6.9 COMBINED SPACE AND GROUND RADAR OBSERVATIONS: AN IMPACT OF TRMM PR MDZ

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1. INTRODUCTION

The availability of orbital weather radars is a great asset for the observation of precipitation. Their joint utilization with ground-based radar is an important factor in maximizing the benefit to be reaped from both instruments. In this sense, Calheiros et al. (2000) suggested that composite reflectivity images from the TRMM PR and ground radars (GR) will constitute a valuable product by profiting from each radar's strengths, while minimizing inherent weaknesses. This is presently being carried out with data from the PR and GR in Bauru, Brazil (22°21', 49°01'). One key issue involved in the research, i.e., the PR sensitivity, is the subject addressed in this paper. Two important aspects of the impact of the sensitivity are explored, the first regarding the indicated top of storms and the other the amount of rainfall which falls below the PR's MDZ. Results obtained with Florida storms (Bolen and Chandrasekar, 2000) are also compared to findings from Brazil. Impact assessments were carried out taking into account the indication of the severity of storms and the estimation of the equivalent energy flux stemming from the observed rainfall.

2. DATA

Simultaneous PR and GR data were reflectivity CAPPIs at 2km and cross-sections. Twelve events from the wet period (October-March) were selected. Corresponding lightning data from TRMM was applied with the reflectivity maps. GR data were 100 km range CAPPIs at 2 km and 4 km. A set of 33 events was used. The available TRMM reflectivity data were in the form of CAPPIs, while for the GR the volume scans were used.

3. PROCESSING AND RESULTS

3.1. *Reflectivities under PR's MDZ Level*

The amount of reflectivities below 17 dBZ, taken as the PR MDZ, were computed for the GR CAPPIs. The results are presented in Table 1, which also includes data from Florida (Bolen and Chandrasekar, 2000). It can be noted that, in general, the number of reflectivities decreases with distance, in accordance with an increase in the MDZ. About one third of the events were from the period from 7:00HLT to 06:30HLT approximately. Four were in the interval of 7:00HLT to 8:30HLT; two of those presented an interruption in the trend of the amount of reflectivities with range.

This interruption was more pronounced in the two events occurring in the 22:30-23:30HLT interval and full reversal was verified in the two events in the interval from 03:31HLT to 06:16HLT, as well as in the one nearer 23:31HLT. In the early evening a substantial influence of the daylight interval remains, although a change begins in the distribution of rainfall between convective-type and stratiform-type patterns. The stratiform regime progressively takes over until winter-like conditions are reached. Except for winter, it can be seen that more than 40% of all reflectivities are below the PR MDZ level in any situation. Values for the 2 km CAPPI are higher than those for 4 km but approach each other at longer ranges. Possibly clutter residuals, more pronounced at the lower levels, have minimal effects at the outer ranges. Results compare favorably with those from Florida.

3.2. *Echo Top Differences from GR*

For 33 events the echo top product for -10dBZ and +17dBZ thresholds were generated, the last one simulating the PR MDZ. The 100 km range maps were inspected for identification of vertical developments. Differences in the indicated echo top heights were registered along with the respective range. Results are presented in Fig.1. Because of processing, substantial discretization exists, leading to the concentration of values in determined differences. While most of the values are in the 1-2 km and 3-4 km height interval, there is a considerable number of differences in the 4-5 km interval and a significant number in the 6-7 km interval. Extreme differences in the 8-10 km range deserve further verification. The data file was range stratified in rings of 20-40 km, 41-60 km, 61-80 km and 81-100 km, resulting in Fig.2. No range effects were identified. In general, the distributions in each range ring show similar behaviors. The sample case from Florida gives a >4 km echo top difference between the PR and the S-Pol radar.

3.3. *Echo Tops and Storm Activity from Simultaneous PR and GR Observations*

For 12 events simultaneous data from PR and GR were processed to generate 2 km CAPPIs with 150 km range. Corresponding TRMM lightning data was also gathered. In each CAPPI, two cross-sections were chosen to cut through storm cores as much as possible. The cross-sections were mapped to a height limit of 15 km. Co-

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located cross-sections for the GR were mapped. In addition, PR RHI-like matrices were generated to 180 km range of the GR site with the TRMM's vertical resolution of 250 m, to confirm echo tops. Maps were inspected and differences in echo top heights registered. Because of the 15 km ceiling, the most intense, very high-reaching storms could undergo only limited analysis. Fig. 3 gives the distribution of the differences only for storms with tops up to 15 km. Since the cut-off for the GR here is zero dBZ and only smaller storms are considered, the distribution is compatible with that in Fig.1. Again, range effects were not identified. Tall storms are listed in Table 2, together with indications of the TRMM detected lightning activity. A comparative analysis of storms has shown that, while in case of storms substantially exceeding the 15 km map ceiling, intense electrical activity was present (as shown in Table 2), it generally decreased in proportion to the smaller vertical development of the storm.

