DEVELOPMENT AND INTERPRETATION OF A M-33 RADAR CLIMATOLOGY FOR THE TEXAS HIPLEX REGION

LP-93

TEXAS DEPARTMENT OF WATER RESOURCES

TECHNICAL REPORT
MRI 78 FR-1581

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TEXAS DEPARTMENT OF WATER RESOURCES
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SUMMARY

A climatology for the Skywater M-33 weather radar, located at Snyder, Texas, in the Texas HIPLEX region, has been developed and interpreted. The M-33 data along with WSR-57 data from the National Weather Service allowed two length and time scales of echo patterns to be analyzed. The first, and largest, is the meso-α (L = 700 km, T = 15 hrs) and the other is the meso-β (L = 150 km, T = 5 hrs).

Classification of the meso-α patterns revealed that all echoes could be represented by four categories. The first two, Type A and Type B, were nonfrontal in nature, and the last two, Type C and Type D, were associated with synoptic fronts. Each of these four meso-α types were further subclassified in order to detail the unique mesoscale and synoptic features associated with each. Finally, all days classified and their meso-α characteristic are presented in tabular form.

An analysis of the data that resulted from classification of the meso-β echo patterns showed that all systems were either isolated or line organized. These line or isolated meso-β systems were composed of isolated cells without orientation to the wind shear, isolated cells with orientation with respect to the wind shear, cell complexes without internal cell organization, or cell complexes with internal line organization. Meso-β tables depicting the days or events classified and their frequency are presented.

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1. INTRODUCTION

The description of cloud processes, including their development, maturation, and dissipation, is an important part of the Texas HIPLEX program. These in-cloud processes respond to and are modified by their environment. Further, the environment changes as a result of mesoscale circulations which in turn are a result of synoptic scale forces. For example, the confluent wind flow along the boundary between dry tropical air from the southwest and moist tropical air to the south and southeast creates a region favorable for convection just east of the Rocky Mountains (Fankhauser, 1971). The parcels experience buoyant forces and convection develops, both as a result of favorable mesoscale changes in the environmental stability forced by the synoptic scale flow (Lewis et al, 1974). While the actual convection is on a scale still considerably smaller, information at this scale can be inferred by studying these mesoscale circulations associated with the macroscale patterns.

The Skywater radar data collected during the 1976 and 1977 Texas HIPLEX operational seasons in conjunction with WSR-57 radar data obtained from the National Weather Service (NWS) allow both macroscale patterns and mesoscale circulations to be associated with a quantative measure of convective development. The macroscale analysis is termed the meso-α scale.

The meso-α scale has a spatial dimension of about 700 km and spans about 15 hours. Meso-α radar patterns are a composite of many radars and are usually associated with familiar mesosynoptic features such as fronts, troughs, and vorticity centers. The mesoscale circulations are considered to be the meso-β scale.

The meso-β scale has a spatial dimension of about 150 km and time frame of five hours and is considerably smaller than the meso-α scale. The meso-β radar echoes are resolved exclusively by the HIPLEX radar. Radar displays on the meso-β scale resolve squall lines, convective complexes, and isolated cells.

Once a scale has been defined, it is possible to identify the radar echo features associated with it. Takeda and Imai (1976) defined echo clusters and documented their formation and movement. Radar investigations of isolated cell and squall line characteristics have also been accomplished (Fujita, 1963). Both of the above are typical examples for the meso-β scale. After a radar echo feature is documented, then its relation to important mesoscale environmental parameters can be studied. For example, radar echo growth was shown to be related to atmospheric stability (Clark, 1960). Vertical shear of the horizontal wind was seen to be important in organizing and maintaining convective storms (Fankhauser, 1971). When a large amount of radar data is available the relationships between radar echoes and mesoscale variables can be determined statistically (Byers and Braham, 1949, Rhea, 1966).

In this report all radar data available from the Texas HIPLEX program were classified on both the meso-α and meso-β scales. A radar echo climatology was generated for each scale using the classifications as a basis for analysis. Statistical relationships between echo groups and mesoscale variables are presented. Finally, recommendations are made for future work concerning both mesoscale systems and radar echo displays.

2. METHODOLOGY

2.1 Meso-α Echo Classification

Of foremost importance in the approach to classification of both meso-α and meso-β echo patterns is complete objectivity in the screening of each system. National Weather Service (NWS) radar summary displays were examined for each hour for each day during the periods of 1 June to 17 July 1976 and 1 June and 10 July 1977. During this meso-α examination no reference was made to any other information or analyses, such as synoptic maps or satellite displays. While the NWS radar summaries are subjective to some extent in outlining of the echo area, it is felt that the large scale echo features are adequately represented. Also since considerable data was missing from the 1976 Snyder radar, the NWS analysis proved to be the only radar data routinely available for that year. Each day, 1000 CDT to 1000 CDT, was cataloged as either:

1. An event day where radar echoes persisted for at least one hour and were within 140 km radially from Snyder, Texas.

2. A vicinity day where radar echoes were outside the Snyder radar coverage but within 280 km radially from Snyder.

3. A no-echo day where no echoes were observed within 280 km of Snyder.

A plastic overlay was constructed and used as a guide for classification when placed over the NWS output. This insured complete objectivity and eliminated bias by the observer. In addition, radar echoes must have persisted for at least one hour to be classified. Operationally this was accomplished by requiring that echoes be observed on two consecutive radar summary displays.

