P6B.3

RETRIEVAL OF THE GROSS STRUCTURE OF REFLECTIVITY :

CORRECTING FOR DEGRADED PEAK VALUES

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1. INTRODUCTION

The deterioration of the structure of reflectivity fields , due to the smoothing imposed by the antenna beam resolution is a basic problem in radar meteorology. Back in 1982, Zawadzki approached the issue quite appropriately in a comprehensive paper (Zawadzki, 1982), where he points out the impact of gradient steepness in the computation of the mean rainfall over an area. Also, he focused the problems related to the change that reflectivity and its spatial variability undergo, as a function of radar range.

Torlaschi and Humphries (1983), developed a research on the statistics of reflectivity gradients, based on its relevance to the improvement of the quality of radar measurements. More recently, Einfalt et al (2004), in a study on the quantitative assessment of a small scale intense rainfall using radar and raingages, stated among their conclusions that it is useful to work on the original polar data as long as possible. They also emphasize the question of the influence of polar to Cartesian coordinate conversion. In this sense, they express that the re-sampling of polar to Cartesian data may distort the spatial distribution of reflectivity pixel values. In addition, they state that this problem is even more serious when one considers that the value shown in a given radar grid cell is already an average over the sampling volume.

At the Meteorological Research Institute (IPMet/UNESP), which operate two radars,i.e., the Bauru radar (from now on BRU), at 22.35º S, 49.03º W, and the Presidente Prudente radar (from now on PPR) , at 22.12º S, 51.38º W, products which are made available to users are the output of a processing suite, from data acquisition to product dissemination. As a result, a loss of native resolution occurs at near ranges and distorted values are presented at mid-to-far-ranges.

Both BRU and PPR systems feature a 2º beamwidth and are operated to far ranges, aggravating the problem.

One of the main efforts within IPMet´s research program aims at improving the quality of user´s products.

Calheiros and Antonio (2005) provided an estimate of the degree of distortion of the reflectivity field in the area of coverage of the Bauru radar, showing statistics of gradients at different radar ranges. In the results the severe deterioration incurred by the reflectivity structure, is evident.

In this paper results of an attempt carried out to correct peak reflectivity values in the region monitored by BRU and PPR, are presented. Those results refer to corrected values of maximum reflectivity in the structure of storms.

Events situated at varying distances from the radars, in three different areas ,i.e., to the West of PPR, between BRU and PPR, and to the East of BRU, were chosen. They were selected so as to span the periods of transition from "dry-to-wet" season, and early and peak summer.

Typical storms along or near the BRU – PPR axis were identified in each event, and considered for the study. Reflectivity profiles in the azimuth direction and fixed range, crossing a peak of reflectivity, were constructed.

The basic theoretical treatment of corrections to the reflectivity from radar observations, is the paper of Donaldson (1965)

Adopting his work, Gaussian functions were fitted to the reflectivity profiles. From the fitted curves, values of the second derivative were calculated. With the derivative values, corrections for the peaks were derived.

Sets of fitted Gaussians, classified according to the storm situation within the

three areas mentioned before, were displayed for evaluation of shape variations.
Second derivative curves as a function of distance were generated. The value of the corrections was plotted against the respective storm distance to the radar, and also against the month of occurrence of the corresponding event.
One typical profile was selected for verification of the quality of the fitting procedure.
The above described results were analyzed and backed the conclusions which followed. Comments were made, in particular, on the relevance of the corrections for BRU and PPR coverage areas.
Finally, plans for the continuation of the work were considered.