3.3. *Sample Storm for Impact on Severity Identification*

An intense storm from 17 October 1999 was selected to check the impact that a relatively high MDZ might have on the use of the radar as an indicator of storm severity. This storm produced damaging hail and intense rainfall. Fig.4 presents an echo top map generated by the radar software where top heights reaching about 19.5 km at 10 dBZ threshold are shown. The storm was re-analyzed setting the top threshold to 17 dBZ to simulate PR sensitivity. Top heights could be determined with reasonable accuracy. When 17 dBZ echo top was computed the indicated storm height went down to about 14 km impairing severity recognition.

3.4. *Amount of GR Observed Rainfall under PR Cut-off*

In their work, Bolen and Chandrasekar (2000) state that the reflectivities undetected by the PR may not translate into a significant amount of rainfall. The rainfall which would go undetected with an MDZ at 20 dBZ was computed for two events observed by the GR. One was a cold front on 8 and 9 September 1998, and the other an isolated rainfall on 9 March 1998. The accumulated rainfall between 0 and 20 dBZ, for the 24h period from 10:01HLT of 8 September to 09:01HLT of the next day was computed hourly, and for the one-hour interval from 16:01HLT to 17:01 HLT of 9 March 1998 was calculated from observations made about every 7 minutes. The results of about 4mm.day^{-1} and 1.6mm.day^{-1} respectively, in reference to a grid of approximately 125X125 km, exceed that suggested by Xu et al. (1999) as equivalent to the negligible threshold of the energy flux which would be produced by a latent heat associated with that rainfall volume.

4.CONCLUSIONS

- The underestimation of storm tops by a threshold setting equivalent to the PR's MDZ of 17 dBZ (or 20dBZ) may lead to equivocal operational indications of its severity.
- The amount of rainfall going undetected due to the cut-off of the PR's MDZ may be significant in terms of the energy flux generated by the LHR equivalent to the lost rainfall volume.
- The results already obtained emphasize the value of integrating both space and ground based radar, indicating that such effort is cost-effective.

5. REFERENCES

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Xu, L., S. Sorooshian, X. Gao, and H.V. Gupta, 1999: A Cloud-Path Technique for Identification and Removal of No-Rain Clouds from Satellite Infrared Imagery. *J. Appl. Meteor*., **38**, 1170-1181.

Table 1. Percent of Z values <17dBZ from GR. Florida values (*italic*) were included for comparison.

Height	Distance					
	43	60	72	100	118	60-100
1.5	*50.4*		*67.6*		*63.3*	
2.0		17.2w 68.7s		22.7w 68.7s		27.2w 53.2s
3.0	*48.4*		*40.4*		*61.4*	
4.0		20.5w 64.9s		26.2w 58.5s		30.6w 51.0s

Height and distance are in km; w=winter, s=summer

Table 2. Vertical radar characteristics of storms during intense electrical activity for events with GR echo tops >15 km. GR reflectivity at the PR top height is tabulated.

Event	PR (top)	GR (Z)
97/12/13	14.5 km	20 dBZ
98/01/07	14.2 km	10 dBZ
98/10/26	13.5 km	15 dBZ
98/12/14	13.2 km	15 dBZ
98/12/22	12.0 km	10 dBZ
99/01/13	13.2 km	22 dBZ
99/01/26	15.0 km	22 dBZ
99/02/20	12.0 km	12 dBZ

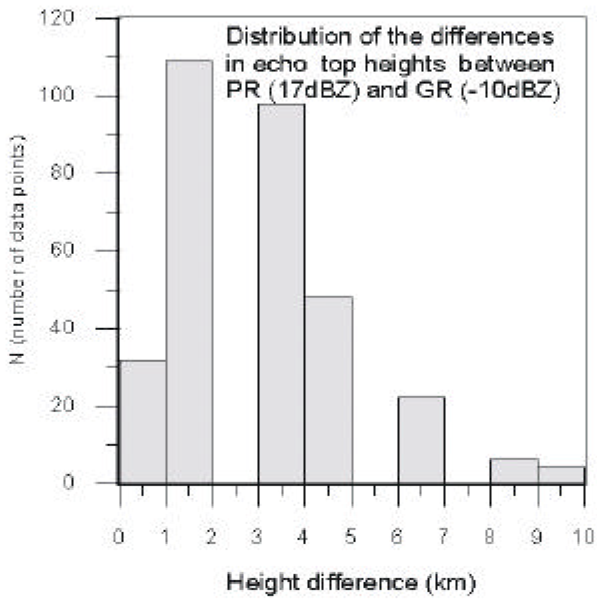

Fig. 1. Differences in echo top heights between 17dBZ (PR equivalent threshold) and -10 dBZ (GR) for 33 cases.

