RAINDROP SIZE DISTRIBUTION MEASUREMENTS AND ASSOCIATED RAIN PARAMETERS AT A TROPICAL LOCATION IN THE INDIAN REGION

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ABSTRACT

Measurements of rain drop size distributions (DSD) at Kolkata (22°34' N, 88°29' E), India, have been carried out using a Joss-type disdrometer since June 2004. The size distribution during the growing phase of a rain event is found biased towards larger drops compared to that during the later phase of the event for identical rain rates. The three-parameter distributions, lognormal and gamma, are fitted to the disdrometer data to model DSD for a number of rain events. The same data are also used to find integral rainfall parameters (IRP), such as liquid water content, radar reflectivity factor and specific attenuation which are compared to that obtained with the modelled DSD and the Marshall-Palmer distribution.

INTRODUCTION

The measurement of rain drop size distribution (DSD) has continued interest in view of its role in determining the microwave properties of rain and evolution of rain events, classifying types of rain and various climatic studies. The DSD data are still sparse in the tropical region, particularly in the Indian part, in view of the complex climatic behaviour of this region. There are some measurements from the Indian region [1-3] reported in the literature, but long term data are still inadequate in this part of the globe. In this paper, the measurements of DSD made at Kolkata have been used to study the evolution of DSD during rain events and to indicate the different phases of the events. Also, an effort has been made to model the DSD data in terms of three-parameter distributions, namely, lognormal and gamma. The integral rainfall parameters (IRP) are estimated from the measured and the modelled DSD and they are intercompared to indicate the efficacy of the modelling of DSD. Also, the integral parameters obtained from the Marshall-Palmer (MP) distribution are compared to the present values to examine the adequacy of the available models to describe the DSD at the present location.

EXPERIMENTAL DATA

A Joss-type disdrometer (model: Distromet RD-80) has been used to measure DSD at Kolkata (22°34' N, 88°29' E), India, since June 2004. The disdrometer is capable of sensing dropsizes in the range of 0.3 to 5.5 mm with an accuracy of 5% and a minimum integration time of 30 sec. In the present study, the measurements are taken with an integration time of 1 min. At the same site an optical raingauge (model: OSI ORG-815-DA) has been operated to measure rain rates with a sampling interval of 10 sec.

DATA ANALYSIS

The DSD data are fitted to the three-parameter lognormal and gamma distributions. The gamma function is given by

$$N(D) = N_0 D^n \exp(-\Lambda D) = N_T \Lambda^{n+1} D^n \exp(-\Lambda D)/\Gamma(\mathrm{n}+1) \quad \mathrm{m}^{-3}\ \mathrm{mm}^{-1} \qquad (1)$$

Three distribution parameters N_T (or N_0), Λ and n are considered to depend on the rainfall rate. Γ(n+1) is the complete gamma function. The lognormal distribution is expressed as

$$N(D) = \frac{N_T}{\sigma D\sqrt{2\pi}} \, exp\left[-\frac{1}{2}\left(\frac{\ln(D)-\mu}{\sigma}\right)^2\right] \quad \mathrm{m}^{-3}\ \mathrm{mm}^{-1} \qquad (2)$$

Here, N_T, μ and σ^2 are rain rate dependent distribution parameters. The distribution parameters are obtained by the method of moments [4] and using the third, fourth and sixth moments of the measured DSD. Liquid water content, radar reflectivity factor and specific attenuation are calculated from the measured and modelled DSDs and are intercompared.

