Jour. Korean Earth Science Society, v. 24, no. 1, p. 30–35, January 2003

Estimation of the Z-R Relation through the Disdrometer for the Coastal Region in the Northeast of Brazil

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Abstract: The preliminary results of the study on the physics of rain using disdrometer data are shown for an area located on the northern coastal board of Maceió, Alagoas (9°33'17.24" and 35°46'54.84" W), at approximately 80 meters above the sea level. The data were obtained during January 2002 using a disdrometer RD-69 (Joss-Waldvogel). After defining the criteria for determining rain type (convective and stratiform), a set of Z-R pairs was analyzed for estimating the Z-R relation for each rain type. The results were quite similar to those for other regions of the globe. This preliminary analysis will be used to study the structure of rain with the meteorological radar as well as to permit a better understanding of the physics of tropical rain.

Keywords : precipitation, convective, stratiform, rain rate, disdrometer, radar

Introduction

Rain is one of the important meteorological variables measured to define its environment. However, although the observation of rain has a long history, only a small fraction of global precipitations is accessible from the conventional methods of measurement. The rain gauges generate accurate temporal data, but they do not represent only precipitation rate at small areas. With diverse hypotheses, it is possible to infer some information on spatial properties of the rain fields (Drufuca and Zawadzki, 1975; Yau and Rogers, 1984).

The precipitation measured by rain gauge, in accordance with its origin, is normally classified in convective or stratiform. Convective rains are originated from the cumulus or the cumulunimbus, while the stratiform rains have their origin in stratiform clouds such as nimbustratus (Houze, 1993). The nimbustratus, typical rain formation of the stratiform (low intensity), are generally associated with the climatic conditions of autumn and of winter. However, they can occur in any season. The cumulus is the cloud with vertical development, with flat bases and upper surfaces in form of dome. With the additional heating of the earth surface, it can develop vertically throughout the day and the top of this cloud can reach easily to 6,000 meters of height or more in the troposphere. Under specific atmospheric conditions, these clouds can be changed into bigger clouds, known as the congested cumulus, and can produce rain. The continuous development can result in the creation of cumulunimbus, which often yields shower lightning, thunders, hail, strong wind and tornado.

The formation of precipitation in convective or stratiform clouds is of great importance in observational studies, modeling and remote sensing because of the intervening microphysical processes. Such processes affect the kinetic fields through the different vertical profiles of latent heat, the estimation of precipitation by radar and the parameterization of cloud models with the different distributions of raindrops (Tokay and Short, 1996). As an example one cites the importance of this association in the modeling and studies of the

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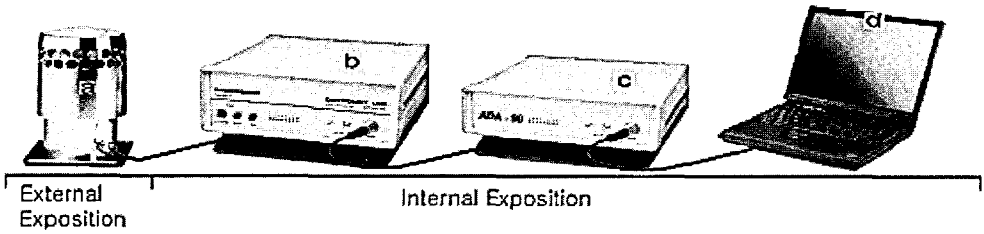

Fig. 1. Illustration of the measurement system and evaluation of raindrops (disdrometer RD-69).

remote sensing, and in the applications used for the National Aeronautics and Space Administration's (NASA) in the TRMM (Tropical Rainfall Measuring Mission) (Simpson *et al.*, 1988).

To carry through a covering of the precipitation in the globe, including the oceanic surfaces and the uninhabited terrestrial surfaces, the observations from satellites and the radar data must be used. The development and application of techniques that allow to study and to understand the features of precipitations from observations of satellite and/or radar data have been an important object in a number of research. In the radar applications, a basic relation between the reflectivity of the radar (Z) and the rain rate (R) must be defined for the region to be studied. The conversion of the radar reflectivity in rain rate through a Z-R relation with Z (mm^6 m^{-3}) and R (mm h^{-1}). Another method used for the estimation of the relation between the radar reflectivity and the rain rate, is a set of values N(D) (drops number in function of a diameter D in unit volume) measured with the disdrometer where the coefficients of the relation (1) can be experimentally determined by measuring a set of corresponding pairs (Z in dB and R in mm h^{-1}), using mathematical methods (Joss and Waldvogel, 1967 and 1969; Campistron *et al.*, 1987).

