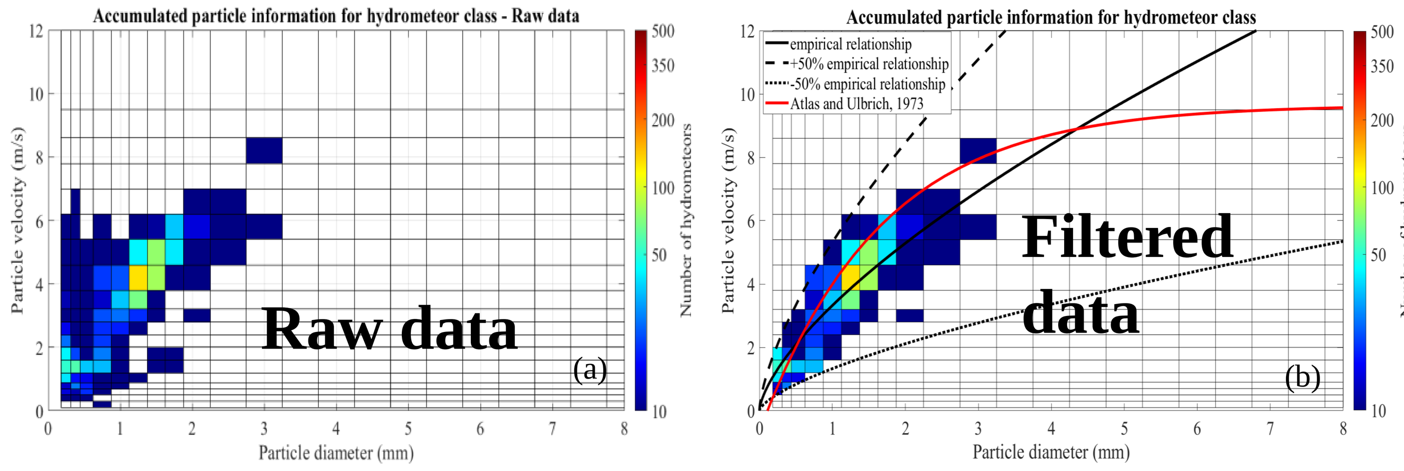

Fig. 2 Example of data filtering process showing a comparison of the empirical drop size-velocity relationship computed on raw (a) and filtered (b) disdrometric data and that proposed by literature for rainy events (Atlas and Ulbrich 1973). The color scale indicates the number of drops in each size-velocity class.

- **Fig. 3** sketches the cumulative precipitation sums of the raw (**Fig. 3a**) and filtered (**Fig. 3b**) disdrometer data as compared to the FAK010AA rain gauge. Filtering process improves the agreement between the two devices by 9% over the full period according to percentage error.

