Drop size distribution of rainfall of different intensities

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Drop size distribution was measured at Thiruvananthapuram, Kerala State, India, during April, June and July 2001 using a Joss-Waldvogel type disdrometer. The instrument gives the number of drops in 20 size classes ranging from 0.3 mm to > 5 mm. Each month's data were sorted, based on rainfall intensity, into periods of rainfall intensity < 1 mm/hr, 1-3 mm/hr, 3-10 mm/hr, 10-30 mm/hr and > 30 mm/hr. The average number of drops in each size class was computed for each set of data. Exponential and \( \Gamma \) distribution functions were then fitted to each data set. The results showed that, in June and July, the data approximated an exponential distribution for low rainfall intensities, but became closer to the \( \Gamma \) distribution at higher intensities. However, in April all data fitted the \( \Gamma \) distribution, irrespective of rainfall intensity.

Key words: Drop size distribution, Rainfall, Rainfall intensities

1 Introduction

The size distribution of raindrops is of interest in diverse areas of study, including microwave communication, radar meteorology, soil erosion and cloud physics. In this paper, the first measurement of drop size distribution (DSD) at Thiruvananthapuram, Kerala State, India, using a Joss-Waldvogel (JW) type disdrometer has been presented.

The impact type disdrometer was developed by Joss and Waldvogel\(^1\) and a number of measurements have been made worldwide using this instrument. A few measurements have been made in India also\(^2-4\). The JW type disdrometer has the advantage that it is relatively simple to install and operate, and is relatively inexpensive. The instrument used in the present measurement was manufactured by M/s Distromet Ltd., Switzerland. It gives the number of drops received in 20 size classes ranging in drop diameter from 0.313 mm to > 5.145 mm. It essentially senses the momentum of raindrops that hit the sensor. This is then converted into drop sizes assuming the terminal fall velocities for the different size ranges. Being an impact type instrument, it suffers from the problem of dead time after the impact of a drop during which period its sensitivity to another drop is reduced. The error due to this can be corrected by multiplying the drop numbers with a correction factor that depends on the number of drops received in the different size classes. This correction was applied to the data. Another source of error is acoustic noise due to winds picked up by the instrument. Precautions recommended by the manufacturers were taken to minimize the errors due to this. Total rainfall during specific spells was computed from the DSD data obtained from the disdrometer and compared with the data from an automatic raingauge installed nearby. In all cases where both instruments had recorded the rainfall, they were found to agree within 15-20%.

The measurements were started in April 2001. Very little rain was received in May, and the data have not been included here. After April, the data pertain to monsoon rainfall in June and July 2001.

2 Data and data analysis

The data set used for analysis was extracted from the entire data recorded by eliminating the events for which the total number of drops was less than 120. This limit was fixed arbitrarily and was intended to eliminate events which had relatively small number of drops. Here we use the word event to mean a 1 min duration of rain recorded in the disdrometer. The drop size data were compiled for each month and sorted in ascending order of rainfall rate \( (R) \). From this, the data for five ranges, namely, \( R < 1 \) mm/hr, \( 1 < R < 3 \), \( 3 < R < 10 \), \( 10 < R < 30 \), and \( R > 30 \) mm/hr, were separated. Thus, fifteen sets of data were obtained corresponding to three months and five ranges of rainfall rate. Each set was separately analysed to derive the mean drop size spectrum, the mean rainfall rate and the mean number of drops. The data obtained for each month is summarized in Table 1.

To each data set, we fitted a simple exponential function similar to the Marshall-Palmer distribution\(^5\) of the form
N(D) = N₀ exp (−λ D)  

and/or a Γ distribution of the form

N(D) = N₀ D^μ exp (−λ D)

where N₀, λ and μ are adjustable parameters. In April, the DSD in all ranges compared well with the Γ distribution, and, therefore, only that was fitted. In the other two months, the behaviour was different for different ranges. For the lowest two ranges, the exponential distribution fitted very well, while the Γ distribution fitted the highest two ranges. In the case of the third range, both functions were fitted, since it showed a behaviour that resembled both the distributions. The fitted values of the adjustable parameters and the standard deviation of the fit are given in Table 2.

