1.1 *DISTROMETRIC DROP SIZE DISTRIBUTION IN SOUTH BRAZIL: DERIVED Z-R RELATIONSHIPS AND COMPARISONS WITH RADAR MEASUREMENTS*

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1. INTRODUCTION

Drop size distribution plays an important role in radar meteorology, among many other areas such as atmospheric physics, telecommunications remote sensing, hydrological modeling and soil erosion, Radar rainfall estimation, in particular, can benefit much from from accurate measurements of DSDs as is also the case with with many meteorological applications like cloud model initialization and verification, and cloud radiative transfer. Ground based distrometers have been used extensively to validated radar based rainfall retrieval, in the process of quantitative precipitation estimation (QPE) and can contribute to keep the quality of dual-polarization (DP) radar parameters at a high level. One of the distrometers most widely used in the in validation and comparisons of weather radar is the OTT Parsivel . Two of those distrometers were deployed in the state of Paraná in Southern Brazil in association with two radars: a single-polarization (SP) at Teixeira Soares (from now on TXS, -50.3613, -25.5053) around 114 km from the nearest distrometer, and a DP at Cascavel (from now on CAS, -53.5293, - 24.8700) the second distrometer being collocated with it. Both S-band radars cover regions of high socio-economical relevance with outstanding agro-industrial and energy production activities, the latter contributing – in the context of South Brazil – to more than 35% of the total hydropower generation in the country.

This paper deals with the derivation of Z-R relationships based on data from the distrometers and comparisons of reflectivity from them with the corresponding reflectivity from TXS and CAS. One work on derivation of Z-R relations was effected back in 2010 by Tenório et al in the geographically opposite region of Northeastern Brazil based on data from a RD-69 distrometer.

Rainfall data derived from the distrometers were compared to those from respectively collocated raingages. Monthly average raindrop spectra were elaborated. Reflectivity was derived from the distrometer data and compared to the corresponding radar reflectivity, for both radars. Z-R relationships were derived for both radars with the following stratification: for the whole period (a general relationship), by season (one for Summer, one for March-to-December), by month and by daily interval. The latter has proven important for flow simulations over catchments in the state of São Paulo (Calheiros and Gomes, 2012).

Results of reflectivity from both distrometers data and radar measurements are compared to works reported in the literature.

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2. DATA

The data for this study are from the area depicted in figure 1.

Radar data were from PPI, at 1.5° for CAS and 0.5° for TXS, generated every 7.5 min. Elevations were chosen taking into account the distance of each radar to the associated distrometer. Data from CAS was from the period 01/05/2016 to 03/10/2017, and from TXS was from 11/12/2013 to 07/15/2016. Data from the distrometers were from the droplet size range 0.3 mm to 5.5 mm. For the distrometer associated with CAS data were from the period 01/29/2014 to 03/10/2017 and for the distrometer at Curitiba, associated to TXS, from the period 11/12/2013 to 07/15/2016. Time resolution of distrometric data was 60 sec. The distrometer associated with CAS was at about 3 km from the radar, in the far radar antenna field. The distrometer associated with TXS was at a distance about 114 km far from the radar. Rain gage data were from the same period of data from the distrometer associated with CAS and the time resolution is 15 min.

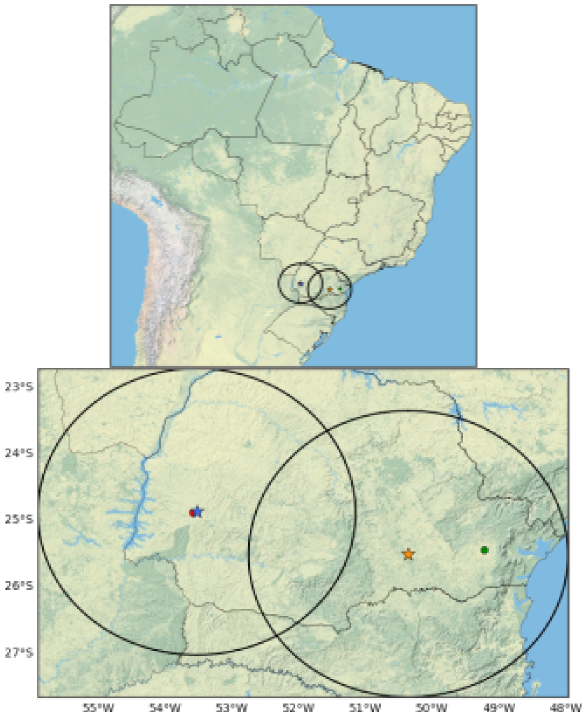

Figure 1: Radar, distrometer and raingage location. Red point indicates Cascavel distrometer and raingage and green point indicates Curitiba distrometer and raingage. Blue and orange stars indicate CAS (dual polarization) and TXS (single polarization) radar, respectively. Radar range is 240 km.