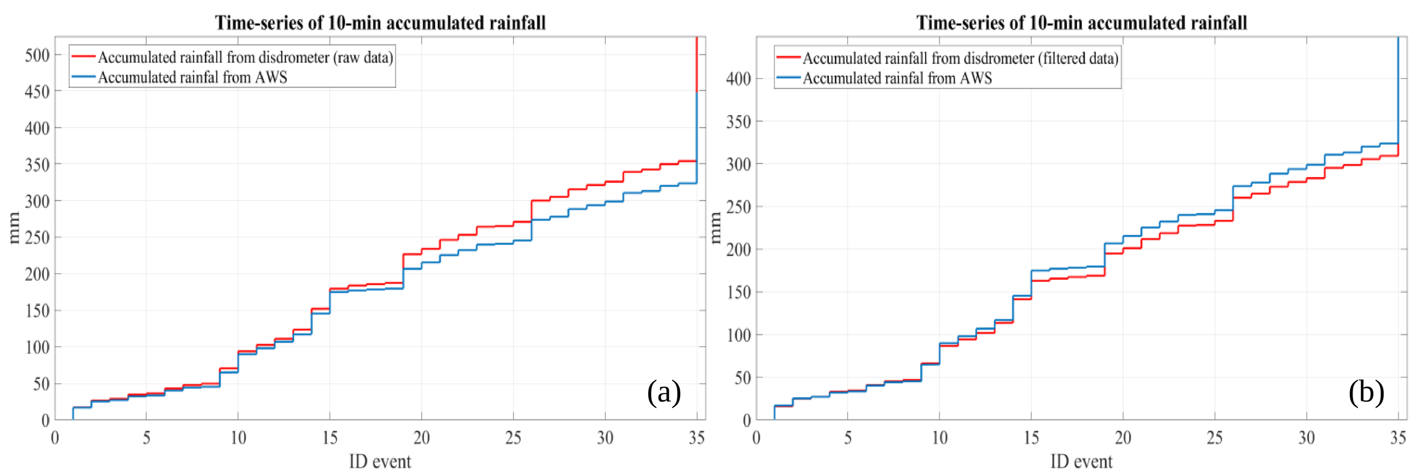

Fig. 3 Comparison of 10-min cumulative precipitation sums (mm) between the raw (a) and filtered (b) disdrometer data and the FAK010AA rain gauge.

- **Fig. 4** shows a scatter diagram between all 10-min rainfall rate measurements collected by the two devices in the analysed period. The analysis of **Fig. 4a**, in which raw disdrometric data are shown, reveals important discrepancies between the two devices, especially for rain rate values greater than 20 mm h^{-1}.

