Proceedings of ERAD 2006

Daily Interval And Range Stratification In Rainfall Measurements With The Bauru Radar

Roberto V. Calheiros[1] and Paulo R.P.Tepedino[1]

[1] Meteorological Research Institute – IPMet/UNESP-Bauru, SP-Brazil

1 Introduction

The Bauru Radar (BRU), 22°21'28"S, 49°01'37"W performs rainfall measurements on a 24h/7day routine basis since 1974.

Covering one of the most important areas in the country, it provides crucial support to Civil Defense in a highly populated region and is intensively explored by the outstanding productive sector. In 1992 an S-Band Doppler radar substituted for the original non-coherent C-Band. BRU has just undergone a substantial upgrade/date which significantly improved the accuracy of rainfall quantification. Logistic and economic reasons determine the use of BRU to the outer radar ranges. Range corretions were developed for the measurements with the old C-Band (Calheiros, 1982) wich permited applications in relatively extensive catchment areas for flood forecasting, among others.

Experience acquired through the decades of observations with BRU have shown that useful quantitative information can be drawn from the top of cell cores up to the outermost BRU range, i.e 450 km. A process of cell "cloning" is under development at IPMet to retrieve the structure of strong convective cells in the far BRU range, through surrounding the cell which core top is detected by the radar, with satellite radiometric imagery (Machado and Calheiros, 2003).

In this sense, preliminary brightness temperature, Tb vs reflectivity relationships have already been derived (Calheiros et al, 2005).

In the "cloning" process, range correction of the cell core is fundamental. On the other hand, while range dependence was much more pronounced for the C-Band, it is significant for quantitative applications in the further rings of the main radar products presently disseminated, i.e, the 240 km range CAPPI at 3.5 km amsl.

Correspondence to: Roberto V. Calheiros

calheiros@ipmet.unesp.br

An update of BRU range correction is now being carried out. Major factors in the correction are stratification by daily intervals and better radial resolution of the range rings.

This paper deals with a new set of daily intervals, based on the distribution of hourly rainfall along the day for a large period of radar observations, and a more detailed refined division of the range rings based on shorter radial intervals.

A radar elementary cell with smaller dimensions was used as better time resolved raingage data to match that cell size became recently available. Coverage of the full radar range was obtained with a composition, using CAPPIs in the lower distance band followed by PPIs rings to the BRU maximum range.

Curves of CDFs (Cumulative Probability Distribution Function) were computed as the basis for the analysis. CDFs were derived for the daily intervals and for each radar ring, on a year-to-year basis.

A comparison between the individual months of January and March was elaborated to verify tendencies of the daily interval and range ring stratification, from peak to late summer periods.

Relative behavior of the CDFs for the January-to-March summer period, and for each daily interval was analysed.

Results of particular importance for operational application are presented.

Comparisons with previous works on range corrections in other areas of the world are mentioned.

2 Methodology and Data

CDFs constituted the basic data set to be matched to raingage statistics for the derivation of range corrected Z-R relationships.

The matching process is the core of the statistical approach of Calheiros and Zawadzki, 1987.

Both the conditional $p\langle Z \,|\, Z_0 \rangle$, and the marginal $p(Z_0)$ probabilities are required.

The former represents the probability of occurrence of a given reflectivity provided that it rained, and the later the probability of occurrence of rain, in the radar coverage area.

The final parameter is the joint probability $p(Z, Z_0)$ = $p\langle Z \,|\, Z_0 \rangle \;\; p(Z_0)$, which integrates to $P(Z' \geq Z, Z_0)$ = $P\langle Z' \geq Z \,|\, Z_0 \rangle p(Z_0)$.

See Calheiros, 1982 for a discussion on this.

This probability is the CDF used in the matching process.

While works following the inception of the statistical methology used here introduced modifications and dicussed limitations of the technique (e.g. Rosenfeld at al, 1994; Chandrasekar et al, 2003), it has been successfully applied to BRU observations.

Data processed in this work to compute the above mentioned CDFs were reflectivities from the operational BRU products specified in the sequence:

- CAPPIs at 3.5 km amsl, to a range of 240 km

- PPIs at an elevation of 0.2° - 0.3°, to a range of 450 km.

Period utilized was from 1993 to 1997, for the January to March summer period.

Reflectivity values were > 0 dBz, and the resolution was 1 dBz.

Files were composed of 4 CAPPIs (whenever there was rain in the area) in the hour, and a PPI surveillance routine each 30 minutes, for the whole period.