A total of 86 days were finally cataloged with; 54 days classified as event days (62.8 percent), 21 days classified as vicinity days (24.4 percent), and 11 days classified as no-echo days (12.8 percent). The radar echo patterns for each event and vicinity day were then classified according to; area and time of echo formation, subsequent growth and development, line orientation and movement, cell movement, and time of echo dissipation. Analysis of these data tabulations indicated four major echo systems could be identified. Synoptic conditions common to each type of echo system were then examined. Synoptic features surveyed at each level include:

Surface -	Pressure patterns, temperatures, dew points, wind flow, and frontal locations
850 mb -	Pressure patterns, temperatures, dew points, and wind flow
500 mb -	Same as 850 mb but including vorticity

Significant and consistent synoptic patterns that were unique to each type of echo system were found. These patterns as well as a detailing of each classification are discussed in later sections of this report.

2.2 Meso-β Echo Classification

All event and vicinity days, where Snyder radar was available, during the periods of 1 June 1976 to 17 July 1976 and 1 June 1977 to 10 July 1977, were examined and classified for meso-β echo patterns. To insure complete objectivity and eliminate bias no reference was made to any other information such as NWS radar summaries, synoptic maps, satellite displays, or previous meso-α classification. As an initial classification each Snyder PPI hardcopy display was characterized as containing either a mesoscale isolated system (Type I) or a mesoscale line system (Type L). These displays were for a 1.5° antenna elevation angle with a minimum contour of 25 dbz at 10 dbz increments. After examining a few days it became apparent that both isolated and line systems occurred on the same day with enough frequency to justify further subclassification. A mesoscale event was defined as an occurrence of either an isolated system or a line system. A mesoscale day was classified by the dominant mesoscale event. A mesoscale day, as in the meso-α classification, was from 1000 CDT to 1000 CDT inclusive.

A total of 13 days were finally cataloged with; 6 days classified as mesoscale isolated systems (46 percent) and 7 days classified as mesoscale line systems (54 percent). A total of 19 events could be identified with; 10 events classified as mesoscale isolated systems (52.6 percent) and 9 events classified as mesoscale line systems (47.4 percent). The I or L letter designation is called the <u>mesoscale character</u> for each day or event. Each mesoscale day and event were subclassified according to <u>echo character</u> as shown below.

Echo Character	Description
1	Isolated cells without orientation
2	Isolated cells with orientation
3	Cell complex without internal line organization
4	Cell complex with internal line organization

Important relationships between wind shear, static stability, and echo orientation and organization resulted from the analysis of the classification results. These relationships are discussed in the later sections of this report.

3. MESO-α ECHO CLASSIFICATION

An in-depth analysis of the data that resulted from the itemization and organization reviewed in the methodology section revealed that all echo systems observed in the 1976 and 1977 Texas HIPLEX operational seasons could be represented by four major categories. These categories are Type A, Type B, Type C, and Type D and are described in detail in the text that follows. After identifying in which category an echo system could be associated, further subclassification was made depending on duration and intensity of convection, upper air wind flow regimes, and system orientation with respect to synoptic environmental features. The first two categories, Type A and Type B, are not associated with frontal systems and rely on surface heating or mesoscale dynamics as the convective trigger mechanism. The latter two categories are associated with frontal activity and differ only in frontal orientation and its subsequent effects. Table 1 outlines the meso-α types that will be discussed.

3.1 Echo System Type A

The Type A echo classification is the most common and recurring echo system in the Texas HIPLEX region and will be discussed in the greatest detail. During the 1976 and 1977 operational seasons 48 percent of the echo events were Type A. This type is characterized by initial formation of radar echoes on the lee side of the Rocky Mountains and/or Sierra Madre Orientals near 1200 CDT. Both echo number and echo intensity increase rapidly along the eastern slopes and form a line oriented north-south along the Texas-New Mexico border with activity often extending northward into Colorado. Echoes develop as a result of the release of convective instability generated aloft by the juxtaposition of hot dry desert air to the west and southwest over the warm moist air from the Gulf of Mexico to the east and southeast. Initial vertical parcel accelerations are provided by rapid surface temperature increases as a result of intense heating.

By about 1530 CDT the line continues to widen and intensify with new echoes being generated over the Texas Panhandle. Peak intensities and maximum areal coverage is observed by about 2030 CDT. The line begins moving eastward with the northern extremity moving slightly faster than the southern end. This differential movement slowly results in an orientation more northeast-southwestward than was evident earlier. The line usually enters the HIPLEX region between 1800 CDT and 0000 CDT depending on when the line developed and how fast it moved. Figure 1 shows the radar echo history for 2-3 June 1976, a Type A example.