RESULTS

Fig. 1(a) shows the variation of DSD during a rain event on 3 September 2004. The contour colourmap in the figure indicates the variation of the distribution of the fraction of total number of drops at different sizes. Fig. 1(b) gives the variation of rain rate during the event. The fractional values are considered to study the relative importance of different dropsizes during the rain event. It can be noted that the larger drops were relatively more abundant during the initial phase compared to the later part of the event. As the rain event progressed, the fraction for smaller drops increased. The dominant dropsizes were in the range of 1 to 2 mm. The variation of DSD becomes more evident from Fig. 2 in which the DSD at two time instants,

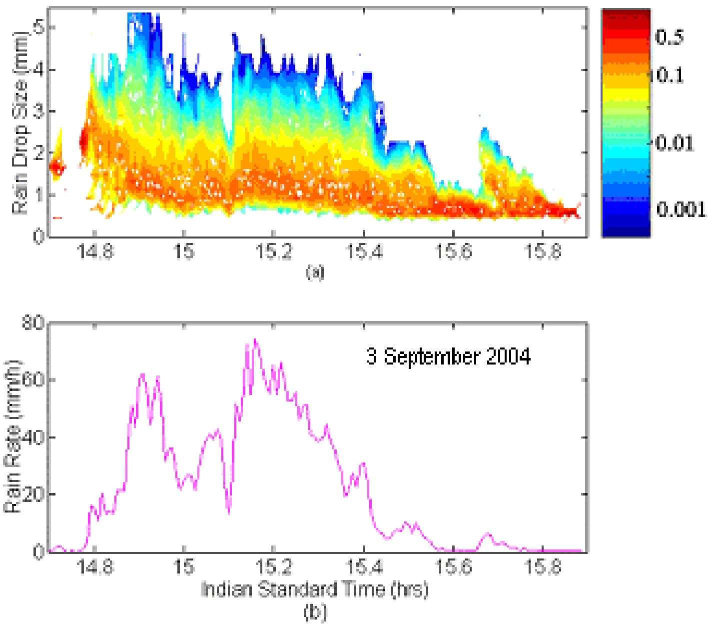

Fig. 1. (a) Contour colourmap showing the variation of the distribution of the fraction of total number of drops at different sizes during a rain event on 3 September 2004
(b) Variation of rain rate during the same event

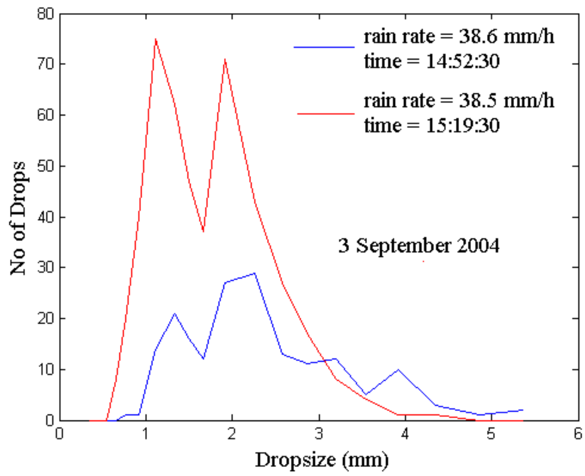

Fig. 2. DSD at two instants of the rain event of 3 September 2005 for identical rain rates indicating a large variation of DSD at different phases of the event.

14:52:30 and 15:19:30 hrs, are shown for identical rain rates around 38.5 mm/h. At the earlier phase, the number of drops in the size range 3 to 4 mm was considerable, whereas smaller drops, in the size range 1 to 2 mm, significantly dominated in the later phase of the event. A dip in the rain rate around 15:06 hrs (Fig. 1) was caused mostly by the disappearance of the larger drops. Since the larger drops are associated with convective processes and the dominance of smaller drops indicates the stratiform nature of rainfall, a continuous depiction of DSD during a rain event using disdrometer measurements can be a useful in identifying the different precipitation processes during the event.

Fig. 3 gives the variation of different integral rainfall parameters (IRP), namely, liquid water content, radar reflectivity factor and Ku-band specific attenuation, during the rain event of 12 September 2004. The four curves depict the values of IRP obtained from DSD measurements, fitted lognormal distribution, fitted gamma distribution and Marshall-Palmer (MP) distribution. It is observed that the lognormal distribution provides the best match with the DSD-generated values. The gamma distribution slightly overestimates the DSD-generated values at low rain rates and underestimates at high rain rates. The MP distribution gives significantly higher estimates of IRP compared to these values. Since the radar reflectivity factor is determined by the sixth moment of DSD, the differences among various sets of data are most prominent for this parameter.