Data were gathered as described below:

- For the 0-6H, 6-14H, 14-19H and 19-24H daily intervals, and
- For each daily interval, for the following range rings:
  a) CAPPIs: in 20 km increments to the 120 km range, and in 30 km increments from 120 km to 240 km ranges.
  b) PPIs: 240-290 km, 290-340 km, 340-390 km and 390-450 km.

  All times are local times.

3 Results and Analysis

Figs. 1. (a), (b) and (c) present the rainfall distribution for each hour along the day for the whole period, and for extreme cases in the month of February, taken as representative of mid-summer conditions. The precipitation in an hour is an average of R from the CAPPIs in that hour, obtained through the M-P relationship.

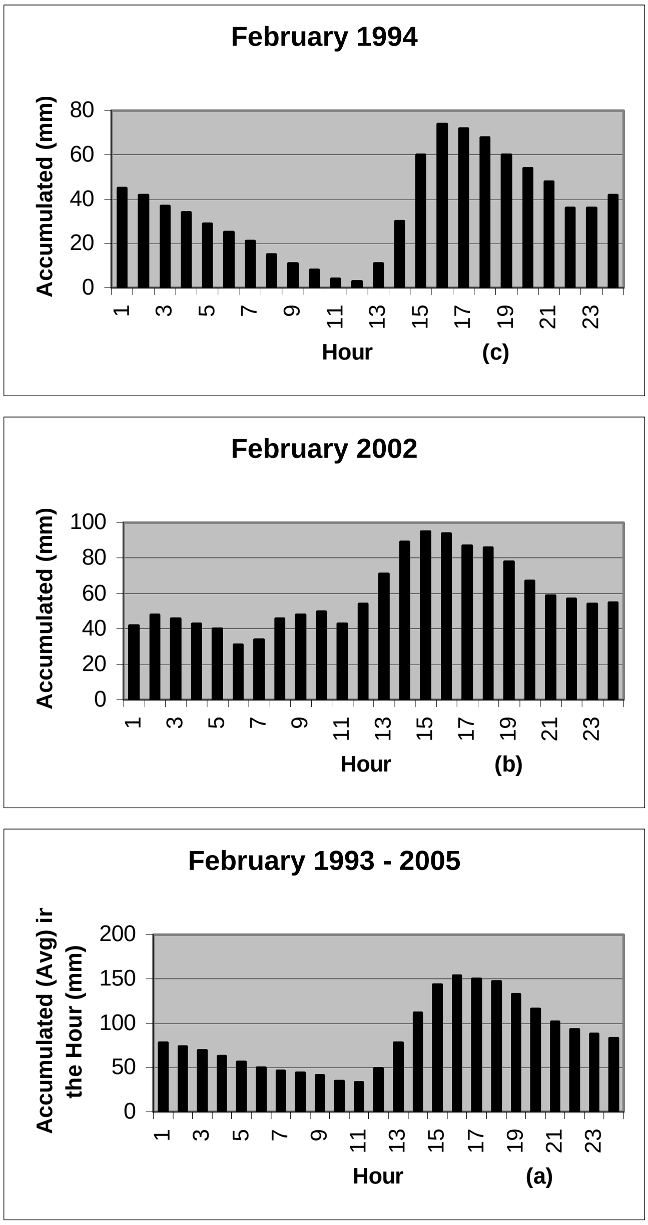

Fig.1. Hourly distribution of rainfall along the day.

In general, the distribution in Fig.1.(a) is followed. For 1994 and 2002 the February distribution shows significant deviation from the typical pattern. The former was a particularly “dry” February, with an extreme minimum in the approximate 10-12H interval, while the latter shows some uniformity of rain values along the whole day, except for the 14-19H period of strong convection. Although times of transition are loosely defined, 4 intervals are characterized in Fig.1.(a), e.g. 0-6H, 6-14H, 14-19H and 19-24H.

CDFs were then derived for each daily interval, for the 10 CAPPI range rings (to 240 km) and for the 4 outermost PPI range rings (from 240 km to 450 km). Curves were generated for each of the five years from 1993 to 1997. This period was initially utilized due to an uniformity of the number of CAPPIs in the hour. Figs. 2. (a), (b), (c) and (d) illustrate the results. Only 0-6H and, 14-19H, daily intervals and range rings 2 (20-40 km) and 10 (210-240 km) (CAPPI) are shown, due to the large amount of curves generated.