Table 1

SUMMARY OF MESO-α RADAR TYPES

TYPE A - Radar echoes not associated with a front
- A_1 - Diurnal in duration
  - A_1N - Northerly flow at 500 mb
  - A_1S - Southerly flow at 500 mb
- A_2 - Persist in next day
  - A_2N - Northerly flow at 500 mb
  - A_2S - Southerly flow at 500 mb

TYPE B - Radar echoes not associated with a front but with large scale moisture advection
- B_1 - Southeasterly flow up to 500 mb
- B_2 - Southerly flow up to 500 mb
- B_3 - Southwesterly flow up to 500 mb

TYPE C - Radar echoes associated with an west to east front
- C_1 - Prefrontal activity
- C_2 - Frontolytic or stationary activity
- C_3 - Post-frontal activity

TYPE D - Radar echoes associated with southwest to northeast front
- D_1 - Pre-frontal activity
- D_2 - Frontolytic or stationary activity
- D_3 - Post-frontal activity

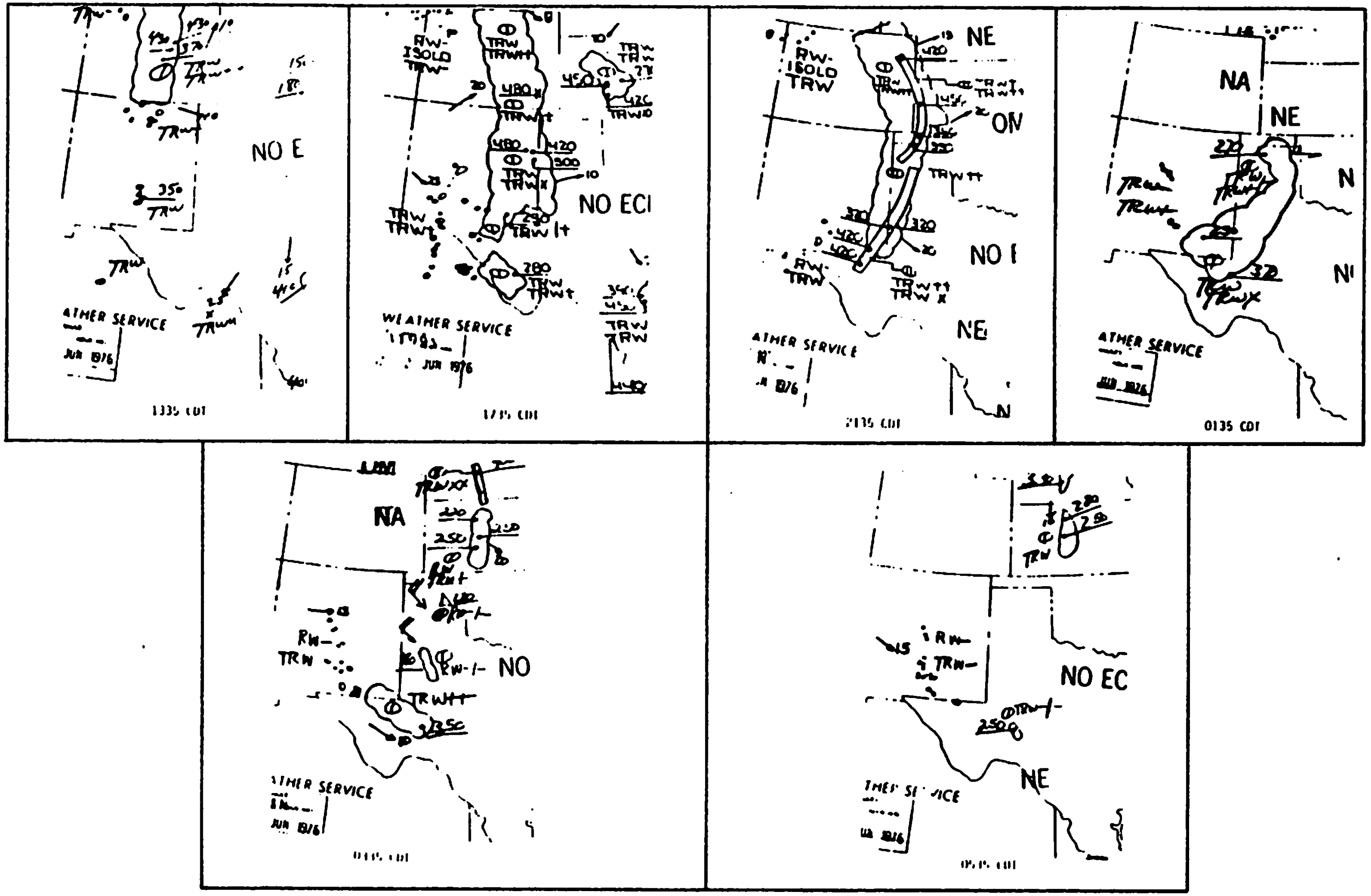


Fig. 1. Echo system Type A - June 2-3, 1976

Two different types of echo/line dissipation in the Type A category facilitate a further subclassification. In most cases the line becomes stationary over or near the HIPLEX area and dissipates by 0500 CDT. This is classified as Subtype 1 or A_1. Occasionally, however, instability can be maintained after surface temperatures have decreased through favorable moisture convergence patterns and upper air temperatures. In this case, echo activity may persist well into the day after formation. This is termed Subtype 2 or A_2. Some evidence also shows that echoes of Type A_2 are further distinguishable from those of A_1 in that they form slightly away from the eastern mountain slopes and closer to the Texas High Plains area.