2. DATA AND PROCESSING

Basic data for this work were reflectivities from the BRU radar, composing the following: a) PPIs at 0.3° elevation, from the volume scan (VOL_SCAN task) used to generate the operational 3.5 km CAPPIs, to a range of 240 km, and b) PPIs at a 2° elevation, to a range of 450 km (SURVEILLANCE task) which is one operational component of IPMet´s routine suite for users.
This last product was used whenever distance to the radar exceeded 240 km.
Fig 2.1 depicts the location of BRU and PPR in the state of S.Paulo. Fig 2.2 (a1 and a2) are from 450 km PPIs from BRU and PPR, respectively, for the 04JAN2007 event. Ellipses indicate the storms used in the analysis. This storm was used to illustrate the quality of the Gaussian fit.
Events were selected from different times of the year, to explore diverse seasonal conditions. Only events seen by both radars were taken. They were gathered into the three previously mentioned sets, each from one distinct region, i.e., to the W of PPR, between PPR and BRU, and to the East of BRU. Distances from the radars to selected storm events varied from 30 to 300 km.

Fig. 2.1 – Map of the State of São Paulo, showing the location of the two radars, and respective ranges

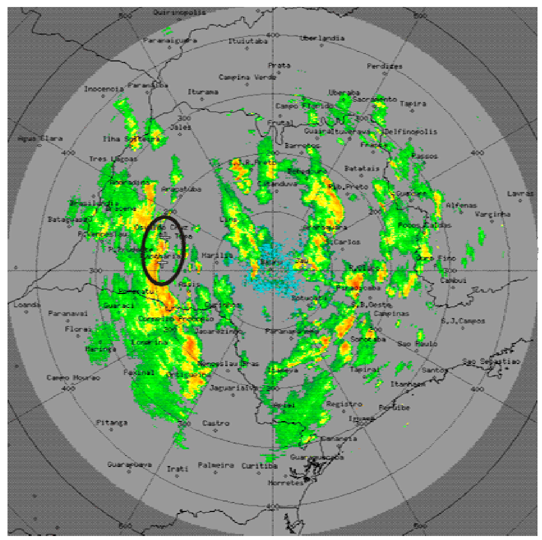

Fig 2.2 (a_1) – Radar scan of event from 04JAN2007 seen by the Bauru radar (SURVEILLANCE task)

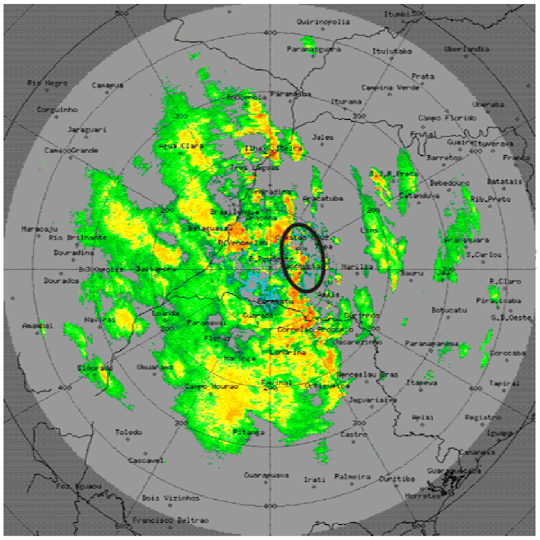

Fig. 2.2 (a_2) – Radar scan of event 04JAN2007 seen by the Presidente Prudente radar (SURVEILLANCE task)

There were events from the transition period (October), end of transition (November), and peak summer (January). One case was from late winter (September).
In all there were 43 events available. For each of those 43 events, the corresponding PPI was inspected in the search for significant convective rain areas where peaks of reflectivity could be clearly identified. From those areas, one was chosen for analysis.
For that area, the position of peak reflectivity (Zmax) was determined, say at
(r Zmax, phi Zmax), and a Z profile was cut in the azimuthal direction from (r Zmax, phi mi) to (r Zmax, phi max), where phi min< phi Zmax< phi max. Both ends of the profile (phi min , phi max) were chosen by inspection, in such a way that the peak reflectivity was clearly defined, approximately a Gaussian shape.
In the following, an in house developed program written in MATLAB was used to fit each profile with a Gaussian curve of the form:

$$Z(phi) = C1e^{\frac{-(phi-C2)^2}{C3}}$$

From the fitted C1, C2 and C3, the 2nd derivative was calculated as:

$$\frac{d^2}{dphi^2}Z(phi) = -2\frac{C1}{C3}$$

This value was, then, used to obtain an estimated value of Q´, as defined by equation (11) in Donaldson (op.cit).
A typical Z-profile with the fitted Gaussian is shown in Fig. 2.3.