3. RESULTS

Results are presented in the figures and tables shown in the sequence. In fig. 2(a) and (b) are presented the scattergrams of rain rate from distrometer and raingage, the data from distrometer being integrated to match the time resolution from raingage. A better agreement is noticed at the lower end of rain rate values. These results compare favorably with with those from works reported in the literature.

In figures 3 (a) to (b) are shown the monthly average raindrop size spectra. The range of drop sizes is one of the standard ranges of the Parsivel instrument used. The set of monthly curves are, in general, confined between the curves for July, in the dry period and December, in the wet season; the July (uppermost) and December (lowermost) curves are approximately parallel in the diameter range of approximately 1mm to 5 mm, i.e. the ratio of the concentration numbers of droplets is approximately constant along that diameter range. The peak concentration of droplets, occurring in the lower end of diameter range is more pronounced in the months of May and June, featuring a "kink" around D~0.4 mm; for the rest of the year the maximum concentration is "smooth" and centered around D~0.5 mm. Accentuated decreases in the concentration number of drops at the smallest drop size portion of the spectra were not observed from the peak down to the 0.3 mm diameter concentration.

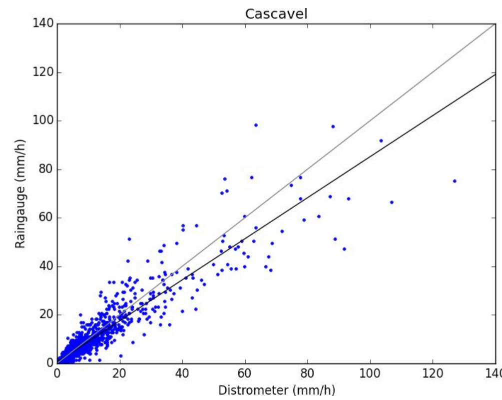

Figure 2 (a): Scattergram of rain rate from distrometer and raingage at Cascavel, time resolution of 15 min. Slope: 0.85 and intercept: 0.58.

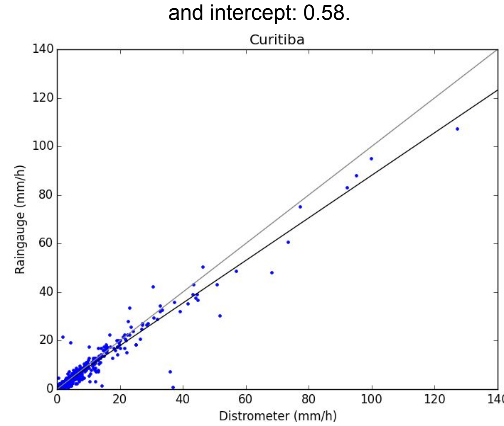

Figure 2 (b): Scattergram of rain rate from distrometer and raingage at Curitiba, time resolution of 15 min**.** Slope: 0.88 and intercept: 0.37.

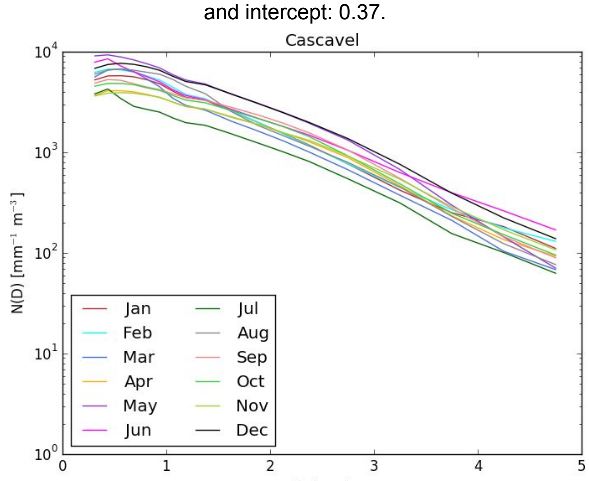

Figure 3 (a): Monthly average DSD for Cascavel.