In order to further classify each A_1 and A_2 system, the 850 and 500 mb wind directions at Midland, Texas at 1900 CDT were tabulated for each event day for both echo patterns. The 1900 CDT (0000 GMT) sounding was selected because of its proximity in time to the peak growth period for both echo regimes. The 850 mb wind direction was between 105° and 185° for 92 percent of the event days. Eighty-five percent of the event days experienced 850 mb winds from 130° to 185°. After examining the tabulations for the 500 mb winds, two distinct ranges were evident. Those events with 500 mb winds between 305° and 010° were classified as north cases and those events with winds between 220° and 295° as south cases. A total of four subclassifications constitute the total A category; A_1N, A_1S, A_2N, and A_2S.

During the summer periods dominated by the flat temperature gradient of the subtropical high pressure system, the 850 mb wind direction will vary diurnally with the degree of surface heating over the New Mexico Rockies. During the early morning hours, wind direction at Midland will be south to southwesterly bringing in dry air from the southwest. Surface heating over the High Plains begins backing the 850 mb flow more to the southeastward. The new air flowing into the region now has a trajectory originating more from the Gulf of Mexico. As the day continues, the 850 mb flow continues to back more to the southeast until the airmass trajectory originates in moist air from the Gulf.

While the 850 mb wind at Midland is backing with time the El Paso 850 mb wind direction is veering. Figure 2 displays (in conjunction with the Midland wind direction) the El Paso 850 mb wind direction for the same time period (1 June to 10 June 1976). Also displayed in the figure are periods of echo events within the HIPLEX region. A confluence zone is formed in the low levels by the surface heating over the New Mexico Rockies. The airflow in the early morning hours is essentially parallel over El Paso and Midland with little thermal contrast.

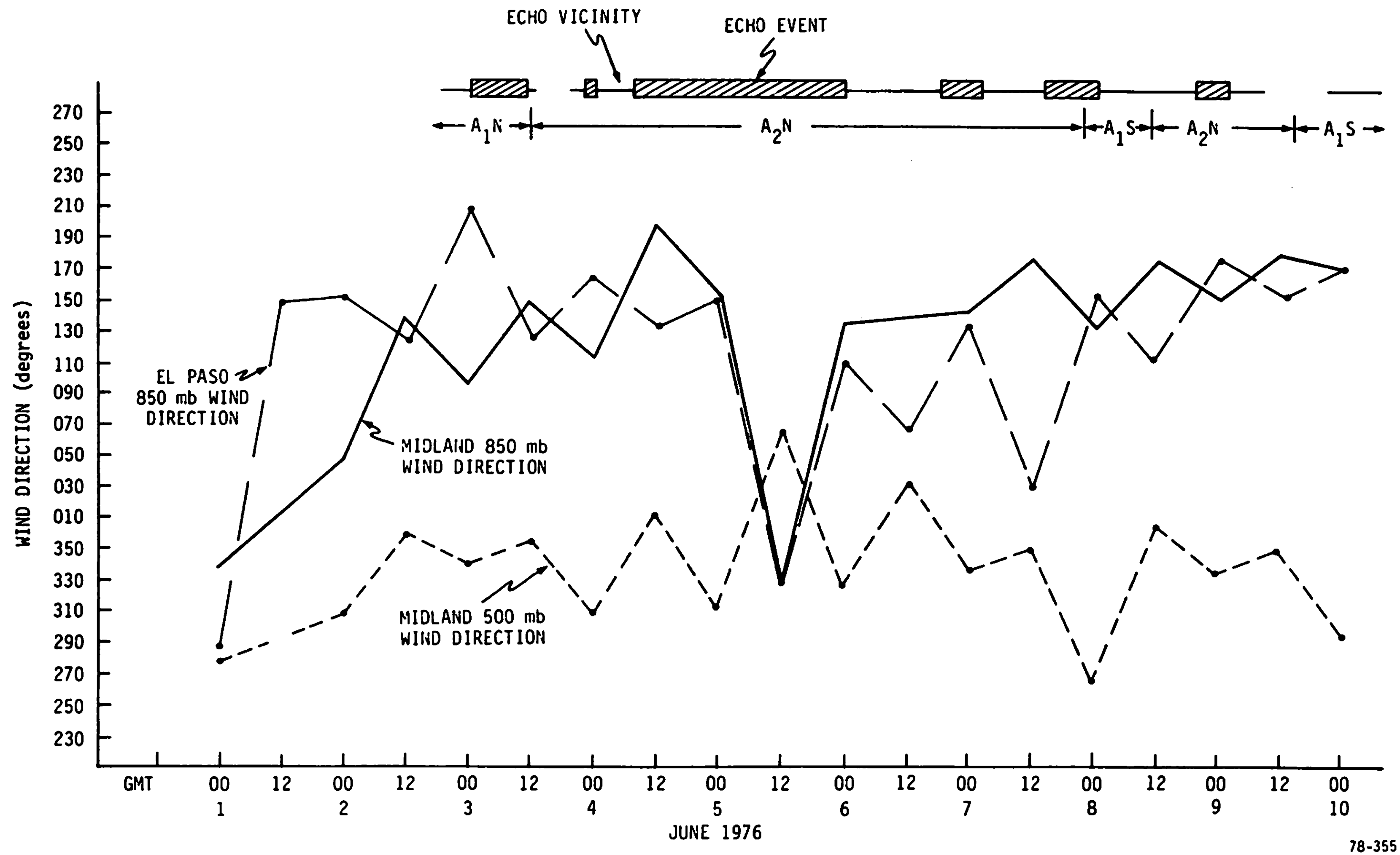


Fig. 2. Midland wind direction and echo events.

