253 **RANGE EFFECTS IN POLARIMETRIC MEASUREMENTS AT THE S, C AND X BANDS IN BRAZIL**

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1. INTRODUCTION

Accuracy of radar rainfall estimates are of paramount importance for several applications as is the case of hydrology. The quality of radar measurements of rainfall degrades with range, thus in countries where large areas are to be covered with a restricted number of radars requiring measurements to further ranges, the range effect issue is emphasized. Such is the case in Brazil, with continental dimensions and a vast hydric network.

By providing a reduction of the effect of drop size distribution variability in rainfall estimates, polarimetry allows progress in rainfall estimates and hydrometeorological applications, and polarimetric radars have become an industry standard. Notwithstanding, mainly due to to the combination of the geometry of radar measurements and the structure of the rainfall systems, the promises of improvements of radar rainfall accuracy are still to be completely proven in the operational scenario.

A recent study (Gorgucci and Baldini,2015) have shown have shown an average increase of about 20% in the difference (in terms of the NSE) between radar and ground rainfall measurements, at C-band, along 60 km, directly attributable to beam broadening. Cross-beam gradients of Z, ZDR and PHIDP within the resolution volume may result in significant biases of ZDR, PHIDP and RHOHV. These biases increase with range as a result of beam broadening, and are larger at shorter wavelengths (Ryzkhov,2007).

In Brazil there are now several operational long range polarimetric radars, one of them in the C-band. In this paper radar rainfall CDF (cumulative probability distribution function) are retrieved from polarimetric algorithms for different ranges along the radar coverage, for three standalone radars operating at the S, C and X bands, the latter being a component of the data acquisition base of a research project.

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Since beam broadening affects both conventional and polarimetric radars a previous work was carried out (Calheiros et al, 2014) with data then available showing range effects on measurements from a non-polarimetric S-band radar and the same polarimetric X-band radar used in this paper.

For the study of this paper, data base was the PPI product from the three radars from the most intense period within the wet period in summer, with the occurrence of strong tropical convection featuring elevated gradients of rainfall. Radar rainfall data were obtained through polarimetric algorithms from the literature. Data were stratified by daily interval reflecting the evolution of the hourly rainfall along the day and by range rings in the full operational range defined to balance capture of range effects and sample size. Gage data from the S and C band radar coverage areas were used as reference. Data and Processing are described in section 2, including radar positioning and characteristics, in section 3 results are presented and conclusions are in section 4.

2. DATA AND PROCESSING

Radar position and coverage is depicted in Figure 1 below. Radar characteristics are shown in the sequence; the Cascavel radar is operated by the Paraná Meteorological System, SIMEPAR, the São José dos Campos radar is operated by the Chuva research project and the Morro do Elefante Radar is operated by the CEMIG (Minas Gerais state hydropower company):

- Cascavel(**CAS**): S-band polarimetric with a 1° beamwidth and 850 KW peak power, sited at -24.8755°,-53.5253° in the state of Paraná.
- São José dos Campos (**SJC**): X-band polarimetric with a 1.3° beamwidth and 55 KW peak power, sited at -23.208702°,-45.952817° in the state of São Paulo.
- Morro do Elefante(**CEMIG**): C-band polarimetric with a 1° beamwidth and 250 KW peak power, sited at –19.9452°,-44.4344°, in the state of Minas Gerais.

Radar data were ZH and KDP for all three radars as specified below:

- **CAS**: PPI at 0.5° elevation generated every 7.5 min to a 250 km range, from the period 01 Dec 2014 to 28 Feb 2015.

- **SJC**: PPI at 1°elevation generated every 6 min to a 100 km range, from the period 01 Dec 2013 to 28 Feb 2014.
- **CEMIG**: PPI at 0.5° elevation generated every 7.5 min to 250 km 01 Dec 2011 to 29 Feb 2012.

Gage data were from stations near the CAS and CEMIG radars. Radar rain rate was derived with the relations expressed below (Crisologo et al, 2014), which includes the local Z(R) developed for the CEMIG radar coverage area (Calheiros et al, 2015):

$$\mathrm{R(Z,KDP)} = w.R(KDP) + (1-w).R(Z)$$

$$\text{with } \begin{cases} 0, & \text{for } KDP \leq 0.5 \\ 2KDP - 1, & \text{for } 0.5 < KDP < 1 \\ 1, & \text{for } KDP \geq 1 \end{cases}$$

where:

$R(Z) = 56.3\ R^{1.6}$ and

$R(KDP) = 129(|KDP|/f)^{0.85}\ \mathrm{sign}(KDP)$.

