NOAA Technical Memorandum ERL OWRM-15

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RADAR ECHO POPULATIONS IN THE PROPOSED CDMP EXPERIMENTAL AREA

Jeffrey H. Morris
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Office of Weather Research and Modification
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RADAR ECHO POPULATIONS IN THE PROPOSED CDMP EXPERIMENTAL AREA

Jeffrey H. Morris and Ronald L. Holle

The Miami WSR-57 radar was used to study characteristics of echoes that formed inside the experimental area in south Florida proposed for the Cumulus Dynamics and Microphysics Program (CDMP). A variety of characteristics of echoes at level 2 or greater was determined for the planned program period between June 15 and August 15 with radar film from 1973, 1975 and 1980. Nearly every day had at least one echo that formed in this area; the average was 8.8 echoes per day. Most echoes reached only level 2 and formed during the afternoon. Maximum area of unmerged echoes (at level 2) ranged from an average of 41 km^2 for level 2 to 572 km^2 for level 5 echoes. The duration of unmerged echoes (at level 2) ranged from an average of 31 min for level 2 to 112 min for level 5 echoes. About one-third of the echoes merged and lasted from an average of 140 min for level 2 to 163 min for level 5. They typically merged with larger echoes inside the area. If seeding were performed during the project, and a change in treatment decision were allowed within a day on clouds that formed in the area 60 min after a previous cloud reached maturity on radar, about half the days could have at least one change in treatment. For a 30-min period between clouds most days could have one or more reverse decisions.

1. INTRODUCTION

Characteristics of radar echoes have been compiled for a mesoscale area of south Florida that has been proposed for a field program of the Cumulus Dynamics and Microphysics Program (CDMP). This study should contribute (1) to making advance decisions concerning the types of meteorological studies that are appropriate for this region, as well as (2) to making operation plans for the optimal deployment of instrumentation to study the convection during the field programs. The results of this report will consist of the distributions of size, duration, and intensity of unmerged and merged echoes, and other features of echoes forming in this area. A large amount of research has already been performed on various topics using echo data in south Florida, most recently by Lopez et al. (1981) and Wiggert et al. (1981). Recent papers on other convective cloud research in south Florida, such as seeding by Woodley et al. (1982), cloud physics by Lamb et al. (1981), mesoscale interactions by Holle and Maier (1980), and satellite rainfall estimation by Griffith et al. (1978) also make reference to the large number of earlier studies on these topics using data from the Florida Area Cumulus Experiment (FACE). The present memorandum has been prepared to provide radar statistics for the same time of year and location as the proposed CDMP program. It should be noted that no important difference was found in 5-, 10- and 15-day frequencies between echo formation early in the summer compared with later in the period of interest from June 15 to August 15, either for all echoes together or when days with high echo formation frequency were examined.

2. DATA

The echo data were obtained from the National Hurricane Center's Miami WSR-57 radar for a rectangular 3300-km^2 area south of Lake Okeechobee, located between 75 and 160 km northwest of the radar. In this area, networks of surface, Doppler radar and upper-air stations have been proposed for a future CDMP program (Fig. 1). The project has been planned to operate between June 15 and August 15; data for the study were collected only during this period. Radar echoes were examined for 3 years (1973, 1975, and 1980) so that some of the year-to-year variability could be shown.

To qualify for this study, radar echoes must have (a) formed in the area, (b) attained at least level 2 (29 dBz) in the area, (c) maintained level 2 for at least 5 min, (d) formed unattached from larger echo systems and remain unattached for at least 5 min, and (e) formed between 0800 and 2000 EDT. The 16-mm (1980) or 35-mm (1973 and 1975) radar microfilm, consisting of contoured photographs every 5 min, was used for the study. The 1980 film on 16 mm was more difficult to use for detection of levels. Data were recorded for each echo on the form shown in Table 1. Times, areas, intensities, and merger status were compiled for each echo, and these statistics are the basis of the results to be reported. Merger (part B of the form) in this study consisted