As surface heating continues the airflow on both sides begins adjusting to the building horizontal thermal gradient. The winds at El Paso veer from 1200 GMT to 0000 GMT while the winds at Midland back. The Type A begins forming in the confluence zone over or just east of the Rockies. Towards evening the echo system begins moving eastward. The winds at Midland switch from southeasterly to southerly as the system passes to the east. Hence, the trajectory origin becomes dryer and a dry line becomes distinguishable passing with the system to the east in the evening and nighttime hours.

After examining the NWS analyses for both the surface and 500 mb levels for all Type A echo events, and with the knowledge gained from the previous discussions, "ideal" surface and 500 mb analyses were constructed. Both Type A_1S and Type A_2N analyses are presented in Figure 3.

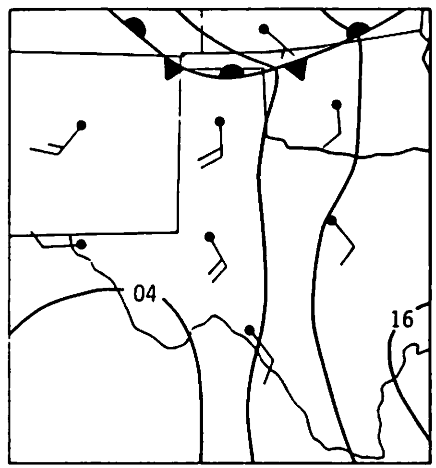
The Type A_2N 500 mb synoptic pattern typically contains evidence of a pressure ridge to the west of the Texas High Plains region. Northwest flow predominates over most of Texas and any frontal systems associated with the trough to the east of Texas have moved well to the east one or two days prior to development of Type A_2N. Fundamental to echo development is for ridging at 850 mb to reestablish below the eastern trough after the surface frontal passage as this results in the necessary southeasterly flow over the HIPLEX area.

The Type A_1S 500 mb synoptic pattern reveals a trough to the west of Texas with moderate south to westerly flow over the western United States. The strength of the trough does not seem to be an important factor in echo development.

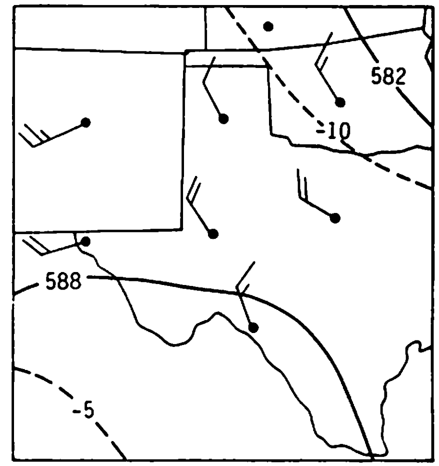
It became apparent during analyses of the two operational seasons that A_2N and A_1S echo systems often follow in sequence with the passage of upper air troughs over the Texas HIPLEX region. Frontal systems associated with these troughs are often weak and remain stationary north of the Texas Panhandle region. The sequence remains undisturbed as long as flow at 850 mb is from the southeast which is a moisture source region.

3.2 Echo System Type B

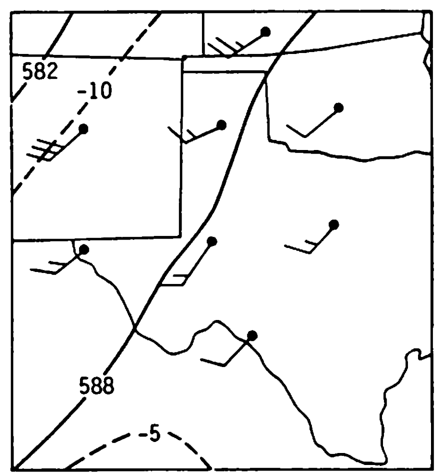
The Type B echo classification is the other category of echo systems not associated with frontal activity. During the 1976 operational period 19 percent of the total events were classified as Type B. No Type B



SURFACE TYPE A



500 mb TYPE AN



500 mb TYPE AS

Fig. 3. Typical Type A analyses

events are documented for the 1977 operational season. This echo system type is associated with strong moisture advection from the Gulf of Mexico at all levels in the troposphere. The characteristic echo pattern associated with this type of system is diurnal in its development and growth but on occasion will persist into the late night and early morning hours. Persistent systems are usually associated with positive vorticity advection at 500 mb. The Type B system is easily recognizable by the large areal coverage of radar echoes.

Further delineation of the Type B system can be accomplished by defining the position of the HIPLEX region relative to the orientation and echo motion. Subtype 1 (B_1), Subtype 2 (B_2), and Subtype 3 (B_3) represent echo motion from the southwest, south, and southeast, respectively. Each subtype is merely a reflection of the relative positions of the subtropical high pressure system and over the Texas High Plains. Figure 4 indicates the typical radar echo coverage for Type B situations and Figure 5 illustrates the different subclassifications of Type B systems.

