SQUALL LINE TRANSFORMATION FROM ASYMMETRIC-TYPE TO SYMMETRIC-TYPE

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1. INTRODUCTION

In this study, we present the results from the analysis of 8 Squall Lines (SL) with triangular Stratiform Region (SR) using a Relative Coordinate System (RCS), moving with a passive translation velocity. In this work we use the local time.

2. METHODOLOGY AND DATA

The experimental support to analyse the Mesoscale Convective System (MCS) that occurred over the São Paulo State (Brazil) was the digitized reflectivity images (dBZ) obtained by the S-band Doppler radar located at Bauru (Lat: 22^{0} 21' 28" S, Lon: 49^{0} 01' 36" W). In this study we used the PPI images with an angle of 1.7 degrees in elevation, and a resolution of 1 km X 1 degree in azimuth and maximum range of 240 km from the radar. The analysis of the MCS which occurred over the Rio Grande do Sul State (Brazil) was based on the PPI images obtained by the S-band radar located at Pelotas city (Lat: 31° 42' S, Lon: 52° 23' W) with a range of 240 km and 480 km from the radar. The analysis of the MCS that occurred over the Paraná State (Brazil) was based on the PPI images of the SIMEPAR's ("Sistema Meteorológico do Paraná") radar that are available on the following site *(http://www.simepar.br/tempo/radar/index.html).* The analysis of the SLs' evolution was made in a RCS using the methodology developed by Starostin *et.al* (1983) and Starostin (1995). This methodology allows the elimination of the passive translation and the observation of the MCS's pure evolution. The radar echo accumulation, in the RCS, was made by using a software developed by the authors.

3. MESOSCALE CONVECTIVE SYSTEMS OCCURRED ON 05/05/1993 AND 24/11/2000

3.1 Detailed description of the convective lines

The evolution of the linear MCS that occurred over the São Paulo State on 05 May 1993 was apresented as the evolution of three SLs and (Figure 1). The every SL had its own SR. The SL 3 approached the SL 2 due to its greater displacement of velocity. At 15:16h (Fig. 1c), these two SLs linked and, from this moment, the rapid dissipation of one part of the SR of the SL 3 began. The area, marked by the letter A, shows the region where this dissipation took place (Figure 1d). During few hours, until 15:16h (Fig.1), the SR of the SL 1 kept its triangular shape and could be considered as an asymmetric-type SL.

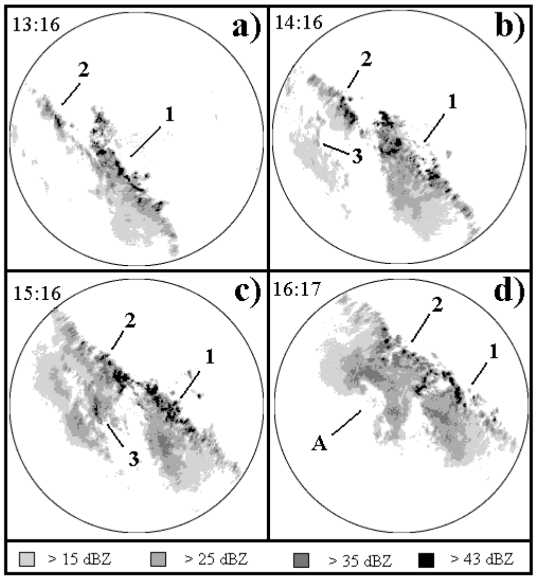

Figure 1. Sequence of PPI radar images of MCS occurred over São Paulo State (Brazil) on 05 May 1993. The numbers indicate the squall lines 1, 2 and 3. The letters A indicates the free radar echoes region.

However, after 15:16h, the SR of this SL lost its triangular shape and, at 16:17h, the SL *1* could be considered as a symmetric-type SL (Fig. 1d). That is one transformation of the SL from one type to the other occurred.

The matter of this study is to understand the nature of this phenomenon. The Figure 2a shows the SL 1, at 14:46h, with the triangular shape SR. The accumulation, in the RCS, of all radar echoes with Z> 40 dBZ, from 11:01 to 14:46h, is shown on the Figure 2c. It is interesting to note that the area occupied by the radar echoes, in this Figure, has also a triangular shape. The Figures 2b and 2d are presented the radar echoes of

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the Figures 2a and 2c in gray and in black color, respectively (the cross, in Figure 2d, indicates the position of radar at 14:46h). Figure 2f presents the result of the superposition of Figures 2b and 2d. The coincidence of the areas occupied by the radar echoes is incredible, once the images from Figures 2b and 2d have different natures. The image of this SL accompanied by its SR on Figure 2b