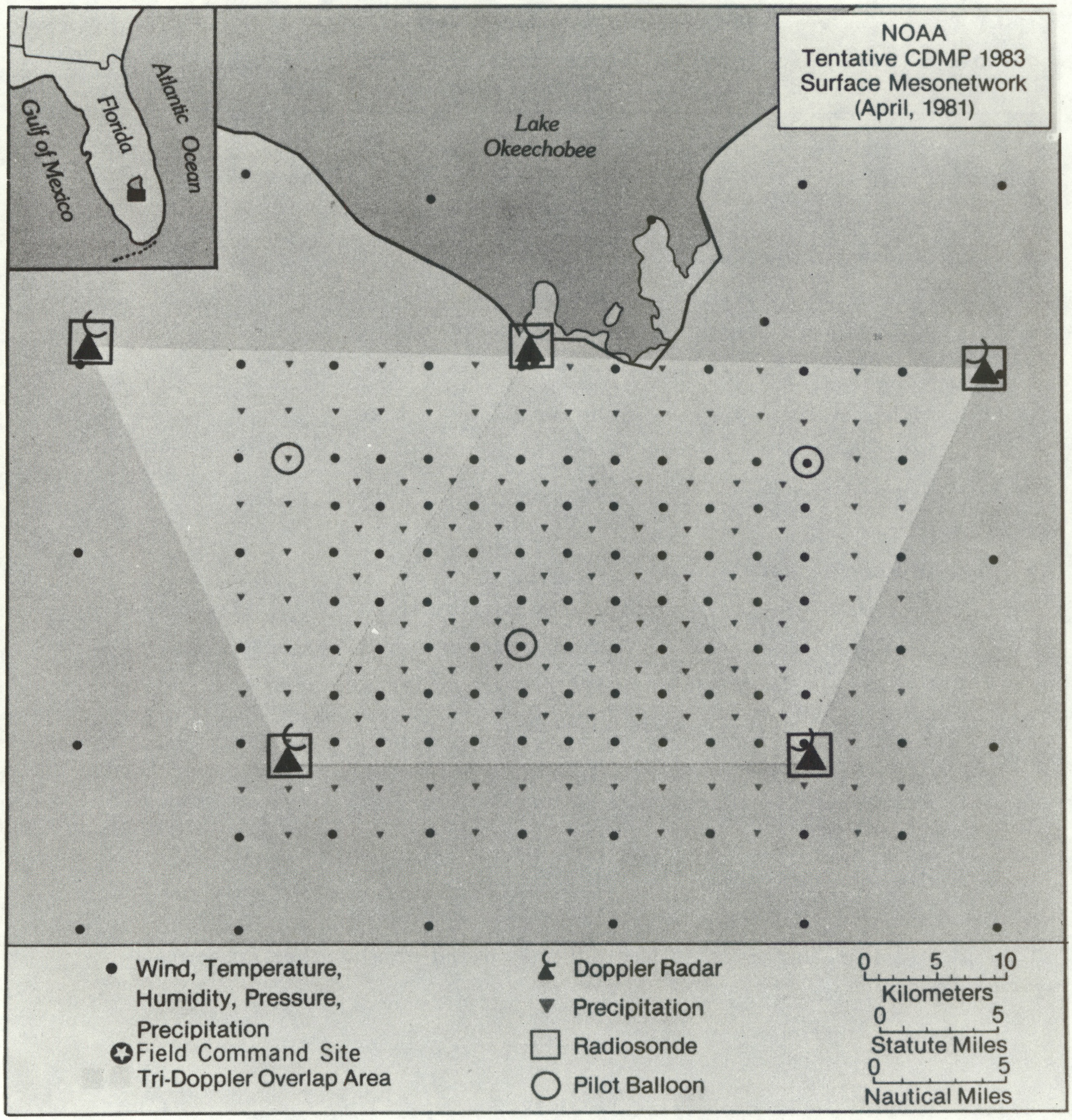

Figure 1. Proposed CDMP mesonetwork where echo study was performed. Inset shows area of south Florida south of Lake Okeechobee in which deployment of a 3300-km^2 network of meteorological, radar, and upper-air stations has been proposed.

Table 1. Form used to record characteristics of each new echo that formed in the proposed CDMP experimental area.

Film roll number ___________ Date _________________ Echo number ___________

A. 1. Quadrant in network _________

2. Time of declaration of echo formation _______

3. Direction of echo ______

4. Did echo leave network? _______

5. If so, maximum area out of network ______ time _______

6. Maximum area in network _______ time _______

7. Maximum contour ______ time _______

B. 1. Did merger occur at level 2? _______

2. At time of merger, was this echo smaller than ______, larger than ____, or same size _________ as echo with which it merged?