The objective of this study is to present preliminary results of the Z-R relation using a set of pairs Z-R by means of one disdrometer RD-69. The appropriate estimation of the Z-R relation was made for both convective and stratiform precipitation.

Data Acquisition

The observation for this study was conducted in the coastal plateau located at the Campus C. Sim es of the Federal University of Alagoas, in the northern region of Macei Alagoas, where the geographic coordinates are 9°33'17.24" South and longitude 35°46'54.84" West, and the altitude is about 80 m above the sea level.

The disdrometer is an instrument currently used to measure the size of raindrops and its distribution. Its principle is to transform the vertical impulse of a drop into electric pulses whose amplitude is in function of the drop size. The system used in this research is composite of one disdrometer RD-69 (Fig. 1a and 1b), of one ADA-90 analyzer (Fig. 1c) hardwired directly to a personal computer (Fig. 1d). Table 1 shows characteristics of the disdrometer RD-69.

The disdrometer has two parts: the transducer (Fig. 1a) transforms the mechanical impulse of a drop that falls in the pecker into the electric pulsation, whose amplitude is proportional to the mechanical impulse, and the processor (Fig. 1b) is composed of circuits to eliminate unwanted signs mainly the acoustic noise and to reduce 90 dB the detected dynamic sign of the transducer. Its main functions are: to provide electric information, to process the sign and to test through a circuit the performance of the instrument.

The analyzer was projected to be used as an interface between the disdrometer RD-69 and a personal computer. ADA-90 receives the pulses

Table 1. Characteristics of the disdrometer RD-69.

Interval of the drop size (diameter)	0.3 mm to 5 mm
Relation between diameter of drop (D) and output amplitude of the pulse (U)	$U=0.94\ D^{1.47}$ (U in Volts, D in mm)
Sampling area	50 cm^2
Accuracy	5% of the diameter of the measured drop
Operational Temperature	0 to 40°C
Dimension & Weight:	
Transducer	10 cm 10 cm 17 cm, 2.4 kg
Processor	10 cm 23 cm 27 cm, 1.8 kg
Length of the cable between the transducer and processor	10 m

Table 2. Technical characteristics of ADA-90.

Amplitude of pulse	160 mV to 10 V
Number of channels	127 (with reduction for 20 channels)
Thresholds of channels (N=Number of Channels)	$U(N)=10^{[1-(127-N)*0,014253]}$
Accuracy	1%
Time of pulse	<0.4 ms
Format of the output archive	ASCII
Dimensions	17 cm 14 cm 5 cm
Weight	0.5 kg

produced by the disdrometer RD-69 and converts them into digital codes, and transmits in a consecutive form through a serial gate to a computer. Table 2 shows the technical characteristics.

Data Analysis and Results

The 'dead time' is the time interval recorded between a drop and the following one, that is, after a drop was registered by the instrument, the following drop can be registered only after a certain time which depends on the size of the first and the following drop. This time is necessary to stabilize the instrument due to the mechanical oscillations in the transducer caused by the impact of the raindrop. In heavy rain conditions the dead time can be a great problem in an error of disdrometer. On the other hand, in weak precipitation, due to the size of drops this problem is negligible.

In accordance with Sauvageot (personal communication, 2002) the data can be processed without the correction of the dead time of disdrometer. This correction can be totally neglected for weak and moderate intensity (until about 20 mm h^{-1}). The correction is more important for intense rains; therefore it does not influence the small drops and can be made only inside channels where the detection is not zero. This is the reason that some researchers prefer not to apply this correction as the case of this work, where the majority of the studied events showed lesser intensities than 20 mm h^{-1}.

We analyzed the rain data obtained in January 2002. These data had been separated per day and by each event, totalizing 20 days with 53 events. Among these events, five had been selected. During this period the precipitation systems responsible for the rain production were the frontal systems, or their remaining portions, described by Molion and Bernardo (2002).