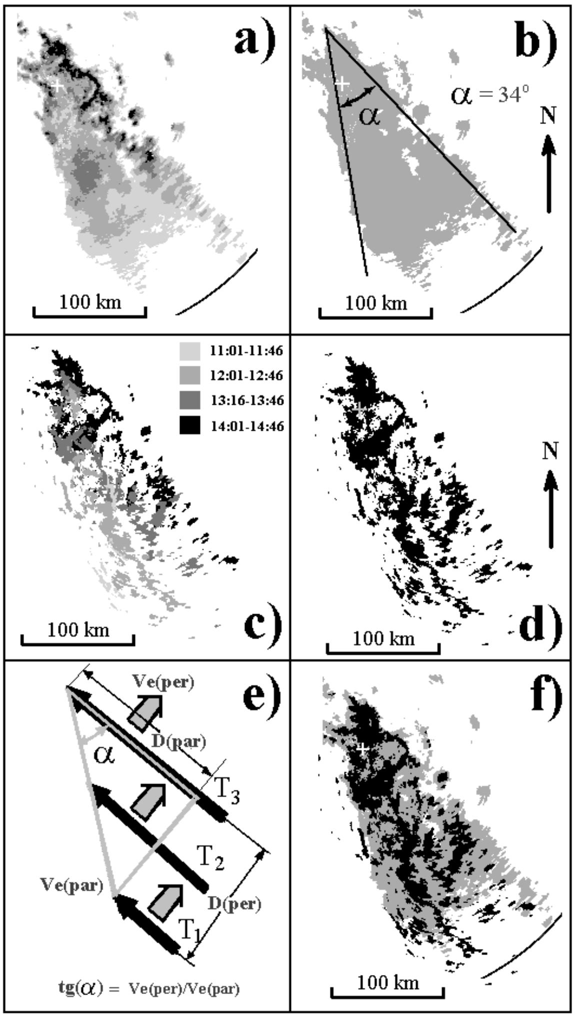

Figure 2. Mesoscale Convective System occurred over São Paulo State (Brazil) on 05 May 1993. (a) and (b) PPI image of the convective line 1 at 14:46h; (c) and (d) accumulation of radar echoes radar with Z>40 dBZ, in the RCS, between 11:01 and 14:46h; (f) superposition of images 2b and 2d; (e) scheme of the triangular stratiform region's development. In the Figura 2c the successive time intervals of radar ecoes acumulation were presented by different colors.

is instantaneous, at 14:46h, while the image in Figure 2d was obtained by the accumulation, in RCS, of all echoes radar with Z> 40 dBZ, during almost 4 hours. It means that the SR is the area where, during few hours, deep convection took place, namely, the SR is the memory about the passed evolution of the SL.

The evolution's type of this SL that occurred over the Paraná State (Brazil) on 24 November 2000 is very rare, because besides the perpendicular evolution of this SL, was observed an evolution in both sides (right and left) at the same time, namely, to the South and to the North. As a result, this SL showed a SR with a triangular shape in both sides (in Table 1 this SL is presented as two cases). The Figure 3 shows the superposition (in a manner described earlier, see Figure 2) of the instantaneous images of the SL, at 17:00 and at 17:45,

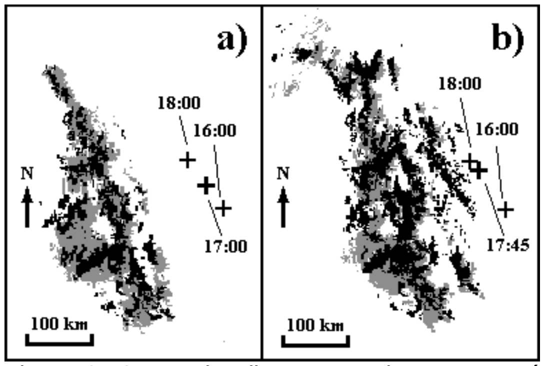

Figure 3. Convective line occurred over Paraná State (Brazil) on 24 November 2000. (a) superposition of the PPI image (gray areas) at 17:00h and accumulated image (black areas) of radar echoes with Z>40 dBZ between 14:30 and 17:00h; (b) superposition of PPI image (gray areas) at 17:45h and accumulated image (black areas) of echoes radar with Z>40 dBZ between 15:30 and 17:45h. The crosses were presented the radar positions in RCS.

(in gray color) and the accumulation of the radar echoes with Z> 40 dBZ (in black color) in the RCS for two periods: between 14:30 and 17:00h (Fig. 3a) and between 15:30 and 17:45h (Fig. 3b). The coincidence of these images is very good, as it was observed in the case on 05 May 1993 (Figure 2).

3.2. Interpretation of the convective line evolution

Due to the evolution of the SL in two directions (parallel and perpendicular to its orientation), the area of the deep convection development, in the RCS, takes triangular shape (in Figure 2e this area is indicated by the triangle). As we can see from the scheme showed in Figure 2e, the angle α of triangular SR depends only of the evolution velocity values in the parallel direction to the SL (Ve(par)) and the evolution velocity in the perpendicular direction (Ve(per)) to its orientation. Actually, during the time interval $\Delta T = T_3 - T_1$, the SL will move, in the RCS, along its axis in a distance D(par)=Ve(par)*ΔT and, at the same time, in the perpendicular sense to its orientation D(per)=Ve(per)*ΔT. Evidently, tg(α) = D(per)/D(par), that is,

$$\mathbf{tg(\alpha) = Ve(per)/Ve(par)} \qquad \mathbf{(1)}$$

The value of the angle α does not depend on the value of the passive translation velocity and can be considered as an evolution characteristic of the SL. We can say that the SR preserves the information about the passed evolution of the SL.

