Z-R relationship and a severe rainfall observed by C-band radar in eastern coast of northeastern Brazil

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1 Introduction

The development and application of techniques that allow to study and to understand the features of precipitations from remote sensing data have been an important object in a number of research. In the radar applications, a basic relation between the reflectivity of the radar and the rain rate must be defined for the region to be studied, that is the conversion of the radar reflectivity in rain rate through a Z-R relationship with two coefficients. One another method used for the estimation of the relation between the radar reflectivity and the rain rate, is a set of the drop number measured with the disdrometer (Joss and Waldvogel, 1969; Campistron et al., 1987). The estimation of Z-R relation will be discussed for each type of rain (convective and stratiform).

Upper Trophospheric Cyclonic Vortices (UTCVs) are synoptic scale systems with a great impact on the regional weather conditions for they are usually associated with high rainfall events. They are characterized by low pressure and convergence region at upper levels of the troposphere with descending motion in its core. The convection in the UTCV´s eastern flank is due to the convergence of the subsiding air with the SE trade winds, generally located over the ocean in the initial stage. UTCVs were described by many authors, among them Palmer (1951) with his pioneering studies, Kousky and Gan (1981). The UTCV season spans from November to March, with highest frequency in January, middle of the north hemisphere winter, when the equator-pole thermal gradient is largest in NH. Apparently, they occur in La Ninã years or years in which the equatorial Pacific sea surface temperatures (SST) are close to their climatic mean while the northern Pacific shows positive SST anomalies. Under these circumstances, the frequency of cross equatorial north hemisphere frontal systems affecting even the south hemisphere tropics seems to be larger. According to Molion and Bernardo (2002), the necessary conditions for the development of an UTCV is likely to be the presence of frontal systems in low latitudes of both hemispheres simultaneously, with the south hemisphere frontal system (SHFS) enhancing moist flux convergence over entire NEB.

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2 *Z-R* relationship for convective and stratiform

A threshold rainfall rate of $R < 10$ mm h^{-1} was adopted for stratiform rainfall events. Rain events were considered of convective class with R equal to or above that threshold, bearing in mind that due to the regional characteristics, it is difficult to distinguish the 2 types of rainfall. With this simple criterion, employed by other researchers, e. g. Nzeukou et al. (2002), 84% of rainfall events were classified as stratiform rain and the remaining as convective rain.

For stratiform class, the coefficient *a* was in the range 134 to 269, being larger in January and February. The coefficient *b* did not vary significantly, remaining in the range 1.22 to 1.38. Again, highest values occurred in January and February. The correlation coefficients were all above 0.66. For the convective class, the monthly values of the coefficient *a* varied widely from 31 to 136 whereas the coefficient *b* values were high, ranging from 1.5 to 1.9. Except for December, the correlation coefficients were all above 0.73 suggesting a good *Z-R* relationship. The *Z-R* regression using the classified data set produced the following relationships and respective correlation coefficients:

Stratiform rainfall: $Z = 167.8R^{1.26}$; [r = 0.70]

Convective rain: $Z = 65.46\,R^{1.69}$; [r = 0.84]

For tropical Western Africa, Nzeukou et al. (2002) found slightly different results using the same criterion. The difference may be due to the fact that these authors used a longer data set, with a 4 years sampling period. The difference may be attributed also to the difficulty to establishing a precise threshold. In the eastern coast of NEB, the clouds are advected within the southeast trade winds field from the Atlantic. Cloud development, thus, results from the low level convergence of the moisture flux near to or on the coast and the associate convective cells are usually imbedded in large stratus layers producing a sort of 'mixed rainfall'. In such circumstances, the coefficients estimates tend towards the stratiform rain ones. The results of stratiform and convective regressions were depicted in Fig. 1 and Fig. 2, respectively.

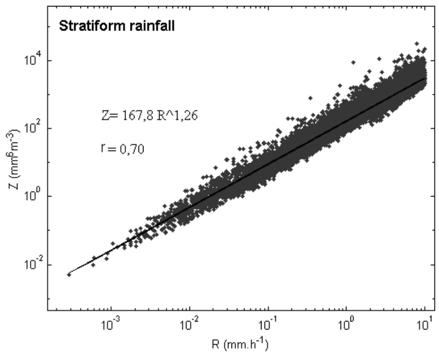

Fig. 1. Regression line *Z-R* for stratiform rainfall with $R < 10$ mm.h^{-1}. The size of the recorded samples was 8,718 min or 145.3h.