3. Was merger in or out of area? _______

4. Time when merger dropped below level 2 _________

C. 1. Did an echo form less than 20 nmi upwind of all previous echoes? _____

2. How many? _______

3. How far from other echoes? _______

D. 1. Did an echo form more than 20 nmi upwind of all other echoes? ________

2. How many? _______

3. How far from other echoes? _______

E. 1. When did echo drop below level 2? ________

2. When did echo move out of area? _________

---

of two echoes previously separate at level 2 becoming merged at level 2 or above. Statistics of merged echoes are shown in chapter 5. Unmerged echoes were usually smaller and were shorter lived than merged echoes, and for this reason, the results will be shown separately in chapter 4. In parts C and D of this form, data were recorded in an attempt to assess the possibility of changing the seed decision within a day if clouds were sufficiently separated in time and space; results are shown in chapter 6.

3. GENERAL RESULTS

a. Days with Echoes

The daily statistics for new echoes forming in the 3300-km^2 area (Fig. 1) are given by Table 2 for individual years and all years combined. A total of 155 days of radar data were analyzed over the 3 years,

Table 2. Daily statistics for new echoes that formed at level 2 or greater in the proposed CDMP study area.

	1973	1975	1980	All years
Days in sample	41	52	62	155
Days with echoes	39	45	57	141
Maximum no. consecutive days with echoes	16	16	45	45
Maximum no. consecutive days without echoes	1	2	2	2
Maximum no. of echoes on one day	19	26	34	34

and new echoes of level 2 or above formed on 90% of the days. In 1980, there was one stretch of 45 consecutive days with at least one echo forming in the area; the most consecutive days in a row without new echoes was only 2 days. The last line shows that as many as 34 new echoes formed on one day. In summary, at least one level-2 echo formed in the area on almost every day during the three summers.

b. Number of echoes

The number of echoes that formed in the area is summarized in Table 3. The average number of echoes per day varied from 7 in 1973 to nearly 12 in 1980, and averaged 8.8 for all 3 years. The median is 8 echoes per day, and the mode is zero. When this rate is applied to a 62-day experiment, and the days with missing radar film in 1973 and 1975 are assumed to have the same rate of echoes per day as the days with data,

Table 3. Number of echoes that formed at level 2 or above in the proposed CDMP experimental area.

	1973	1975	1980	All years
Number of echoes	287	336	736	1359
Number of days	41	52	62	155
Average number of echoes per day	7.0	6.5	11.9	8.8
Number of echoes per 62-day experiment	434	401	736	544

the prorated numbers on the bottom line of Table 3 apply. That is, from 401 to 736 echoes--level 2 or above--formed in this proposed area during the period from June 15 to August 15; this represents a large sample of echoes for study.

The distribution of these echoes on a daily basis is shown in Table 4. There were 14 days when no echoes formed in the proposed CDMP area, 12 days when one echo formed, etc. Quite a few days had up to 12 echoes form in the area; the frequency lowers rapidly after that number.

Table 4. Number of days with echoes over all 3 years of data collection.

Echoes	Days	Echoes	Days	Echoes	Days
0	14	12	9	24	0
1	12	13	2	25	1
2	5	14	3	26	2
3	11	15	3	27	1
4	9	16	4	28	1
5	6	17	1	29	2
6	10	18	4	30	0
7	9	19	2	31	0
8	11	20	2	32	0
9	7	21	2	33	0
10	10	22	0	34	1
11	9	23	2	35	0

c. Frequency of Unmerged and Merged Echoes

Echo merger status was recorded, as stated in the introduction and shown in the data form (Table 1). If the subject echo merged at level 2 with another echo at level 2 or stronger, this was considered a merger. Table 5 shows various measures of the number and frequency of mergers. For all 3 years, the top three lines indicate that echoes of any type formed on 91% of the 155 days with data, and 75% of the 155 days had at least one merging echo. The next group of four lines indicates about a 2-to-1 ratio for the number of unmerged to merged echoes. The bottom pair of entries shows an average of three merged echoes per day using radar data; there were four merging echoes per day if at least one merger formed. Further distributions of echoes by merger status will be shown in chapters 4 and 5.

Table 5. Merger status according to number of days and echoes.