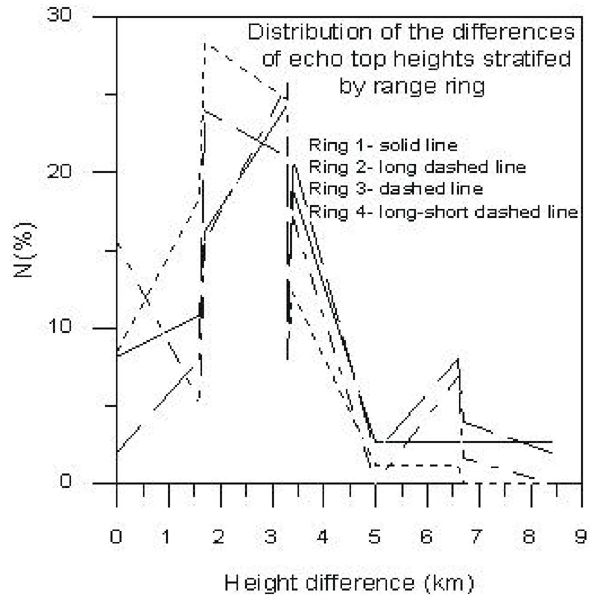

Fig. 2. Distribution of differences of echo top heights in Fig1., stratifield by range rings (33 cases).

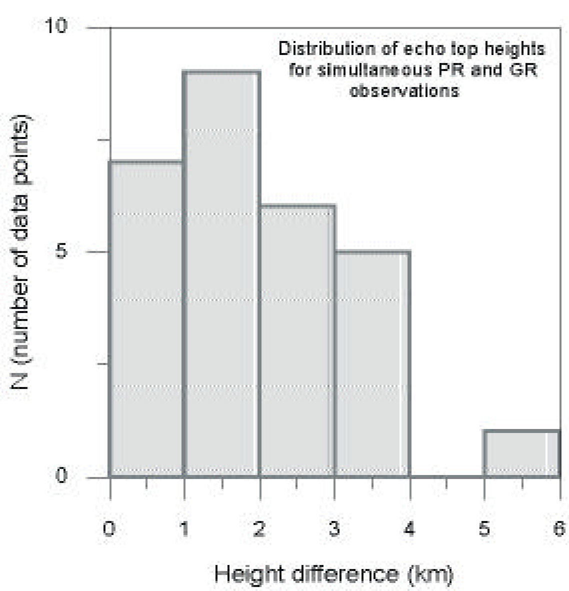

Fig. 3. Distribution in echo top heights for simultaneous PR and GR observations, for echo tops below 15 km as indicated by GR (12 cases).

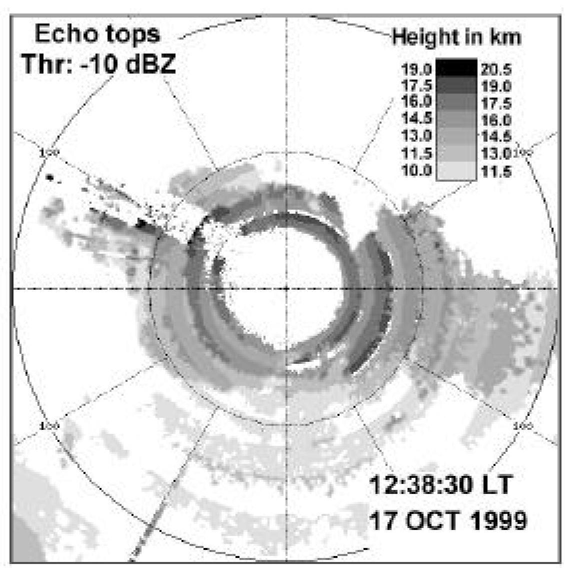

Fig. 4. Echo top heights from Bauru GR using a -10 dBZ threshold, for a severe storm with rainfall.