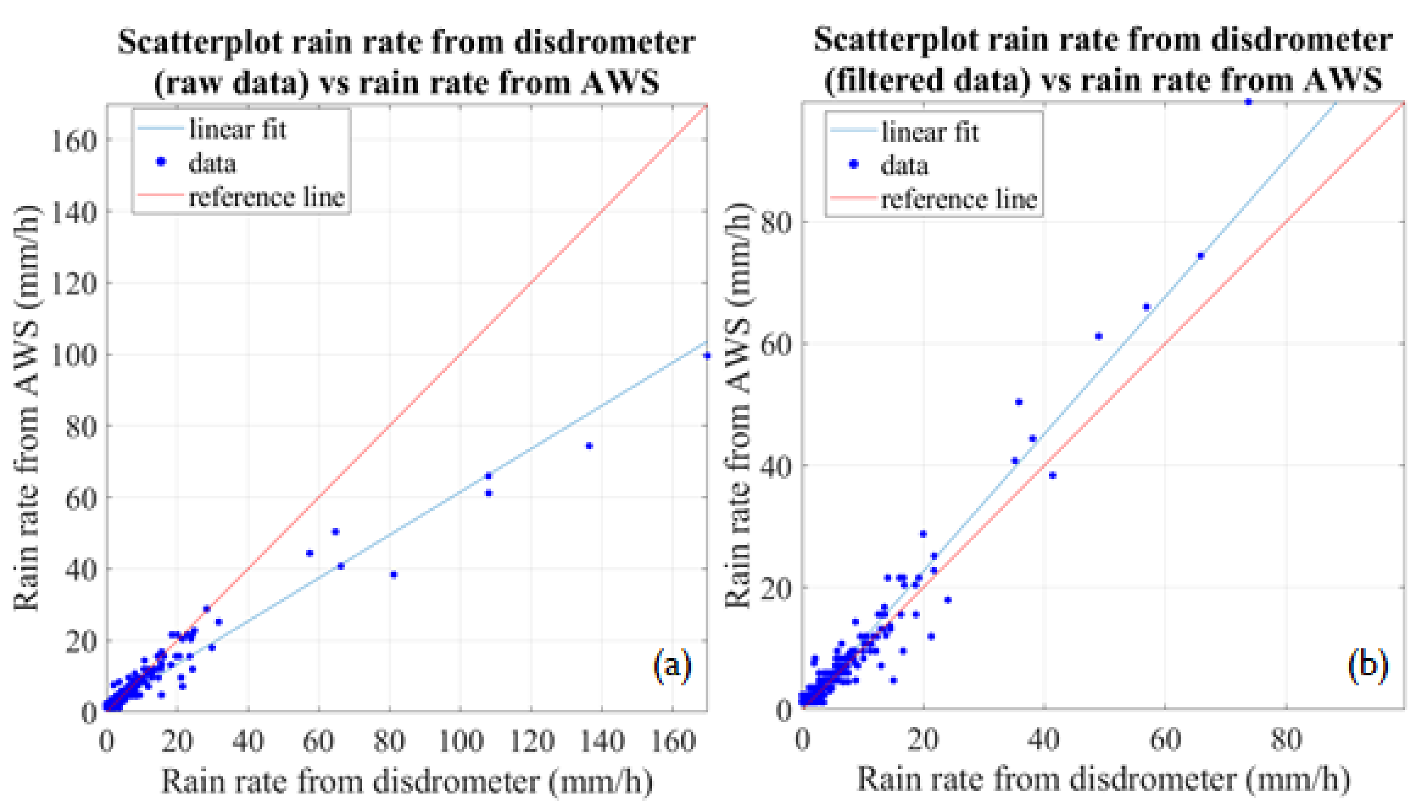

Fig. 4 Scatter diagram between 10-min RR measurements (mm h^{-1}) collected by Thies disdrometer (raw data (a) and filtered data (b)) and FAK010AA rain gauge in the analysed period. The linear fit is reported in both panels in order to highlight systematic errors and has respectively a slope of 0.6 (a) and 1.13 (b).

- The impact of filtering process determines, for all scores, a slight improvement in terms of mean value and a reduction of standard deviation (**Table 1**).

Statistical indicator	Raw data		Filtered data	
	Mean (mm h^{-1})	Std (mm h^{-1})	Mean (mm h^{-1})	Std (mm h^{-1})
MAE	1.17	1.13	0.95	0.57
BIAS	0.3	1.14	-0.3	0.51
RMSE	1.96	2.9	1.29	0.98

Table 1 For each statistical indicator, mean and standard deviation are listed for both raw and filtered disdrometer data.

4. Wind speed and disdrometer spectrograph

- **Fig. 5** provides a graphical evidence of the results of wind effect analysis. This figure presents the aggregated Thies spectrograph for different wind speed classes, ranging from calm wind (0-0.5 m s^{-1}) to moderate breeze winds (6-8 m s^{-1}). Combinations differing by more than 50% with the theoretical fall velocity are represented in the figure with a transparency. It can be easily noted that the number of anomalous velocity-diameter classes rapidly increase with increasing wind speed thresholds.