	1973	1975	1980	All years
Days in sample	41	52	62	155
Days with echoes	95%	87%	92%	91%
Days with mergers	71%	73%	81%	75%
Total number of echoes	287	336	736	1359
Unmerged echoes	170	205	479	854
Merged echoes	113	123	236	472
Merger status indeterminant	4	8	21	33
Merged echoes per sample day	2.8	2.4	3.8	3.0
Merged echoes per day with mergers	3.9	3.2	4.7	4.0

d. Time-of-Day Variations

The distribution of echo formation by time of day is shown in Table 6. Data were collected only between 0800 and 2000 EDT. The peak hour of formation was between 1500 and 1600 EDT. Rather few level-2 echoes formed in the area until 1100 EDT, and the frequency of echoes remains high between 1800 and 1900. Operations during the field experiment, then, should be prepared to start relatively late in the morning and continue late in the afternoon (EDT).

Table 6. Number of echoes that formed in the CDMP area by time of day.

Hour of day (EDT)	1973	1975	1980	All years
08-09	2	0	3	5
09-10	2	0	9	11
10-11	8	9	38	55
11-12	28	45	48	121
12-13	26	31	47	104
13-14	48	45	97	190
14-15	42	49	119	210
15-16	39	60	122	221
16-17	42	25	85	152
17-18	24	34	64	122
18-19	22	18	65	105
19-20	4	20	39	63

4. UNMERGED ECHOES

Table 5 showed the distribution of echoes by merger status; this chapter will describe only the unmerged echoes' statistics. Table 7 shows the maximum area attained by unmerged echoes that formed in the area. The average maximum area (at level 2) of unmerged echoes that attained level 2 was 41 km^2 for all years; the area rapidly increased for those few unmerged echoes that reached levels 4 or 5. The frequency distribution of areas for all unmerged echoes in Fig. 2 shows a dominance of small echoes in the 15- to 44-km^2 category. Most of the unmerged echoes, then, reached level 2 only and were under 44 km^2 in area at their largest.