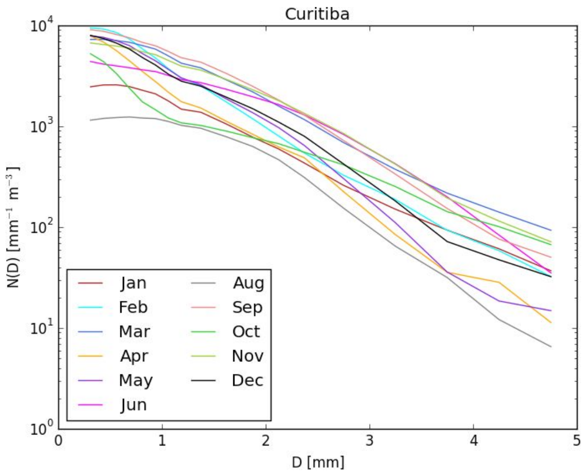

Figure 3 (b): Monthly average DSD for Curitiba. No data available for July.

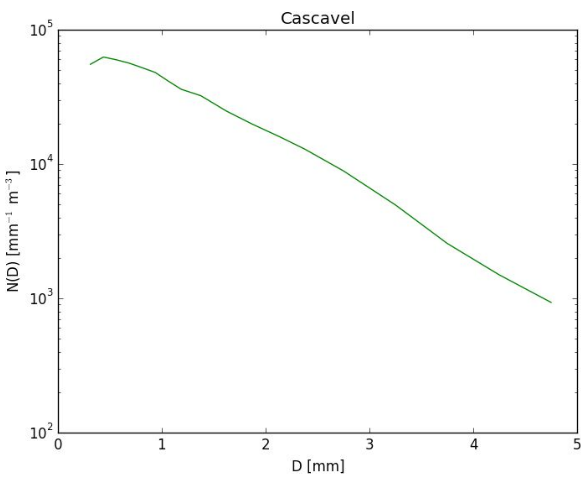

Figure 3 (c): DSD for the whole data period for Cascavel.

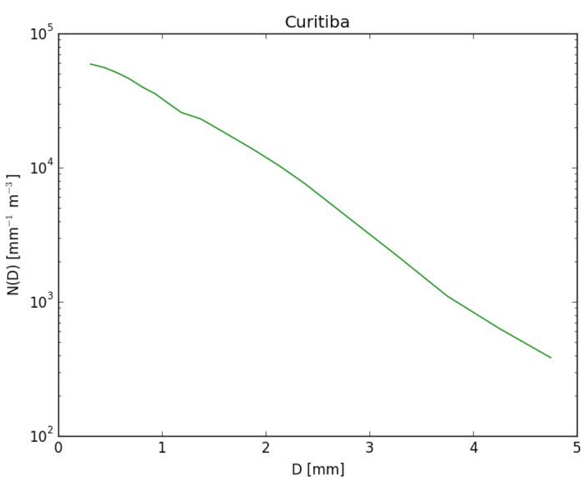

Figure 3 (d): DSD for the whole data period for Curitiba.

In Tables 1(a) and (b) are presented the parameters of the Z-R relationships derived from the distrometer.

Table 1 (a)

A and b coefficients for Cascavel for different relationships

General	288.5, 1.5					
Seasonal (1)	184.5, 1.6					
Seasonal (2)	422.0, 1.4					
Monthly	Jan	Feb	Mar	Apr	May	Jun
	237.0, 1.5	130.0, 1.7	209.0, 1.5	495.5, 1.3	292.5, 1.5	269.0, 1.5
	Jul	Aug	Sep	Oct	Nov	Dec
	387.5, 1.5	265.0, 1.7	378.5, 1.5	276.5, 1.6	382.5, 1.4	195.5, 1.6
Daily Interval (UTC)	10–14	14–17	17–22	22-10		
	164.0, 1.6	163.5, 1.6	152.6, 1.7	242.0, 1.5		

(1) Summer (December to February)
(2) Transition and Dry (March to November)

Table 1 (b)

A and b coefficients for Curitiba for different relationships

General	236, 1.5					
Seasonal (1)	229.5, 1.5					
Seasonal (2)	238.5, 1.5					
Monthly	Jan	Feb	Mar	Apr	May	Jun
	221.5, 1.5	138.5, 1.8	326.5, 1.4	352.0, 1.3	118.5, 1.8	157.5, 1.6
	Jul	Aug	Sep	Oct	Nov	Dec
	–	263.5, 1.6	164.0, 1.7	489.0, 1.3	352.0, 1.4	285.5, 1.4
Daily Interval (UTC)	10–14	14–17	17–22	22-10		
	152.0, 1.5	257.5, 1.5	422.5, 1.4	275.5, 1.3		

(1) Summer (December to February)
(2) Transition and Dry (March to November)

For CAS, for the monthly relationships the multiplicative coefficient, A, showed a substantial variation from a minimum of 130 in February to a maximum of 496 in April, while the exponent, b, varied between 1.5 and 1.7 except for April (1.3) and November (1.4) while for the daily interval relationships the respective variations were 153 to 242 and 1.5 to 1.7, respectively. For TXS the monthly relationships presented a variation of A from 119 to 489 with b varying from 1.3 to 1.8, while for the daily interval relationships A went from 152 to 423 and b from 1.3 to 1.5.