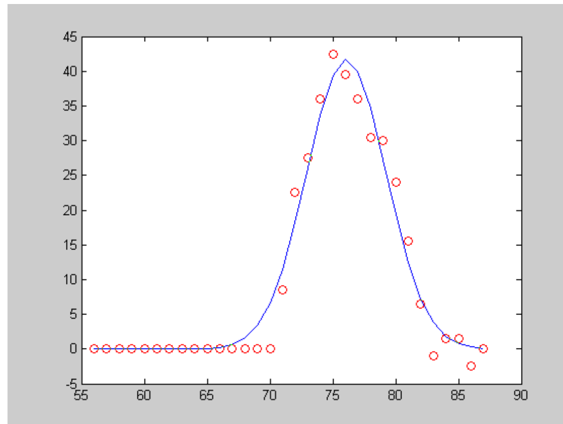

Fig 2.3 – Typical Z-profile with the fitted Gaussian (event from 04JAN2007)

3. RESULTS AND ANALYSIS

The correctness and quality of the fits were assessed by comparing the results obtained with the MATLAB program (developed in house), with the fit obtained for the same data using the program Datafit, version 8.20. Also, the MATLAB program was translated into SCILAB.
The values of C1,C2 and C3 are essentially the same, to better than 1%.
As an example of the typical quality of the fitting, the results of the fit for the selected event shown in Fig. 2.3 is presented. The fit could explain 94,9% of the variance, and R2= 0.873 and Ra2 = 0.8449. R2 and Ra2 are the coefficients of multiple determination, and adjusted coefficient of multiple determination, respectively. R2 and Ra2 are sufficiently close to one for the fit to be considered good.
Figs. 3.1 (a1, a2), (b1, b2) and (c1, c2) show the set of Gaussians fitted to the storm profiles. For all these figures, abscissae are distances in km, and ordinates are reflectivities in dBZ. The sets a) E of BRU, b) in-between both radars, and 3) W of PPR seen by BRU and PPR, present some degree of homogeneity. For the set of events between radars the highest and lowest peak values are around 50 and 40 dBZ, respectively. For the set W of PPR,

seen by BRU, the values are approximately 48 and 28 dBZ, while the corresponding values for the set E of BRU, seen by PPR, are about 43 and 23 dBZ. The peak values for these two last sets are noticeably lower than those for the previous sets, and span larger reflectivity intervals. This is compatible with the fact that the two sets refer to events in the upper range of distances from the observing radar, where radar range effects are more pronounced and their impact grows faster with distance. The procedure adopted to compile the 2nd derivative provides substantially better accuracies than, for instance, the one using finite differences.

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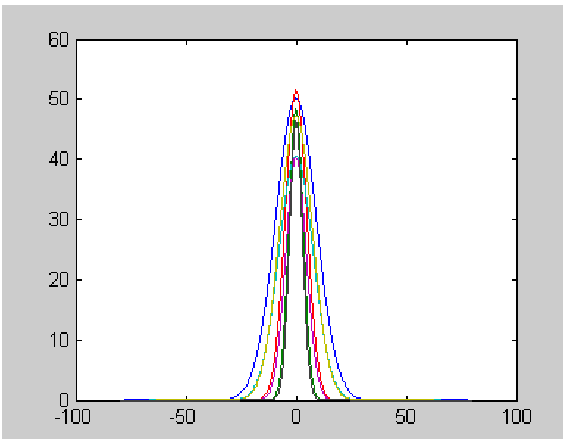