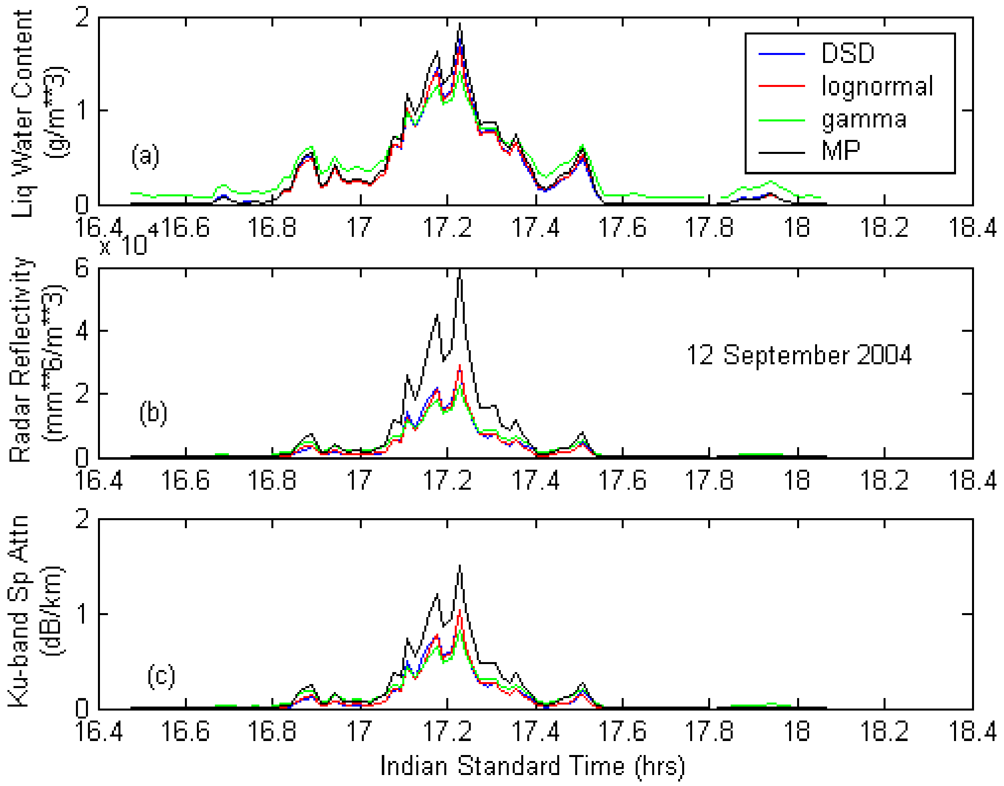

Fig. 3. Variation of different integral rainfall parameters (IRP) obtained from DSD measurements, fitted lognormal model, fitted gamma model and Marshall- Palmer (MP) model

To understand the discrepancies shown by the models, a contour colourmap showing the variation of the difference between the measured and modelled DSD values during the rain event is given in Fig. 4. A positive difference indicates a higher measured value and a negative one a lower measured value compared to the modelled value. It is seen that both the lognormal and gamma distributions significantly underestimate the number of drops at small sizes ($\leq$ 0.5 mm) which have less effect on IRP. The underestimation by the gamma model , however, extends to the higher sizes at higher rain rates resulting in lower estimates of IRP by the gamma. The lognormal model provides a better fit, on the whole, over the size ranges which have the most significant contribution to the estimate of IRPs. The study with a large number of rain events will reveal a definite preference to a particular model out of the two.