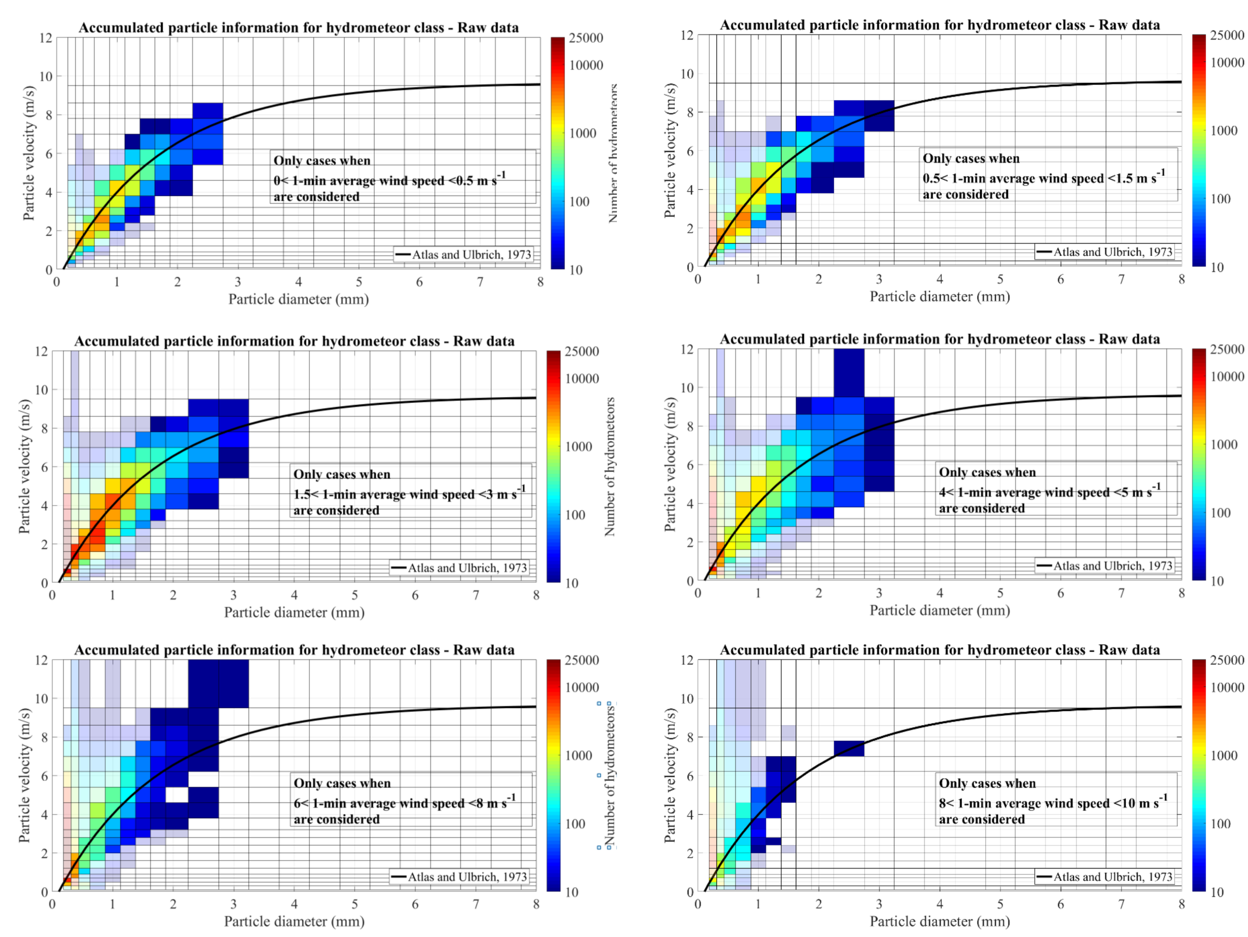

Fig. 5 Aggregated Thies spectrograph for different wind speed classes, ranging from calm wind (0-0.5 m s^{-1}) to moderate breeze winds (6-8 m s^{-1}). The color scale indicates the number of drops in each size-velocity class and deviation larger than 50% from theoretical drop size-velocity relationship are indicated in transparencies.

- The percentage of anomalous drop size classes goes from 43% in calm wind events to around 70% when wind speed is more than 8 m s^{-1} (**Fig. 6a**). Moreover, according to **Fig. 6b**, for wind speed ranging to 0 and 0.5 m s^{-1} almost the 70% of the hydrometeors is well classified. This percentage dramatically drops with increasing wind speed, reaching a value below 20% for wind speed exceeding 4 m s^{-1}.