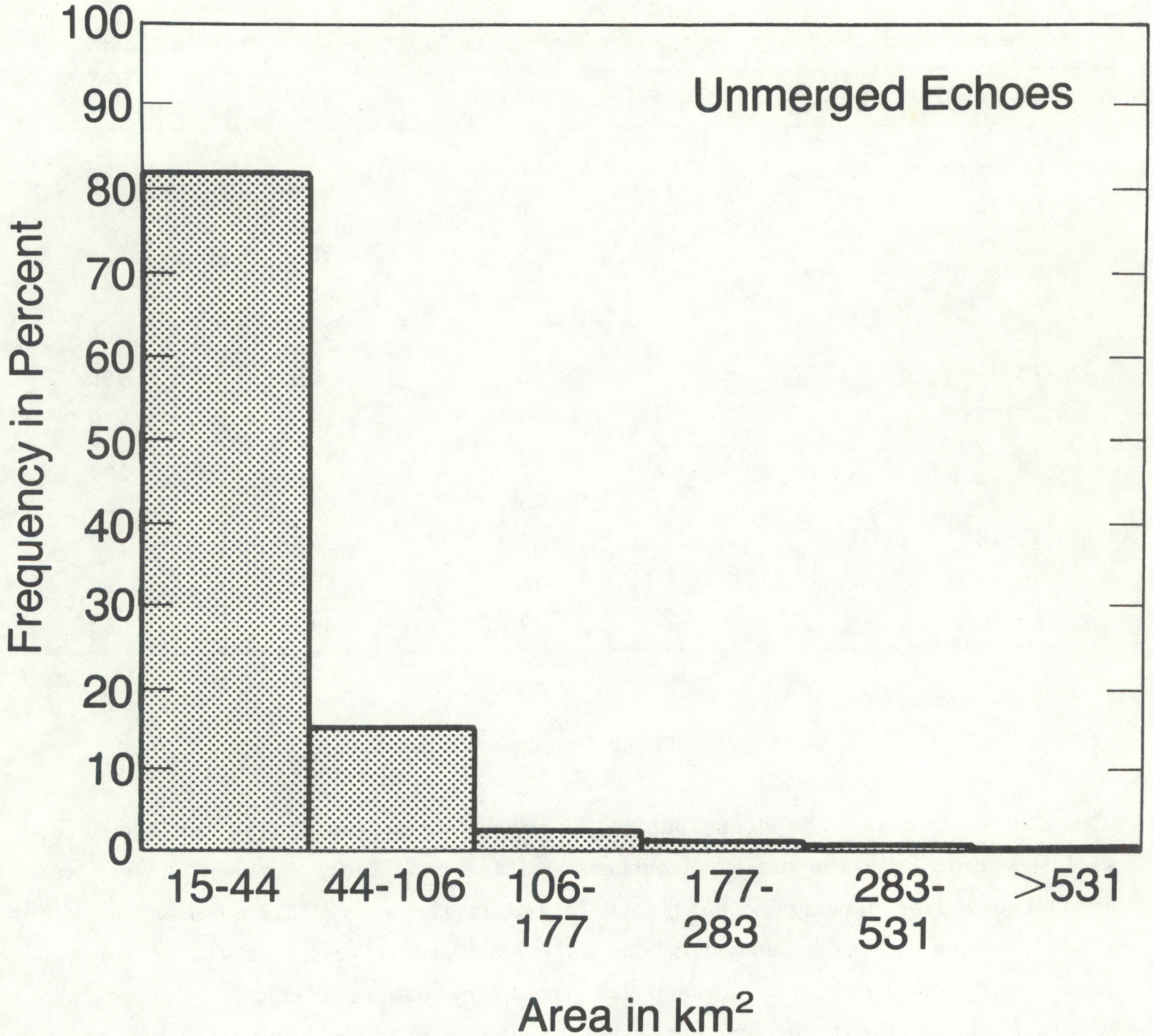

Figure 2. Frequency distribution of the level-2 area (km^2) of unmerged echoes that formed in the proposed CDMP area.

Table 7. Average maximum area (at level 2) of unmerged echoes characterized by maximum radar level attained by echo during its lifetime.

Maximum area	1973	1975	1980	All years
Level-2 echoes	32 km^2	32 km^2	47 km^2	41 km^2
	(150)	(180)	(466)	(796)
Level-3 echoes	138 km^2	115 km^2	128 km^2	128 km^2
	(17)	(14)	(13)	(44)
Level-4 echoes	452 km^2	555 km^2	--	493 km^2
	(3)	(2)	--	(5)
Level-5 echo	--	572 km^2	--	572 km^2
	--	(1)	--	(1)

Notes: The number in parentheses is sample size in each category. In 1975, the areas of eight echoes were indeterminate because of ground clutter. Level 1 = 20 dBz, level 2 = 29 dBz, level 3 = 40 dBz, level 4 = 45 dBz, level 5 = 50 dBz.

Duration of unmerged echoes applies to their existence at level 2 or above. In Table 8, the same 796 unmerged echoes discussed in Table 7 are described. Echoes that formed in the area and never exceeded level 2 averaged 31 min in duration, and the most intense echo (level 5) lasted 112 min. The frequency distribution for the duration of all unmerged echoes in Fig. 3 indicates a broad range up to about 50 min and a few very long lifetimes for echoes that never merged.

Table 8. Duration of unmerged echoes (at level 2) categorized by maximum radar level attained by the echo during its lifetime.

Duration	1973	1975	1980	All years
Level-2 echoes	32 min	32 min	30 min	31 min
	(150)	(180)	(466)	(796)
Level-3 echoes	62 min	57 min	38 min	54 min
	(17)	(14)	(13)	(44)
Level-4 echoes	56 min	64 min	--	59 min
	(3)	(2)	--	(5)
Level-5 echo	--	112 min	--	112 min
	--	(1)	--	(1)

Notes: The number in parentheses is sample size in each category. In 1975, the durations of eight echoes were indeterminate because of ground clutter.

Because of their relatively short duration, these unmerged echoes tended to remain in the area. Table 9 shows that 96% of the unmerged echoes that formed in the area remained in the area, and only 4% moved out of the region before dropping below level 2.

Table 9. Percentage of unmerged echoes that remained in the area compared with those that moved out of the area.