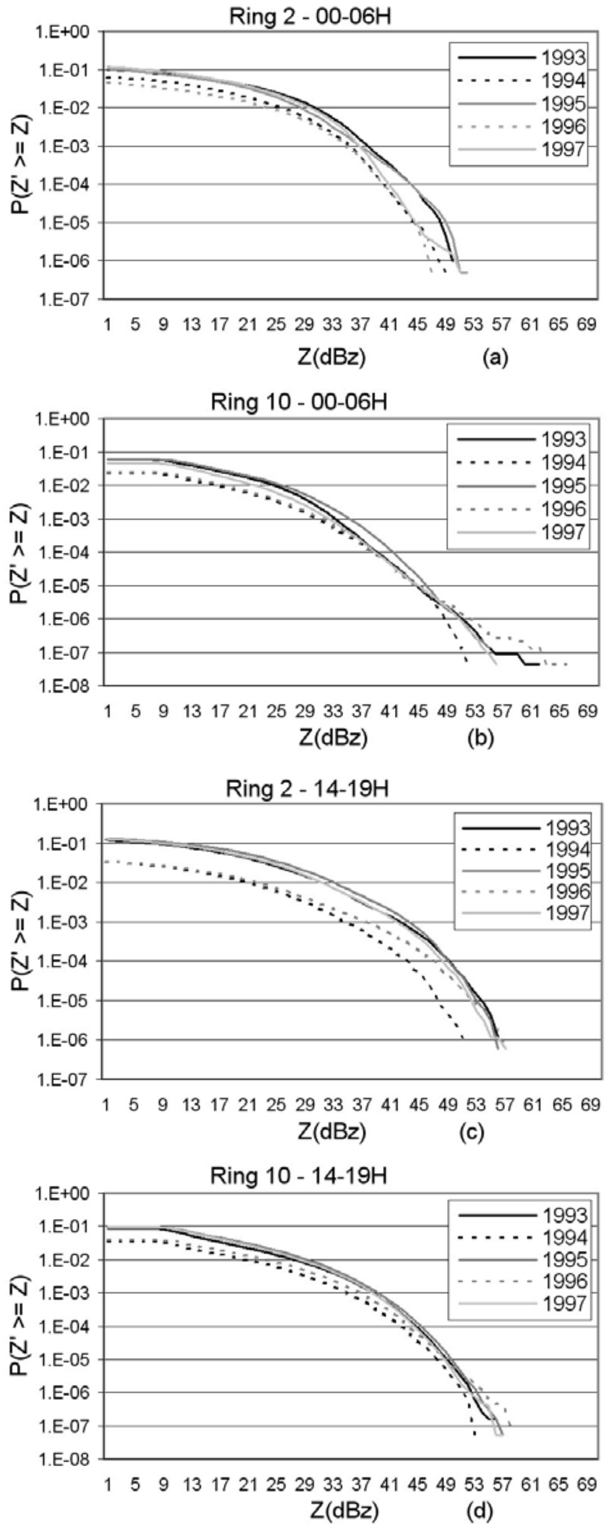

Fig. 2. CDFs for 0-6H and 14-19H daily interval, and the indicated range rings.

An analysis of all daily intervals shows that:

- For ring 2, at the 10^{-2} probability level Z values are approximately 29 dBz except for 6-14H interval when it decreases to 26 dBz. At the upper range of Z values, at the 10^{-6} probability level the 0-6H and 6-14H periods have Z values around 51 dBz , increasing to 56 dBz for the 14-19H interval.

- For ring 10, Z values for 10^{-2} probability are around 21 dBz for 0-6H and 6-14H, increasing to 24-26 dBz in the other two intervals. For the upper tail of the curve (10^{-6} probability) those values are ~50 dBz and 51-53 dBz, respectively. Loss of reflectivity at high Zs is around 3 dBz.

In general curves run in parallel for most of the dBz range indicating that the rainfall structure is kept stable from one year to the other.

In figure 3 are curves for rings 2 and 10 (CAPPI) for the peak convection period (14-19H) for January and March, 1995.

CDF values for March are under those for January, clearly evidentiating the distinction between peak and late summer.

Notwithstanding, curves run in parallel indicating that rainfall structure is preserved.

While stratification for rings 2 and 10 is well established for January, it is barely noted for March.

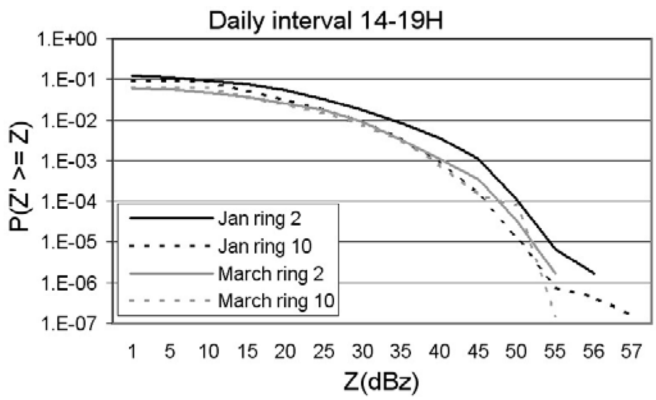

Fig.3. CDFs for January and March, 1995, and indicated range rings.