Rains of the convective type were characterized as the precipitation with high rainfall intensity (R up to 100 mm h^{-1}) and short duration (up to 5 minutes), while rains of the stratiform type distinguished by its continuous form, show low rainfall rate ($R < 10$ mm h^{-1}). In this study, for the determi-

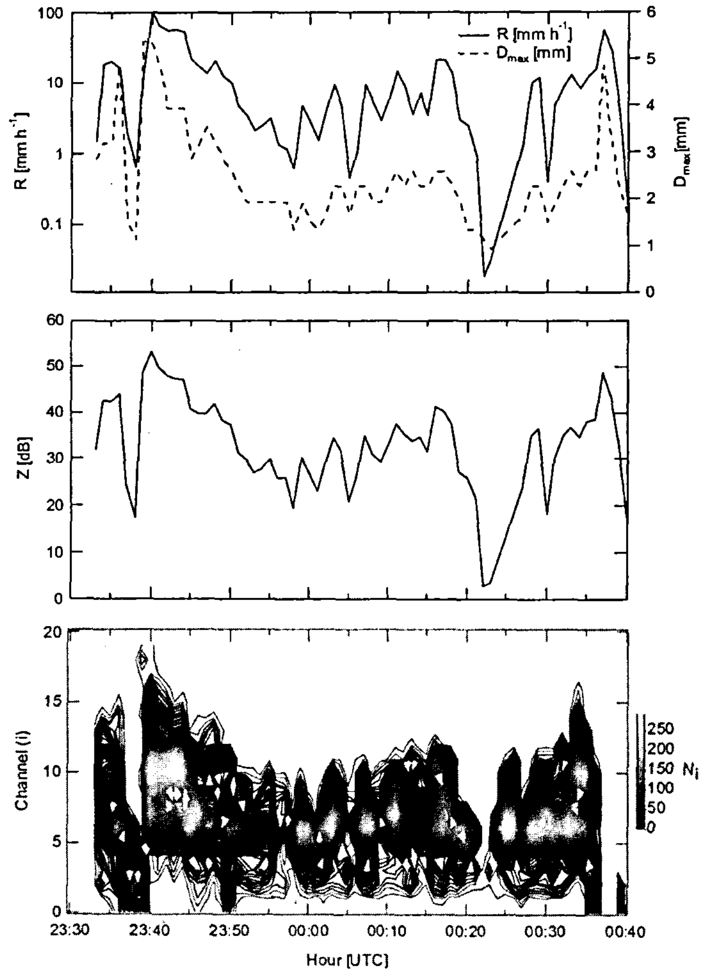

Fig. 2. Time series of R [mm h^{-1}] and D_{max} [mm], Z [dB], and number of drops (Ni) per channel (i) elaborated for all the events (10 January 2002 between 2333 UTC and 0037 UTC).

nation of the rain type, the following criteria were used: convective events with $R > 10$ mm h^{-1} and the maximum diameter of the drop $D > 2$ mm; stratiform events with $R < 10$ mm h^{-1} and the maximum diameter of the drop $D < 2$ mm. Using these criteria, the determination of the rain type was made through the analysis of time series (Fig. 2) of R [mm h^{-1}], Z [dB], D_{max} [mm] and of the drop distribution in channel elaborated for all the events. Later the Z-R relations were determined for each type of rain grouping all the selected events. The Z-R relations were determined for each type of rain (convective and stratiform) grouping all the dataset of the selected events.

The coefficients a and b of the relation $Z = aR^b$ were obtained through the linear regression, with the data Z [dB] in function of R [mm h^{-1}].

$$a = e^{\frac{\ln 10}{10}\alpha} \quad (3)$$

$$b = \frac{\ln 10}{10}\beta \quad (4)$$

where and are the regression parameters.