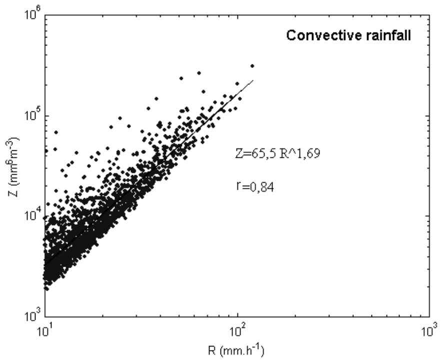

Fig. 2. Regression line *Z-R* for convective rainfall with $R \geq 10$ mm h^{-1}. The size of the recorded samples was 1,648 min or 27.46h.

3 Upper tropospheric convective vortices

Rainfall is a product of the local convection, that is, ascending motion of warm and humid air producing deep rain cells. The local convection, in turn, is controlled - intensified or inhibited - by the variability of larger scale circulation patterns resulting from a complex interaction between the atmosphere and the Earth's surface. The variability of rainfall in NEB is related to the general circulation of the atmosphere (GCA) shifts and to the air-sea interaction in the Pacific and Atlantic oceans. The El Niño-Southern Oscillation (ENSO) events are examples of planetary scale climate perturbation that modify the rainfall totals and distribution. In general, strong warm phase events (El Niño) may cause severe droughts whereas cold phase events (La Niña) are responsible for rainfall above normal. The main large scale mechanisms are the Intertropical Convergence Zone (ITCZ) and the frontal systems are responsible for 60% to 70% of the observed rainfall on average. Wavy disturbances in the trade wind field, convective cloud complexes and land and sea breezes are part of mesoscale systems whereas orography-induced and small convective cells are examples of microscale phenomena (Molion and Bernardo, 2002).

Presently, it is thought that the semi-aridity of NEB is provoked by the descending branch of the Hadley-Walker cell and the associated psychrothermic inversion over the region (Molion and Bernardo, 2002). In the annual cycle, the inversion is broken by the incursion of the ITCZ in the northern part of NEB (NNE) and the penetration of southern hemisphere frontal systems over the southern part of NEB (SNE) and over the eastern coast (ENE). Wavy disturbances within the Trade wind field (WDT) are produced by the penetration of frontals systems in lower latitudes of both hemispheres over the Atlantic and Tropical Africa and occur anytime of the year. In the period December to April, the WDTs propagate within the ITCZ and, as they reach the NNE, large rain-cells are produced associated with the low level moisture flux convergence. An example is the event of April 2001 when the city of Fortaleza (3.8°S; 38.5°W) in NNE coast recorded over 800 mm due to a sequence of WDTs during that month. During May to August, the WDTs, associated with local sea-land breeze circulation, seem to be the most important mesoscale rain producing mechanism in ENE, responsible for 30 to 40% of the observed totals. An example is the event of August 2000 when parts of eastern coast recorded over 300 mm in one single day. In principle, the genesis and the structure of the WDTs could be studied with space born radar such as the TRMM except for the temporal coverage, since these systems grow and decay quite rapidly. On the other hand, a daily rain data analysis showed that 75% of the rainy days in the region had rain totals smaller than 10 mm/day, suggesting that, in general, rain cells are smaller than the TRMM highest resolution which is 4 km at the sensor's sub-point.

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References

Kousky, V. E., M. A., Gan, 1981: Upper tropospheric cyclonic vortices in the tropical South Atlantic. *Tellus*, **33** (6): 538-551.

Palmer, C. E., 1951: On high-level cyclones originating in the tropics. *Transa. Ame. Geoph. Union*, **32** (5):683-695.

Campistron, B., G. Despaux and J. P., Lacaux, 1987: A microcomputer data-acquisition system for real-time processing of raindrop size distribution measured with the RD69 Distrometer, *J. Atmos. Oceanic Technol.*, **4,** 536-540.

Joss, J. and A. Waldvogel, 1969: Raindrop size distribution and sampling size errors,. *J. Atmos. Sci*., **26**, 566-569.

Molion, L. C. B. and S. O., Bernardo, 2002: A review of the dynamics of rainfall over Northeastern Brazil, *Braz. J. Meteor.* **17**(1), 1-10.

Nzeukou, A., H. Sauvageot, A. D. Ochou and M. F. Kebe, 2002: Raindrop size distribution and radar parameters at Cape Verde, *J. Appl. Meteor*., **42**, 1031-1034.