Fig. 3.1 (a_1) – For events E of BRU seen by BRU

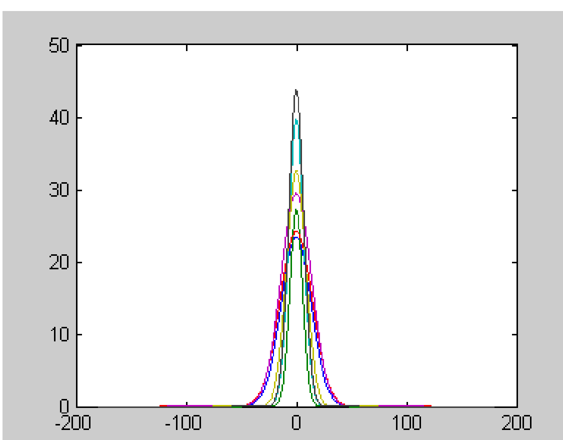

Fig. 3.1 (a_2) – For events E of BRU seen by PPR

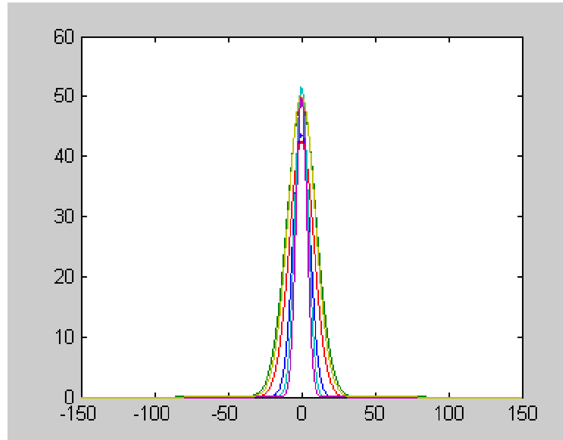

Fig. 3.1 (b_1) – For events in-between both radars seen by BRU

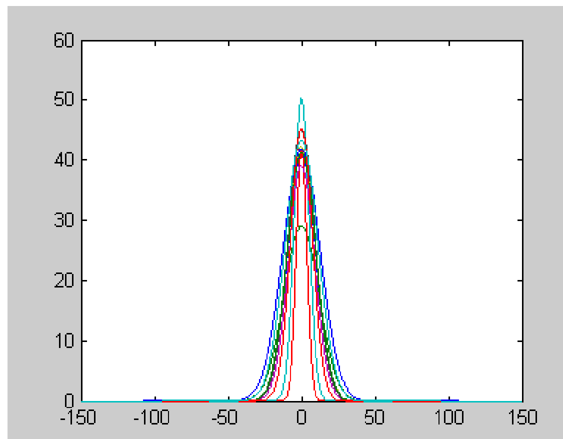

Fig. 3.1 (b_2) – For events in-between both radars seen by PPR

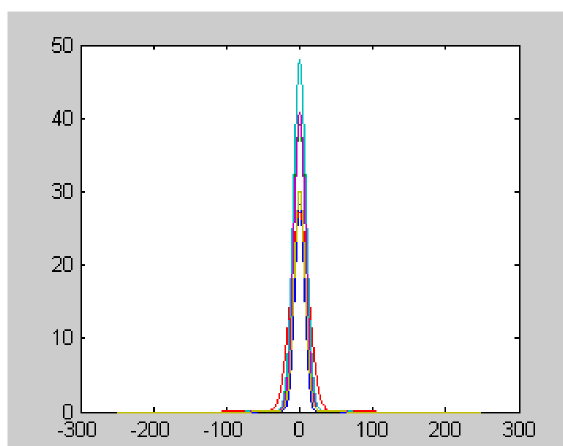

Fig. 3.1 (c_1) – For events W of PPR seen by BRU

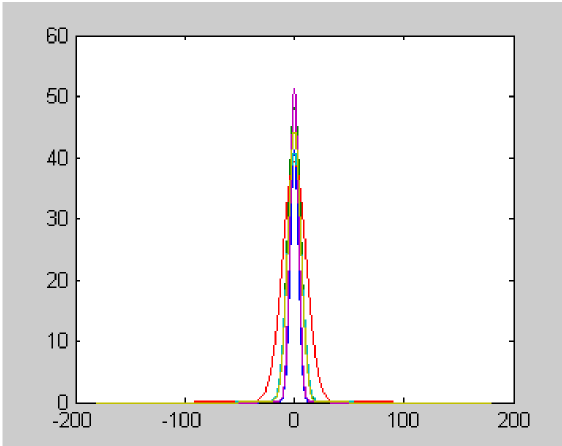

Fig. 3.1 (c_2) – For events W of PPR seen by PPR

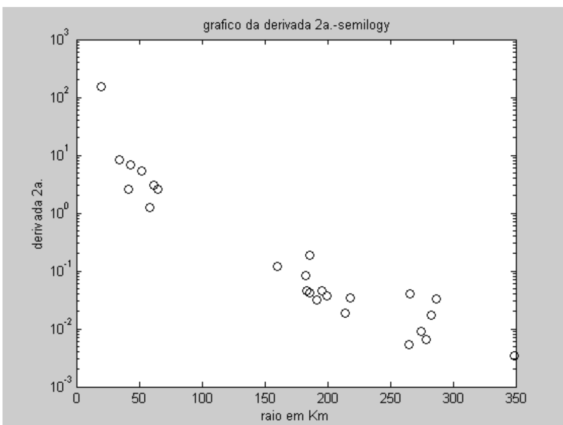

Fig. 3.2 (a_1) – Second derivatives as a function of range for all events seen by BRU

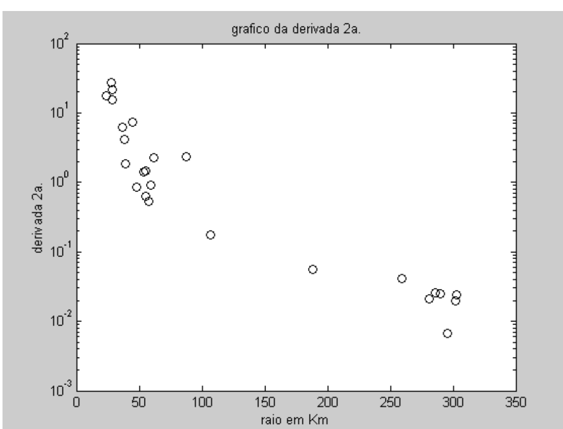

Fig. 3.2 (a_2) – Second derivatives as a function of range for all events seen by PPR

Figs 3.2 (a) and (b) display the second derivatives, as a function of range, for all events as seen by BRU and PPR, respectively. In both cases, the range of values spans about 4 decades, in compatibility with the corresponding variation found in Donaldson (op.cit.). The noted decrease of the rate of change of reflectivity gradients with increasing smoothing of storm structure, is in general steeper in the lower and upper range of distances. There are no substantial differences between the two distributions of the 2nd derivatives .

Fig.3.3 shows the distribution of the peak corrections derived from the 2nd derivative, range and antenna beam width, for each of the three regions of radar observations mentioned before, i.e. West of PPR, between the radars, and East of BRU, as function of radar range. Near the radars, in the approximate range interval of 25 to 65 km, the estimated average correction is around 2.5 dBZ, for the 150 to 220km interval that correction is about 5 dBZ, and at the farthest interval included in this work (approximately 270 to 330 km it is a little less than 5 dBZ. Corrections for the first two range intervals are consistent with those obtained through the statistical technique of Calheiros and Zawadzki (1987). A typical value (Calheiros and Tepedino, 2006) for the statistical correction at the 150 to 220 km range interval is plotted (black point) in the figure.

However, for the farthest interval the correction is much lower than that provided by those authors. Such discrepancy gives an indication of the distances to which Donaldson's procedure apply, and is compatible with the fast degradation of storm structure in the far ranges.