In figures 4 (a) to (d) are presented the scattergrams of reflectivity as derived from distrometer data and measured by the radars.

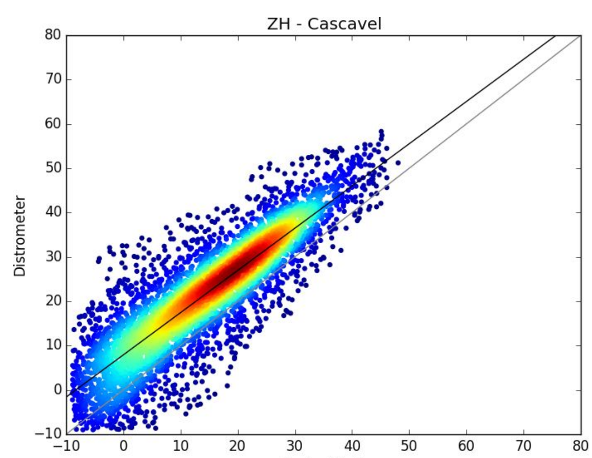

Figure 4 (a): Scattergram of ZH radar vs ZH distrometer. Radar data are averages over 3x3 cells. Slope: 0.95, intercept: 7.89 and bias: -7.2.

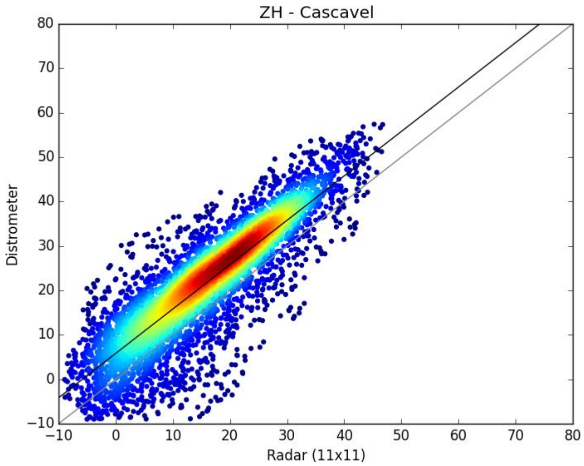

Figure 4 (b): Scattergram of ZH radar vs ZH distrometer. Radar data are averages over 11x11 cells. Slope: 0.99, intercept: 5.82 and bias -5.8.

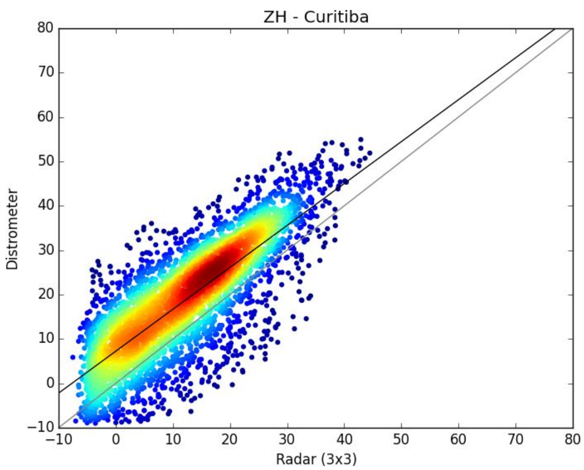

Figure 4 (c): Scattergram of ZH radar vs ZH distrometer. Radar data are averages over 3x3 cells. Slope: 0.94, intercept: 5.82 and bias: -6.6.

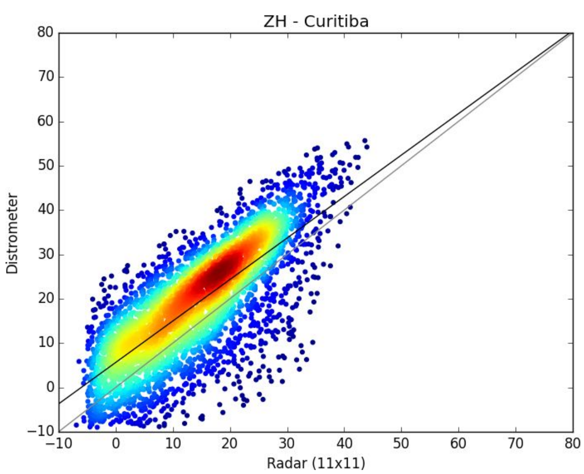

Figure 4 (d): Scattergram of ZH radar vs ZH distrometer. Radar data are averages over 11x11 cells. Slope: 0.93, intercept: 5.64 and bias: -4.7.