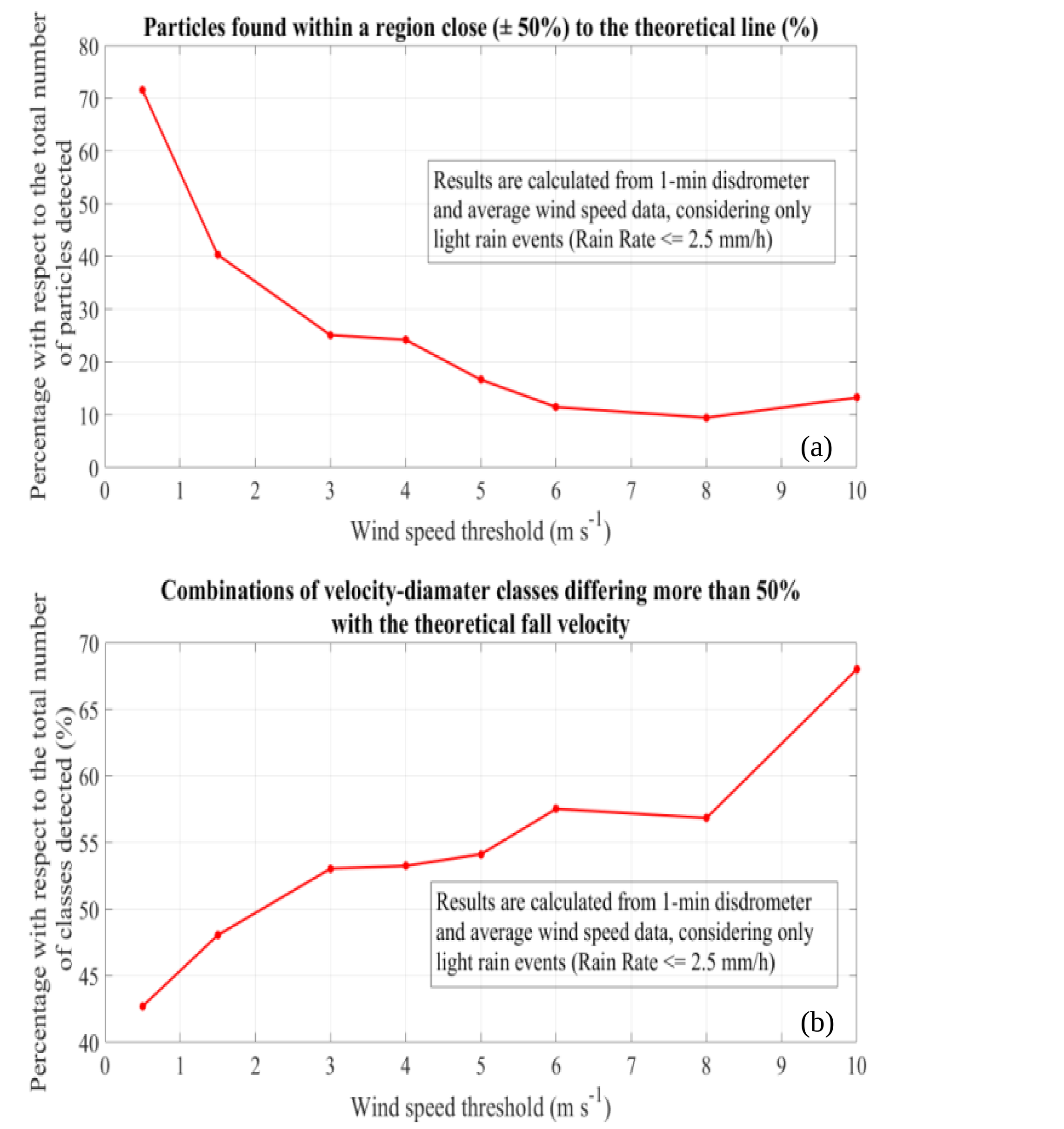

Fig.6 Methods to quantify wind effect on Thies spectrograph. (a) Combinations of velocity-diameter classes differing more than 50% with the theoretical fall velocity (Atlas and Ulbrich 1973). (b) Particles found within a region close (±50%) to the theoretical line (Atlas and Ulbrich 1973).

5. Conclusions

- The benefits introduced by the filtering process of disdrometer data are well highlighted by all considered statistical indicators. More specifically, a relevant improvement has been observed in MAE (from 1.17 to 0.95 mm h^{-1}) , RMSE (from 1.96 to 1.29 mm h^{-1}) and E (from +17 to -8%).
- Thies disdrometer almost systematically underestimates the rainfall amounts, especially when rain rate is above 20 mm h^{-1}.
- As wind speed intensifies, an increase in the number of both anomalous classes and particles has been observed.
- This investigation reveals that for wind speed larger than 4 m s^{-1}, only about 20% of the detected hydrometeors belong to the theoretical velocity-diameter combinations for rain events.

6. Future perspectives

Future research should be dedicated to the analysis of solid and mixed precipitation events, in order to assess the performance of Thies disdrometer in snow, graupel and hail conditions. Moreover, additional efforts should be carried out for a quantitative evaluation of wind impact on disdrometer rain rate, rainfall amount and particle size distribution measures.

References

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