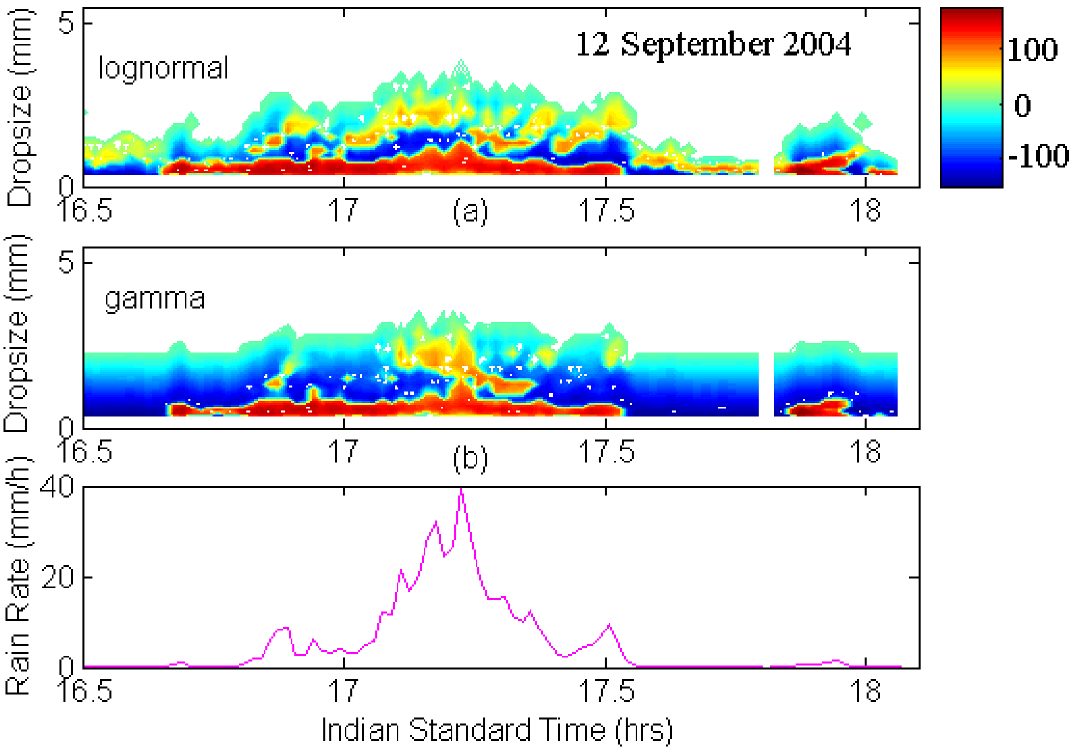

Fig. 4. Contour colourmap showing the difference between the measured DSD values and the modelled values with (a) lognormal and (b) gamma distributions during the rain event of 12 September 2004

CONCLUSION

The present study indicates that a significant variation of DSD can occur within a single rain event which can be used to identify the different processes involved in the event. The measured DSD can be effectively modelled in terms of three-parameter functions which can yield integral rainfall parameters (IRP) that agree very well with that obtained from the measured DSD. The M-P model significantly overestimates IRP indicating the inadequacy of the standard model at the present location. The long term data that is presently being gathered will be used to obtain a statistically reliable picture for the present location.

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REFERENCES

[1] A. Maitra, “Three parameter raindrop size distribution modeling at a tropical location,” *Electron. Lett.*, vol. 36, pp. 906–907, 2000.

[2] K. I. Timothi, S. Sharma, M. Devi, and A. K. Barbara, “Model for estimating rain attenuation at frequencies in range 6–30 GHz,” *Electron.Lett.*, vol. 31, pp. 1505–1506, 1995.

[3] Recommendation ITU-R P.618-8, “Propagation data and prediction methods required for the design of Earth-space telecommunication systems”, *ITU-R Recommendations*, ITU, Geneva, 2003.

[4] G. O. Ajayi and R.L. Olsen, “Modeling of a tropical raindrop size distribution for microwave and millimeter wave applications”, Radio Science, Vol. 20, pp. 193-202, 1985.