In the case of the SL, shown on Figures 1 and 2, during the period of three hours, between 11:46 and 14:46h, Ve(per) was equal to 27 km/h and Ve(par) was equal to 52 km/h. Therefore, the calculated angle of the triangular region (α_{cal}) must be equal to α_{cal} = arctg[Ve(per)/Ve(par)]= 28°. The actual angle of the SR of this SL, at 14:46h, was equal to 34° (Fig. 2b). It is a good agreement between the calculated angle and the observed one.

The shape of the SR depends on the relation between Ve(per) and Ve(par). If Ve(per) is greater than Ve(par), the angle α will be greater than 45°. It means that, in this case, the SL will correspond to the symmetric-type. On the contrary, if Ve(per) is smaller than Ve(par), the angle α will be smaller than 45°. In this case, the triangular SR will appear, corresponding to the asymmetric-type SL. This result means that the occurrence of the concrete type (symmetric or asymmetric) will depend on the relation between Ve(per) and Ve(par). It explains the formation of asymmetric and symmetric-types (Houze, 1993) of SLs accompanied by a wide SR. Therefore, if the relation between Ve(per) and Ve(par) changes during the SL's life time, than the transformation from one type to the other occurs.

One transformation from the asymmetric-type to the symmetric-type happened with the SL 1 of the MCS that occurred on 05 May 1993 (Fig. 1). In one of the two SLs occurred on 11 January 1996 (see Table 1), a reduction of the parallel component of the evolution velocity Ve(par), from 80 km/h to 18 km/h, occurred. As a result, the observed angle α changed from 25° to 55°. The calculated angle α (in according to the equation 1) changed from 22° to 63°, respectively. On Table 1, this SL is presented as two cases.

4. OTHERS CONVECTIVE LINES WITH TRIANGULAR STRATIFORM REGION

The 8 SLs with the presence of a triangular SR were analysed. Some characteristics of these SL are presented on Table 1. The mean duration of the triangular SR was 2,3 ± 0,5 hours. The perpendicular Ve(per) and parallel Ve(par) component values of the evolution velocity of the SL changed from 16 to 46 km/h and from 18 to 80 km/h, respectively. The mean values of these components were Ve(per)=28,5±9,5 km/h and Ve(par)=55,4±18,6 km/h. The agreement between the measured angles α (observed on the radar images) of the triangular SR and the calculated angles α_{cal} (in according to the equation 1) was very good.

5. CONCLUSIONS

In this study, we showed the results from the analysis of 8 MCS that presented SLs with triangular SR. It was showed that the SR constituted the area where, during few hours, deep convective clouds had developed, i.e. the SR was the "memory" about the passed evolution of the SL. The shape of the SR depends on the relation between the perpendicular component Ve(per) and the parallel component Ve(par) of the evolution velocity of the SL. If Ve(per) is greater than Ve(par), the SL will correspond to the symmetric-type. On the contrary, if Ve(per) is smaller than Ve(par), the SR will present a triangular shape, corresponding to the asymmetric-type SL. Therefore, if the relation between Ve(per) and Ve(par) changes during the life time of the MCS, we will observe the transformation of the SL from one type to another as many times as the relation between these two components changes. The analysis of 8 asymmetric-type SLs showed that the mean values of the parallel component Ve(par) were twice time bigger the perpendicular component Ve(per). The mean duration of the triangular shape of the SR was 2,3 ± 0,5 hours. The agreement between the observed angles of the triangular SR and the calculated angles, in according to the equation (1), was very good.

Table 1. Characteristics of squall lines with the presence of triangular stratiform region (α_c – calculated angle and α_m – measured angle of triangular SR of SL).

Date	Region	Duration (hours)	Ve(per) (km/h)	Ve(par) (km/h)	α_c (°)	α_m (°)	Notes
05.05.93	SP	3	27	52	28	34	
27.11.95	RS	2,3	39	44	40	40	
11.01.96	RS	3	46	69	34	35	1st SL
11.01.96	RS	1,4	21	80	22	25	1st interval of the 2nd SL
11.01.96	RS	2	36	18	63	55	2nd interval of the 2nd SL
08.02.96	RS	2,5	20	40	27	25	
13.03.96	RS	2,2	16	48	18	22	
26.03.96	RS	1,5	21	63	18	21	
24.11.00	PR	2,5	30	68	24	30	South area
24.11.00	PR	2,25	29	72	20	25	North area

6. REFERENCES

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