CDF stratified by daily interval and range rings were computed from the rain rate data.

3. RESULTS

Figures 2, 3 and 4 show the CDF curves for the 3 radars. Only curves for a near and the furthest range rings, e.g., 20-40 km and 210-240 km are presented for a clear illustration of the range effects. The furthest range ring has a larger radial dimension for the **CAS** and **CEMIG** radars in an attempt to keep a statistically representative sample size; this was not applied to the SJC radar because of its much shorter range. Because of the relevance of daily stratification for hydrologic applications verified in the state of São Paulo in a previous work (Calheiros and Gomes,2011) curves for all daily intervals were included.

4. CONCLUSIONS

Curves for the near and furthest range rings present, in general, a clear stratification for all radars and all daily intervals, with the exception of those for the **CAS** radar for the 14-19 LT interval. The smallest degree of stratification is for the interval of maximum daily rainfall, e.g. , 14-19 LT, under the criteria of the ratio of probability levels at the reference rain rates of 10 mm/h and 100 mm/h rain rates. Overall, stratification is more pronounced at shorter wavelengths. For the **CAS** radar the ratio of probabilities is practically one along the rain rate range, for the 14-19 LT interval, with the CDF curves quite close. A noticeable higher degree of stratification is verified for the **SJC** and **CEMIG** radars for the same interval. Caution should be exercised when comparing the range stratification with the **SJC** radar because its operational range is much shorter than those for the other two radars; a comparison for the same range is to be explored in continuing work. Rain gage CDF is noticeably closer to the radar CDF for the **CAS** radar as compared to the **CEMIG** radar; in the comparison of the gage and radar CDF it should be taken into account that the time resolution of radar and gage data are different. Results in this limited first study suggest the occurrence of range effects to different degrees in the operational coverage range of the three radars at S, C and X bands in Brazil. Quantification of these effects is considered for the work in continuation.

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Figure 1: Radar site and coverage area. Range circles are 240 km, 100km and 250 km for the Cascavel (CAS), São José dos Campos (SJC) and Morro do Elefante (CEMIG) radars, respectively.

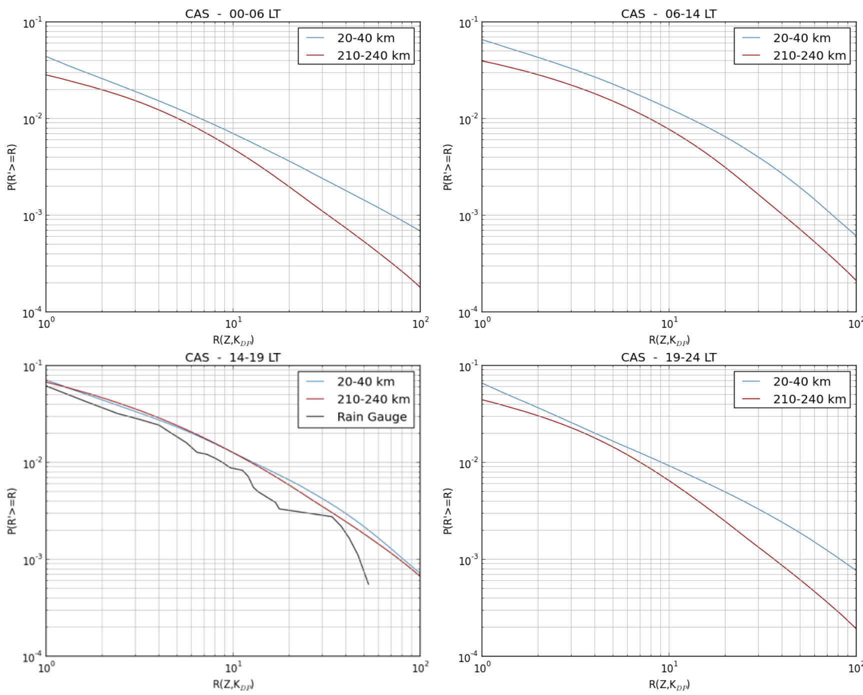

Figure 2: S-Band Cascavel (CAS) weather radar results. Cumulative probability distribution function (CDF) for CAS at the indicated daily intervals and range rings. Rain gauge data from station Cascavel at 15 min resolution , for the 14-19 LT interval.