The fifth column in Table 2 gives the standard deviation of the fit (stdfit), i.e., the root of the sum of the squared residuals (difference between fitted value and measured value) divided by the number of degrees of freedom (number of data points less the number of fit parameters). The value of 'stdfit' is an indicator of the goodness of fit. If the fit is good, the value of 'stdfit' should be close to zero. In all cases given above, 'stdfit' lies between 1 and 2, which indicates reasonably good fits.

### 3 Results and discussion

The values given in Table 1 show that the mean rainfall rate is comparable in all the three months for all the ranges except R > 30 mm/hr, in which the mean rate is higher in April. Normally, heavy thundershowers are expected in April, but no thunderstorm passed directly overhead during the present measurement. However, a few isolated heavy showers were received. While rainfall rates higher than 30 mm/hr occurred only 3.84% of the time in April 2001, the corresponding values for June and July are 5.03% and 4.25%, respectively. Thus, showers heavier than 30 mm/hr were recorded more often in June and July than in April. The mean number of drops is also higher in June and July, which indicates that smaller drops were present in more numbers, because the rainfall rates are comparable.

The drop size distributions for the five ranges for the month of April 2001 are shown in Fig. 1 along with the fitted Γ distributions. In all cases, the data fit well with the Γ distribution. In all graphs, the range of values of the x and y co-ordinates has been kept the same to facilitate comparison. The concentration of large drops can be seen to increase with increasing rainfall rate. While in range 1 (R < 1 mm/hr) the drops are all smaller than 2.3 mm diameter, in ranges of higher rainfall rate, the largest drop size increases to
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Fig. 1—Drop size distributions for the different ranges of rainfall intensity for April 2001

Fig. 2—Drop size distributions for the different ranges of rainfall intensity for June 2001

3.9 mm, 4 mm, 4.5 mm and 5.7 mm (not visible on the x-axis), respectively. In the highest range of rainfall intensity ($R > 30$ mm/hr), an initial fall in drop concentration is seen, which reaches a minimum around 0.5 mm. This behaviour is not seen in the lower ranges of rainfall rate in April or in June and July.

The drop size distributions in June (Fig. 2) and July (Fig. 3) are basically different from those in April. The drop size spectrum is very close to an exponential distribution for low rainfall rates. The spectrum approaches the $\Gamma$ distribution only in the higher ranges of rainfall rate, viz., for the two ranges with $R > 10$ mm/hr. The spectra for the range $3 < R < 10$ mm/hr also show a tendency to fall for drop sizes below about 0.6 mm/hr. The increase in drop sizes in the higher ranges of rainfall rate is seen in these months also.

Table 1 shows that the mean rainfall rate in all the three months are comparable in four out of five ranges. Only in the highest rainfall range the mean rainfall rate is significantly higher in the month of April. For the other four ranges, the number of drops is much smaller in April as compared to the other two months, indicating that the drops are generally larger in April, as is seen in Figs 2 and 3.

Functional fits to drop size distributions are of interest, especially, in microwave communication, because rainfall reduces the signal strength at the receiving end. Exponential distributions of the type proposed by Marshall and Palmer\textsuperscript{5} have been widely used for this purpose. In 1983, Ulbrich\textsuperscript{6} proposed the $\Gamma$ distribution as an alternative. It fits a greater variety of drop size distributions and includes the exponential distribution as a special case when $\mu = 0$.

In most of the cases, either the exponential distribution or the $\Gamma$ distribution is used to compute radar reflectivity factors or rainfall kinetic energies. In other words, either of these two is taken as the model for all rainfall. It is also recognized that the type of distribution depends on the type of clouds producing the rain. The distribution is different for rainfall from
stratiform and cumuliform clouds. Our measurements here appear to show that the type of distribution depends not only on the type of cloud, but also on the intensity of rainfall during the S-W monsoon. The distribution is closer to exponential for low intensity rainfall, while it becomes clearly \( \Gamma \) distribution for high intensity rainfall. For pre-monsoon rainfall, the drop size follows \( \Gamma \) distribution for all intensities.

4 Summary
The drop size distribution data presented here are the first measurements from Thiruvananthapuram. In this study, the periods of similar rainfall intensity have been clubbed together and their mean taken to determine the drop size distribution. The results show that the form of the distribution depends on the intensity of rainfall. During periods of low intensity rainfall, the distribution is close to exponential, while during periods of high intensity rainfall, the drop size distribution is closer to the \( \Gamma \) distribution. During pre-monsoon rainfall, this kind of distinction is not seen.

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References