The figure 4 contains curves for the inner range ring 02 and the outermost rings for the CAPPI based coverage (210-240 km) and the PPI region (390-450 km). Probability levels for a given reflectivity shows differences of more than 3 decades in the upper range of Z values evidentiating the severe impact of large distance from the radar. Still, relative position of the curves suggests that the actual rainfall structure is somewhat present in those far radar ranges.

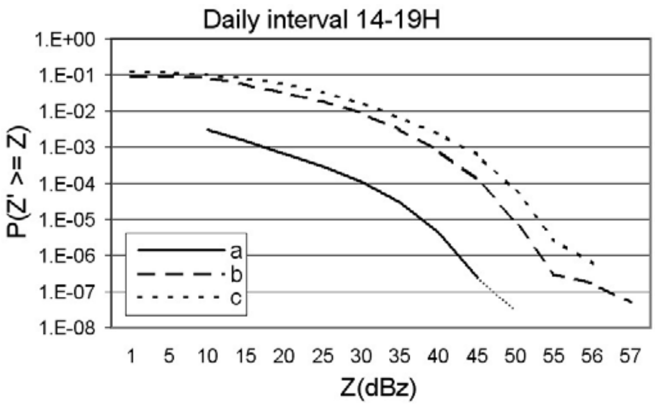

Fig. 4. CDFs for January to March 1995. (a) refers to PPI ring 10 (390-450 km), (b) refers to CAPPI ring 10 (210-240 km) and (c) refers to CAPPI ring 2 (20-40 km).

Marginal probabilities were:

Table 1. $p(Z_0)$ for each year and daily interval

year / daily interval	1993	1994	1995	1996	1997
00-06	0.60	0.41	0.76	0.45	0.78
06-14	0.46	0.28	0.68	0.40	0.67
14-19	0.83	0.58	0.93	0.51	$\leq$ 1.0
19-24	0.82	0.52	0.88	0.50	0.94

Probability values are compatible with the characteristic of the year ("dry" or "rainy").

The figures on Table 1 were calculated for the Jan-March period based on CAPPIs.

4 Comments and Conclusions

Results suggest that usefull corrections of the Z measurements are feasible even at quite far distance.

Comparison with range effects as shown in the works of Wilson (1975) and Koistinen et al (2002) indicates values. One must take into account here the differences of climate, equipments, processing, etc.

Impacts of daily intervals and periods within a season (e.g. summer) on CDFs were assessed indicating the need of stratification of the curves, to different extents.

In general, no significant variations of rainfall structure from year-to-year were detected for far the larger position of Z ranges. Statistical stability considerations suggests that caution be exercised when dealing with structural issues at the upper range of Z values.

Next step is to extend computations to the 1998-2005 BRU data and assessment of the degree to which Bauru gage data represent the climatology prevailing in BRU coverage area. Derivation of range corrected Z-R relationships will follows.

References

Wilson, J., 1975: Radar-gage precipitation measurements during the IFYGL, CEM REPORT 4177-540, the Center for Environment and Man, Inc., pp. 93.

Calheiros, R.V., 1982: Space resolution of precipitation estimates with hydrometeorological radar (in Portuguese), Ds Thesis, S.Carlos Engineering School, p.p. 205, available from the author.

Calheiros, R.V. and I. I. Zawadzki, 1987: Reflectivity-rain rate relationships for hydrology in Brasil. *J. Climate Appl. Meteor*., **26**, 118-132.

Rosenfeld, D., D. B. Wolf and E. Amitai, 1994: The window probability matching method for rainfall measurements with radar. *J. Appl. Meteor*., **33**, 682-693.

Koistinen, J. and D. B. Michelson, 2002: Baltex weather radar-based precipitation products and their accuracies, Boreal Environment Research, 7, p. 253-263.

Chandrasekar. V., R. Meneghini and I. Zawadzki, 2003: Global and local precipitation measurements, in radar and atmospheric science: a collection of essays in honor of David Atlas, Roger M. Makimoto and Ramesh C. Srivastava (Ed.), Chapter 9, 215-236.

Machado, R. and R. V. Calheiros, 2003: Cloning radar cells, a test with the Bauru radar, Proceedings, 31[a]. Conference on Radar Meteorology, AMS, Seattle, U.S.A., p. 843-845.

Calheiros, R. V., R. Machado and M. A. Lima, 2005: Cell detection at for ranges: supporting Tb-Z relationships, *Atmospheric Sciences Letters*, Vol. **6**, issue 1, March, p. 54-58.