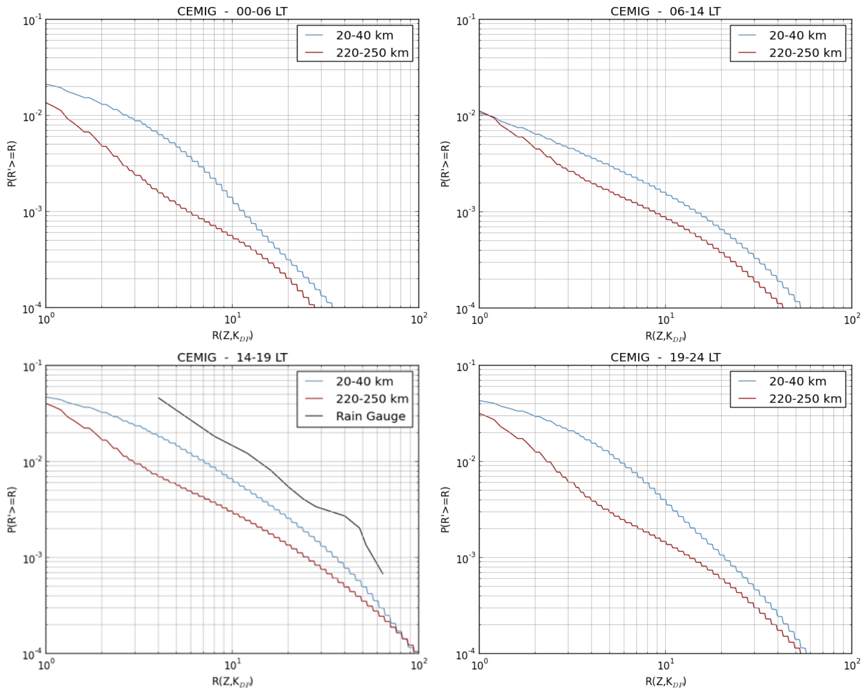

Figure 3: Cumulative probability distribution function (CDF) for CEMIG at the indicated daily intervals and range rings. Rain gauge data from station Rio de Pedras at 15 min resolution , for the 14-19 LT interval.

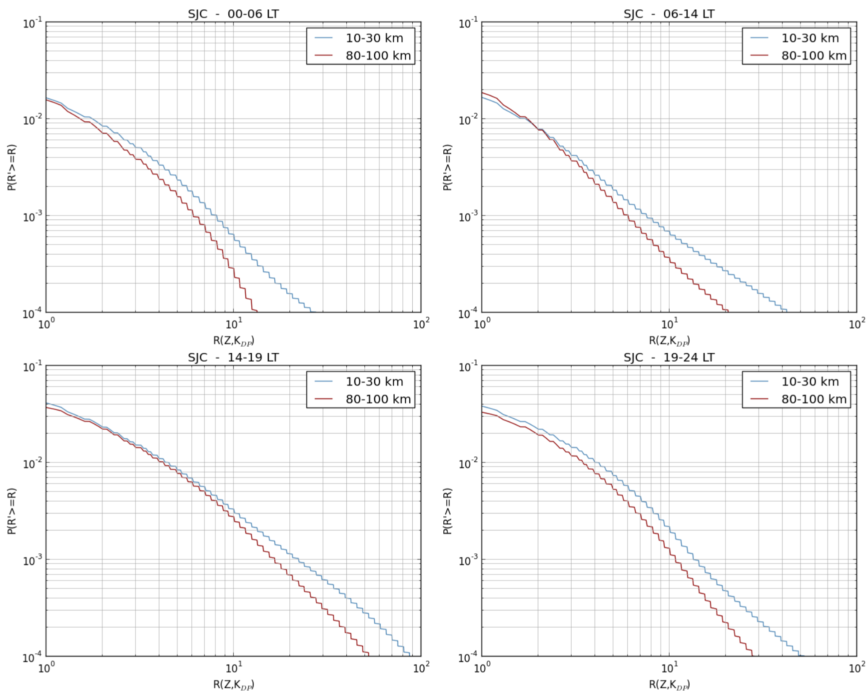

Figure 4: Cumulative probability distribution function (CDF) for SJC at the indicated daily intervals and range rings.