As was done for Type A systems, the 850 mb and 500 mb wind directions for Midland at 1900 CDT (0000 GMT) were tabulated and analyzed. Again, as in Type A, the 850 mb wind direction is important. All wind directions at 850 mb for the eleven Type B cases were between 190° and 115°,which indicates the importance of the low-level moisture sources to the development and maintenance of convective activity. The 500 mb wind direction shows no relation with echo motion.

Typical surface and 500 mb analyses for Type B echo systems are presented in Figure 6. The surface synoptic pattern associated with Type B echo systems is dominated by subtropical high pressure extending across the southeastern portion of the United States into Oklahoma and occasionally even further west. The axis of the high pressure system is usually east to west and north of the Texas HIPLEX region. This provides the essential southeasterly moisture laden flows into the HIPLEX area. At 500 mb all Type B cases featured a weak trough or closed low pressure west of the High Plains. This low pressure zone results in southeasterly flow aloft and intensifies the moisture advection in lower levels.

Further classification of Type B systems can be made when more cases are observed. The frequency of Type B situations is small but these systems produce significant precipitation so more study is needed.

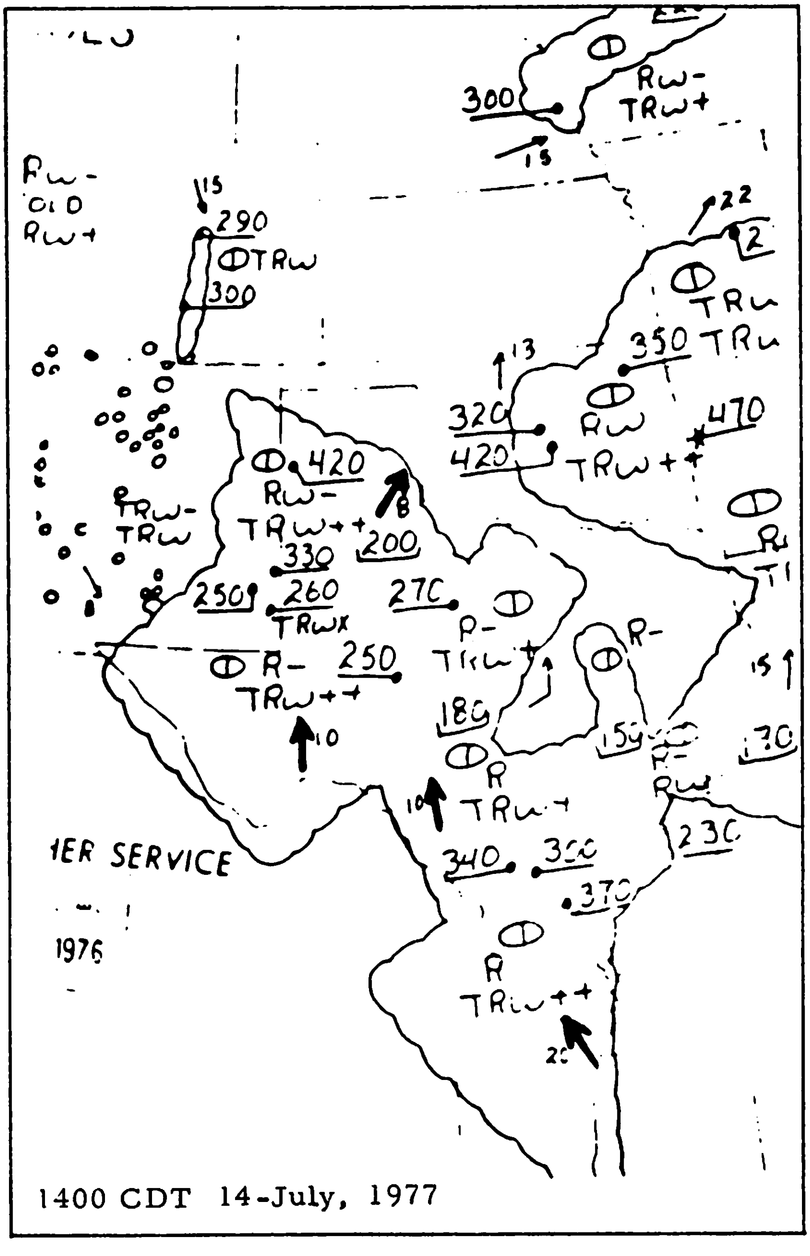


Fig. 4. Echo System Type B

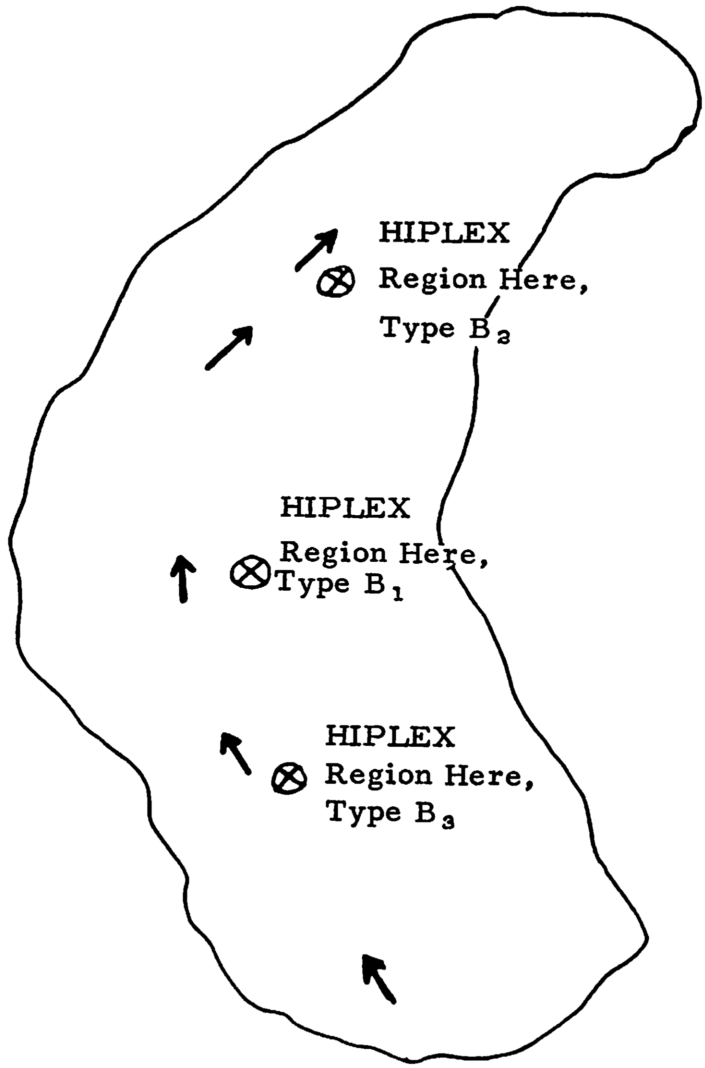
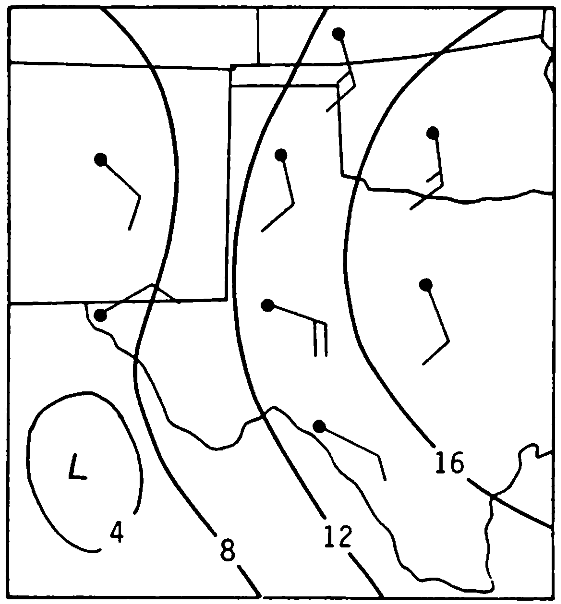
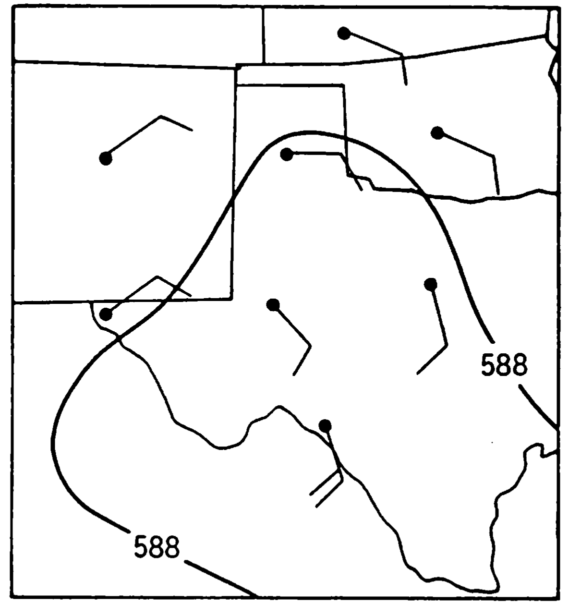


Fig. 5. Subclassification of Type B systems.



TYPE B SURFACE



TYPE B 500 mb

Fig. 6. Typical Type B analyses.

3.3 Echo System Type C

The Type C echo system is the smallest in percent of the total of the two categories of frontally induced or enhanced convective systems. The other group is a Type D system discussed in a later section. Type C systems accounted for about eight percent of the total event days. These systems are associated with surface cold or stationary fronts with an east to west orientation. Radar activity was observed to form in lines parallel to the frontal surface. Most east to west fronts remained well north of the HIPLEX region and most echo activity was also north of the area. Figure 7 shows a Type C echo system.