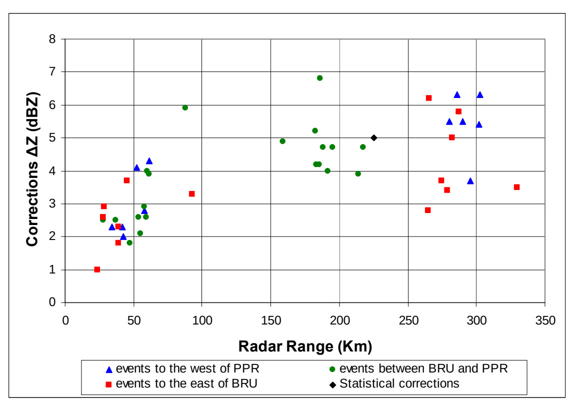

Fig. 3.3 – Peak correction as a function of radar range

Fig. 3.4 presents the average value of corrections for events classified according to the time of the year when they occurred. Each curve corresponds to events classified into two broad range intervals, i.e. approximately 25-150 km and 150-330 km. The period covered by this study evolves from the transition of the "dry-to-wet" season to peak summer. There were no events from December, and the one September storm featured peculiar characteristics of late "dry" season.
The smaller average value for October vis-à-vis the summer values might be attributed, among other factors, to their characteristic of strong vertical development resulting on the average in a less pronounced decrease with range of peak reflectivity values.

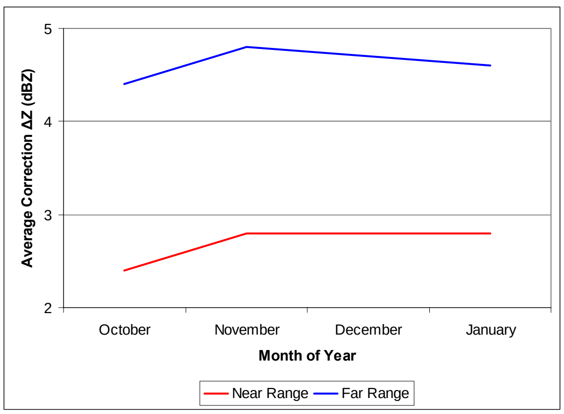

Fig. 3.4 – Average value of correction as a function of the month of the year

4. COMMENTS & CONCLUSIONS

Results from this work suggest that analytical approaches (Donaldson, 1965) can be effective in correcting the degradation of the reflectivity peaks, in the process of recovering the gross structure of rainfall fields, as reproduced by radar.
Operationally useful corrections were obtained up to, approximately, the maximum range of CAPPI products routinely generated at IPMet (240 km). For storms situated beyond that range, corrections have fallen significantly short of the required values to recover the real peaks.
Comparison of this analytical approach with the method of equating cumulative probabilities (Calheiros and Zawadzki, 1987) confirmed the above mentioned range limitation of the correction procedure. It has also indicated that seasonal stratifications of the corrections should be considered . A kind of preliminary validation of Donaldson´s pioneer work (Donaldson, 1965) was performed, disclosing a substantive potential for extending the area of useful operational application of radar observations, which may not have been thought of at the time he wrote his paper.
It should be emphasized that such recovery of storm structure, while not of much relevance for radar systems operating up to mid-range in climates where steep rainfall gradients are not much frequent, it is of paramount importance in regions of highly variable rainfall. This is the case with the tropics, in special when long range use of radar is required, as occurs with BRU and PPR.
The continuation of this work includes stratification of the corrections by daily intervals, and the sought of algorithms to allow the operational implementation of images(products) corrections. One approach to be explored, regarding real time corrections, is the use of neural network assisted Gabor filtering, to automatically fit Gaussians to the storm profiles. In short, one scheme envisaged establishes that the algorithm a) will check profiles along the azimuth direction, at the appropriate radar ranges, recognizing the portions of interest in the storm (assisted by Gabor functions) b) will fit Gaussians to those portions, and then calculate corrections. In the sequence, a corrected image will be generated. The experience gained with the fitting of storms in this work is promising in the sense that such an approach would be much effective, in the operational scenario at IPMet.

5. REFERENCES

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