Summary and Conclusions

Based on the adopted criteria, two distinct groups of data can be generated: convective and strati-

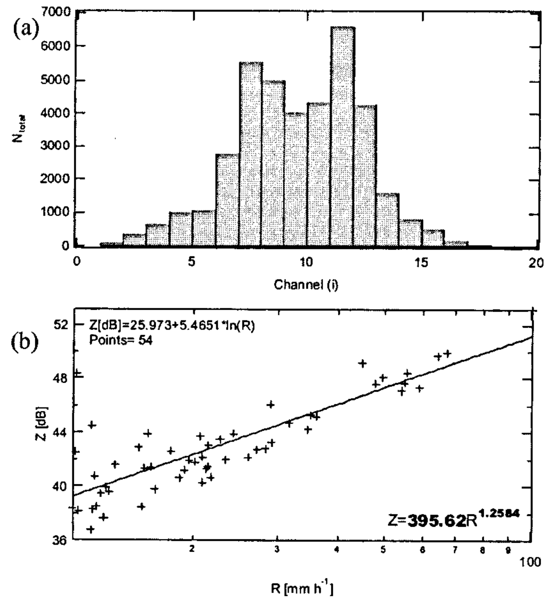

Fig. 3. Results of the convective rain analysis (events for R >10 mm h^{-1} and maximum diameter of the drop $D>2$ mm): (a) relation between the total number of drops and the channel, (b) determination of the Z-R relation.

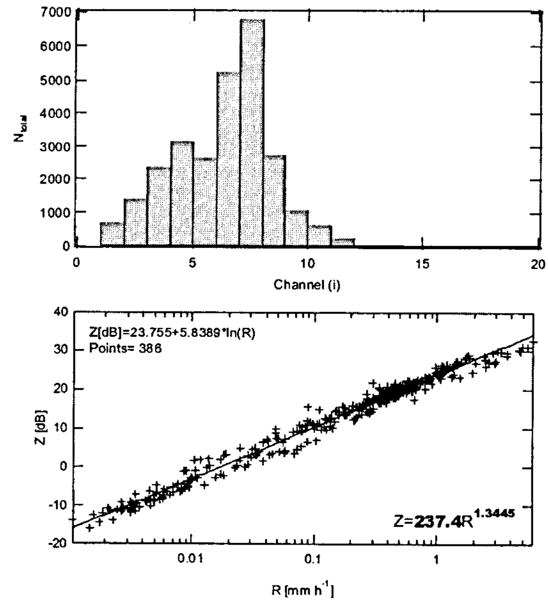

Fig. 4. Results of the convective rain analysis (events for R <10 mm h^{-1} and maximum diameter of the drop $D<2$ mm): (a) relation between the total number of drops and the channel, (b) determination of the Z-R relation.

form. Fig. 3(a) shows the relation of the total number of drops ($N_{i\ total}$) in relation to the number of channels for rain of the convective type. It is possible to verify in Fig. 3(a) that rain of the convective type reach up to the channel number eighteen, that is, $D=4.35$ mm. The lesser numbers of drops are concentrated in the first three and last three channels, with a main concentration of drops in the intermediate channels, characterizing a quasi-normal distribution. The greatest number of drops was verified in channel 12 ($=2.259$ mm) by approximately 7000 drops. Fig. 4(a) shows the relation of the total number of drops ($N_{i\ total}$) with the number of channels for rain of the stratiform type. Stratiform rains were analyzed in the same way. A similar behavior to convective rains is noticed, that is to say, less numbers of drops are concentrated in the first and the last channels with a greater concentration in the intermediate channels.

Fig. 3(b) and Fig. 4(b) show the Z-R relation for the convective rain:

$$Z=395.6R^{1.2584} \tag{5}$$

and for the stratiform rain:

$$Z=237.4R^{1.3445} \tag{6}$$

The a and b values, in the case of convective rains as much as stratiform rains, show the same order of magnitude and an inverse behavior, that is, in equation (4) the coefficient a is smaller than in the equation (3), but the coefficient b is larger. We can find the analogous results for different tropical regions of the planet (Battan, 1973; Sauvageot, 1992), and also for other tropical regions of Brazil (Antonio, 2000). This preliminary analysis will facilitate the rain study by means of the weather radar as well as the understanding for the physics of the rain in the northeast coastal plateau region of Brazil.

Acknowledgment

This study was supported by the project "The

Development of Dual Use Technology" of Ministry of Science & Technology.

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Manuscript received, June 20, 2002
Revised manuscript received, September 15, 2002
Manuscript accepted, September 25, 2002