	1973	1975	1980	All years
Stayed in area	94	95	98	96
Moved out of area	6	5	2	4

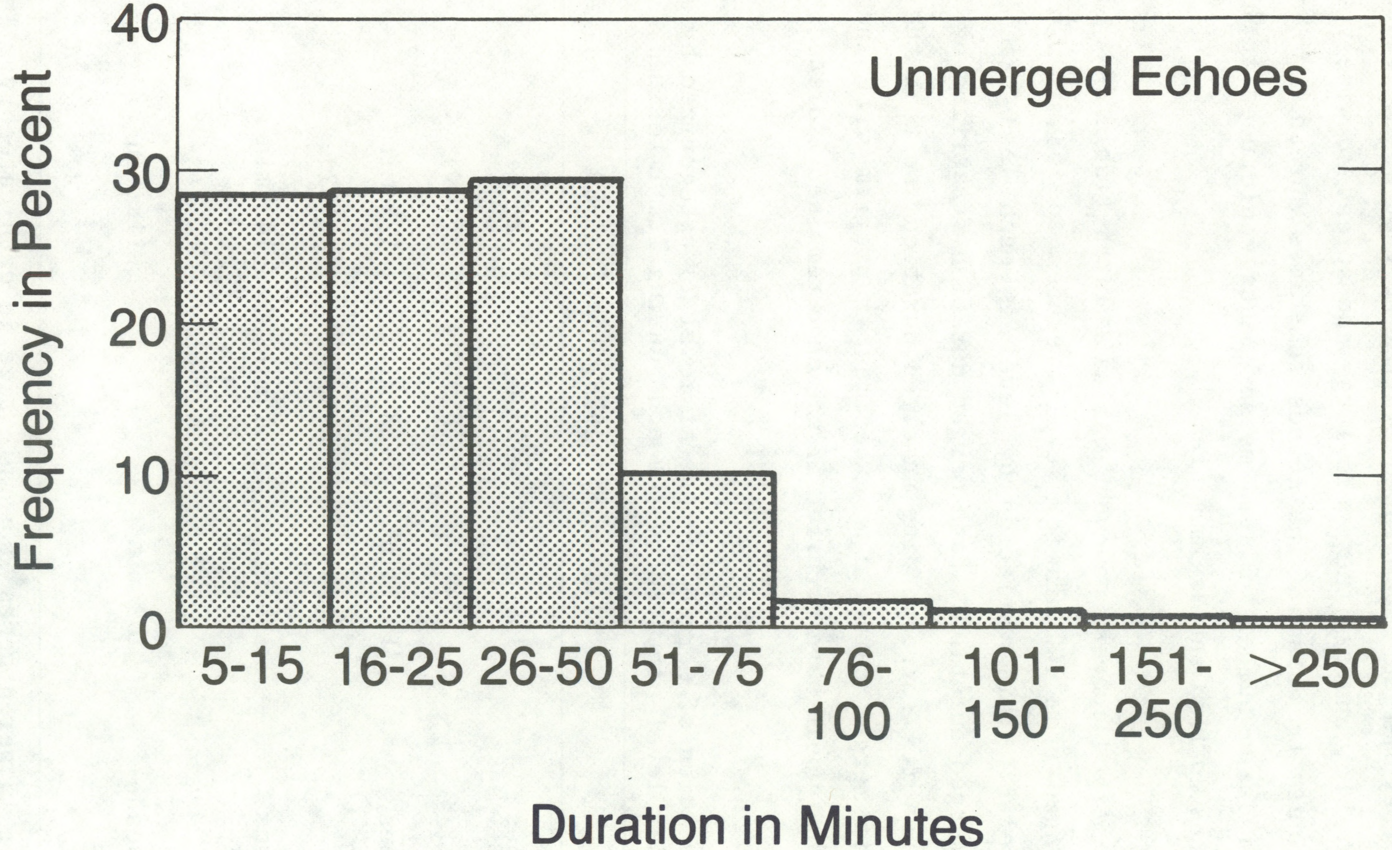

Figure 3. Frequency distribution for duration (min) of unmerged echoes at level 2 that formed in the proposed CDMP area.

5. MERGED ECHOES

The merged echoes in Table 5 have also been studied; however, the maximum area was not measured. This was due to two factors associated with their larger size: (1) they merged with ground clutter so that an individual echo's area was not separable, and (2) they were large and spread so widely that area became very difficult to obtain. The echoes sometimes spread far beyond the study area, and a large number of area measurements would need to have been made every 5 minutes to find the maximum area.