For both radars, reflectivities were derived for arrays of (3 km x 3 km) and (11 km x 11 km) range gates centered at the gate containing the distrometer (Kalina et al, 2014). The dispersion curves show slopes varying from 0.93 to 0.99 and biases from -4.7 to -7.2 dBZ. These values are comparable with results from the literature (e.g. Kalina et al, 2014).

Figures 5 (a) and (b) show standard distribution functions fitted to the data from the distrometer associated to CAS (Baltas et al, 2016).

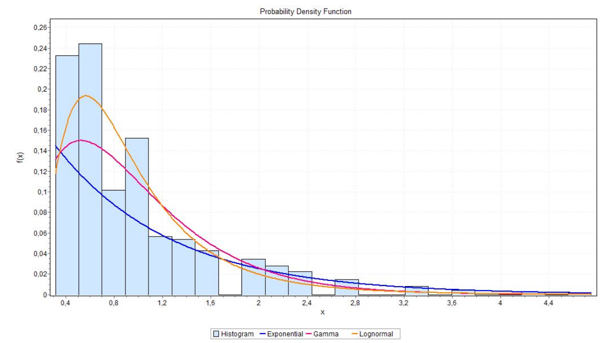

Figure 5 (a): Probability density functions curves for Exponential (1P), Gamma (2P) and Lognormal (2P).

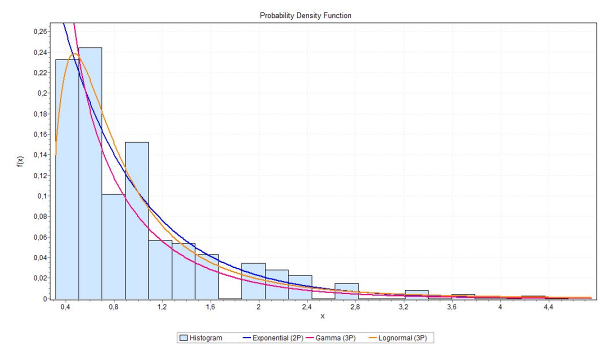

Figure 5 (b): Probability density functions curves for Exponential (2P), Gamma (3P) and Lognormal (3P).

4. COMMENTS AND CONCLUSIONS

Distrometric Z-R relationships were derived, which were stratified by season and by daily interval. The relations apply to most relevant radar covered areas in South Brazil with outstanding agro-industrial activities and hydropower generation. The Summer tuned (December-February) relationship is undergoing tests in the context of radar rainfall input to hydrological models.

Reflectivities both from radar and distrometer were compared for two different radar cell areas. Scatterplots show slopes above 0.93 and a shift from the 1.1 curve; approximate bias range was 5-to-7 dBZ. Verification of this shift includes a thorough radar calibration procedure.

DSD for the distrometer at CAS remain, in general, between the curves for July (dry season) and December (wet season); those two curves run approximately in parallel (ratio of droplet concentration about constant). Curves feature peak concentrations at the lowest diameter range, which are not much pronounced. For the Curitiba distrometer the curves run, in general, between those for March and August. Only the curves for December and January feature peak concentration; peaks are quite smooth.

Exponential, Gamma and Lognormal standard distributions were fitted to the Cascavel distrometer data. The order of ranking (best-to-worst) through the K-S Goodness of fit Test was: lognormal, lognormal (3P), exponential (2P), gamma, gamma (3P) and exponential.

6. REFERENCES

Baltas, E., Panagos, D., Mimikou, M., 2016: Statistical Analysis of the Raindrop Size Distribution Using Disdrometer Data. *Hydrology , 3*(1), 9 .

Calheiros, R. V., Gomes, A. M., 2012. Impact of Z-R relationship on flow estimates in central São Paulo. *Weather Radar and Hydrology,* 650-654.

Kalina, E. A., Friedrich, K., Ellis, S. M., Burgess, D. W., 2014: Comparison of Disdrometer and X-Band Mobile Radar Observations in Convective Precipitation. *Monthly Weather Review*, 142, 2414-2435.

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