Duration of merged echoes, however, was calculated (Table 10). Durations for all years ranged from 140 min for level-2 echoes to 163 min for echoes that reached level 5. This variation by level is much less than Table 8 indicated for unmerged duration. Each merged duration stratified by level and year is longer than its corresponding unmerged duration, so that the presence of a level-2 echo merger during the experimental program will indicate a longer duration than would have occurred if the echo remained isolated.

Table 10. Duration of merged echoes (at level 2) categorized by maximum radar level attained by the echo during its lifetime.

Duration	1973	1975	1980	All years
Level-2 echoes	159 min	127 min	133 min	140 min
	(49)	(85)	(107)	(241)
Level-3 echoes	153 min	128 min	129 min	137 min
	(29)	(29)	(57)	(115)
Level-4 echoes	130 min	151 min	143 min	142 min
	(7)	(3)	(7)	(17)
Level-5 echoes	209 min	--	116 min	163 min
	(1)	--	(2)	(3)

Notes: The number in parentheses is sample size in each category. The duration of some merged echoes could not be determined because of ground clutter and missing film.

The subject echo must have merged with another echo at level 2 to be considered a merger. Table 11 indicates the size relationship between the two echoes. Most situations consisted of the original echo that formed in the CDMP area joining with a larger neighboring echo. Another 24% of the neighboring echoes were smaller than the original echo, and a few were of the same size.

Table 11. Percentage of echoes that were larger, smaller, or the same size as the original echo before merger. Larger indicates that neighboring echo was larger than subject echo before merger, etc.

	1973	1975	1980	All years
Larger	70	72	66	70
Smaller	25	22	26	24
Same size	5	6	8	6

Since the merging echoes were generally larger and longer lasting, some of the echoes could merge outside the proposed CDMP area. Table 12 shows that most mergers occurred inside the 3300-km^2 area, so observations can be made of a large percentage of mergers using the fixed array of mesonetwork sensors.

Table 12. Percentage of echoes that merged inside and outside the CDMP area.

	1973	1975	1980	All years
Merged inside area	86	91	88	88
Merged outside area	14	9	12	12

6. REVERSE TREATMENT DECISION

Seeding with silver iodide pyrotechnic flares for dynamic effects has been considered as one of the components of the south Florida CDMP field experiment (CDMP Office, 1981). To compare natural and seeded clouds, the question has been raised whether it is advisable to keep the treatment the same for the entire day or to change it.

One approach is to keep the same treatment decision for the entire day. In this situation, silver iodide seeding would be performed on all clouds or on none of the clouds that formed in the CDMP experimental area on that day. On days without seeding, then, all cloud characteristics and evolution would be free from any concern about the effects of seeding on that day. This statement is true if one assumes no effect from seeding on a prior day or days.

The other approach is to change the treatment decision within the day. In this situation, both treated and untreated clouds could be studied in as similar an environment as possible. The moisture and temperature profile in the vertical, stability, winds, synoptic environment, aerosols, etc. would be the same for both seeded and untreated clouds so that comparisons could be made between clouds. Some variations in these factors would likely occur within the same day, but they usually are less than interday changes. The relative values of each approach need to be resolved by extensive additional discussion.

One set of criteria for changing treatment within the same day was advanced in the Program Development Plan (CDMP Office, 1981). An opposite treatment decision could be declared for a new cloud developing in the area if (1) the new cloud is at least 20 nmi (37 km) upwind of the first cloud, and (2) the cloud develops at least 60 min after the last treatment of the first cloud. The second criterion has been applied to past data, but the first was not. It was impossible, with the available radar film, to evaluate relative positions of clouds without a great deal of intercomparison and arbitrary procedures. As a cloud dissipates and finally is not visible on radar, one must track the plume or volume of this cloud. An assumption must be applied that would extrapolate the invisible cloud by such parameters as its prior motion, mean wind, seeding-level wind, etc. In addition, the relative positions of several echoes may need to be tracked simultaneously as a new echo is forming. This is quite difficult to perform with 5-min radar film, and no reasonably short procedure was developed.

The time constraint was applied objectively, however, without regard to spatial relationships between echoes. The time difference between entries A.2 and A.7 of Table 1 was applied. A new echo was declared on line A.2 of this form when it reached level 2 and remained at level 2 at least until the next film frame 5 min later, as described in chapter 2. An echo was assumed to have been no longer eligible for treatment (seeded or natural) when it reached its maximum contour at the time given on line A.7. Although this is not necessarily the time when treatment would have ended, it is probably the best representation of the end of treatment available on the film on the basis of experience from seeding conducted during the Florida Area Cumulus Experiment (FACE). When the cloud reached its maximum intensity on radar, it was frequently reaching or passing its maximum growth stage (Holle and Watson, 1982).

With these assumptions, the time criterion for reverse treatment was investigated with the radar film. Time intervals of both 60 min and 30 min were applied (Table 13). Over the 3 years, there were 67 days that had no period of more than 60 min between the end of treatment, as defined here, and the formation of a new echo in the area. There were 38 such days with no 30-minute period available. These days included a few when only one echo formed and no opposite treatment was possible. In the next line of the table, with the 60-min rule, there were 57 days when one opposite treatment could occur, which is 40% of the days with new echoes forming in the area. A total of 15 days had long enough periods between echoes for two seed decision reversals to occur with the 60-min criterion, and three reversals occurred on two days for the 60-min rule. For the 30-min rule, there were many more days

(27) with two reversals than for the 60-min requirement. There were 18 days with three reversals, using a 30-min interval; some days had enough time between echoes for four or five reversals with the 30-min period.

Two factors would modify these results; both would reduce the number of days for opposite decisions. One, a distance criterion could be applied, and some new echoes may have formed so close to the old echoes that the treatment decision should not be reversed. Two, the procedure followed in Table 13 considered only new echoes that formed in the CDMP area. Other echoes which formed outside the area may move, grow, or propagate into the area, and the time and distance factors for these outside-forming echoes might affect the treatment decision. Nevertheless, Table 13 shows that one or more treatment changes may be allowed on many days when the only consideration is the time interval between cloud dissipation and formation in the area on the same day.

Table 13. Reverse treatment decisions based on time elapsed between dissipation and formation of echoes on the same day. The number of days with each treatment reversal is shown for 60-min and 30-min criteria. Only the days with echoes forming in area are included in table.

Treatment reversals within a day	1973 60 min/30 min	1975 60 min/30 min	1980 60 min/30 min	All years 60 min/30 min
None	21 days/14 days	24/14	22/10	67/38
One	15/17	14/13	28/22	57/52
Two	2/3	7/12	6/12	15/27
Three	1/4	0/6	1/8	2/18
Four	0/1	0/0	0/4	0/5
Five	0/0	0/0	0/1	0/1

7. CONCLUSIONS

New echoes at level 2 or more formed in the proposed 3300-km^2 area south of Lake Okeechobee on 90% of the days studied during 1973, 1975, and 1980. No more than 2 consecutive days ever passed without new echo formation, and as many as 45 days in a row had new echoes in 1980. From 400 to over 700 echoes can be expected to reach level 2 within this area during the period from June 15 to August 15, based on this 3-yr study. An average of 8.8 new echoes per day applied for the entire period. Most new echoes formed between 1100 and 1900 EDT.

Echoes that did not merge at level 2 with other echoes accounted for two-thirds of the total. The unmerged echoes tended to remain at level 2 in most cases and to stay in the study area. The average maximum area for level-2 unmerged echoes was 41 km^2 (at level 2), but it reached 500 km^2 for the strongest echoes. These unmerged echoes averaged 31 min in duration at level 2 when that was their peak intensity, and 112 min at level 2 for the echo that reached level 5. These results show that a very large supply of small, unmerged echoes formed and died within the proposed area during the summer.

All merged-echo categories had longer durations than corresponding unmerged echoes. Area was difficult to measure for mergers because of ground clutter and connection to other echoes beyond the study area; no areas were calculated for merged echoes. Most mergers were with larger echoes than the original return, and most mergers occurred within the study area.

A set of time and distance separation criteria has been proposed to change the echoes' treatment within the same day. The distance criteria were not capable of application without undue effort, and separation from other echoes forming outside the study area was not considered. For new echoes forming inside the area, however, two time separations were considered: those of 60 min and those of 30 min. If 60 min were required from the end of treatment until the next cloud formed to apply reverse treatment, about half the days could have one or more treatment reversals. If only 30 min were required, nearly three-fourths of the days would have reversal in treatment; up to five reversals could occur on the same day for the short interval on the basis of time alone. Further discussion of the question is needed; however, the data show that the potential exists for changes to and from seeding within the same day with the proposed time criteria.

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