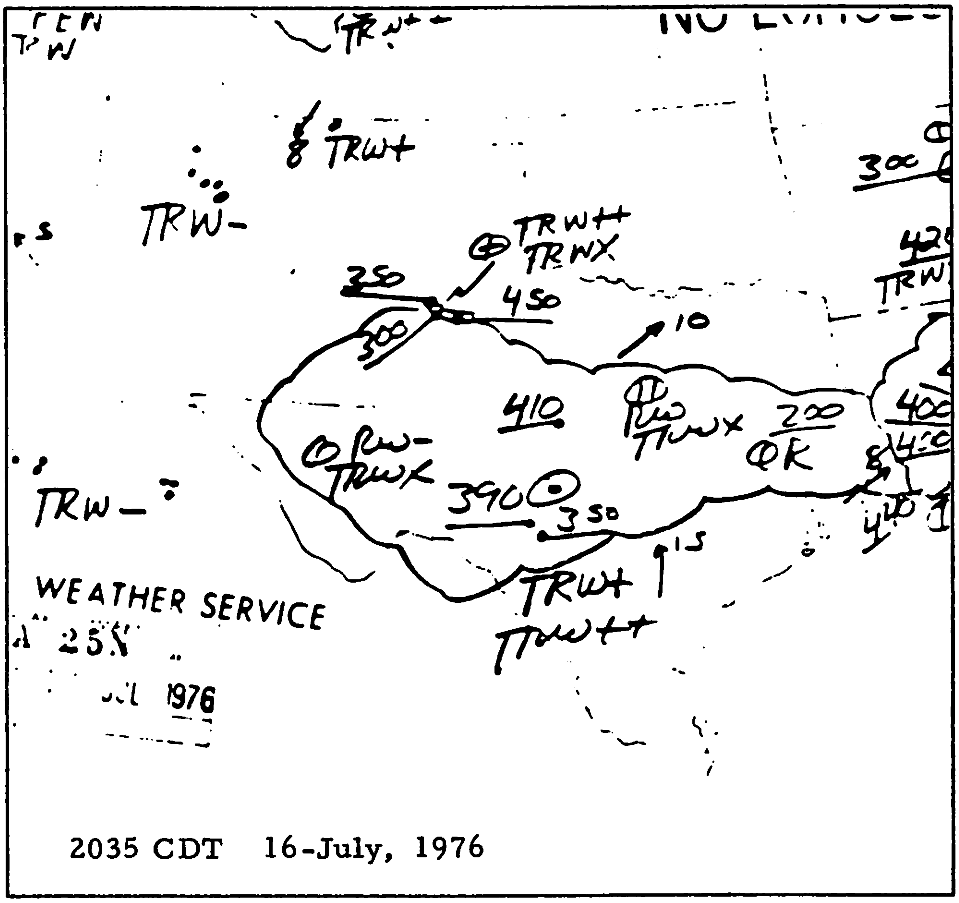
Three subclassifications of Type C events became apparent after examining the data tabulations. The Subtype C_1 includes all echo events associated with prefrontal cold or stationary fronts located to the north of the HIPLEX region. The Subtype C_2 includes prefrontal cold or stationary fronts undergoing frontolysis or changing into northeast advancing warm fronts. The Subtype C_3 includes postfrontal echo events following frontal passage or postfrontal echo clusters in cyclonic northerly flow accompanying advancing cold fronts or stationary fronts to the south of the HIPLEX region.

Two types of surface synoptic patterns are associated with Type C systems. They are the prefrontal and postfrontal regimes. The prefrontal flow is from the south or southeast and very similar to the Type A surface conditions (Figure 3). Postfrontal Type C conditions are as indicated in Figure 8. Moderate north to northwesterly flow, usually no more than 10 knots, is typical. The front pushes slowly through the HIPLEX region and becomes stationary near the position indicated in the figure. As the synoptic trough moves toward the east coast of the United States, the cold front becomes a warm front and slowly retreats northeastward, again moving through the HIPLEX region. Echo activity may be present in all stages of the frontal system and hence the C_1, C_2, and C_3 classifications previously mentioned.

At 500 mb the synoptic pattern is similar to the type AS 500 mb analyses shown in Figure 3. A trough exists west of the High Plains and flow is southwesterly to westerly at 20 knots.

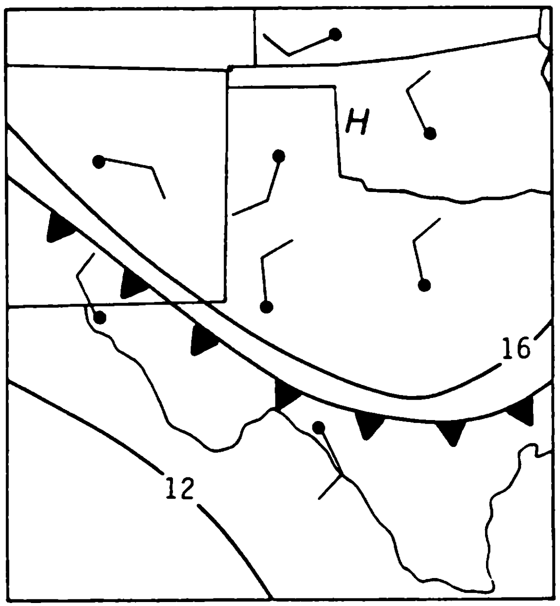
3.4 Echo System Type D

Type D echo systems are associated with advancing cold fronts moving into and through the HIPLEX region and oriented northeast to

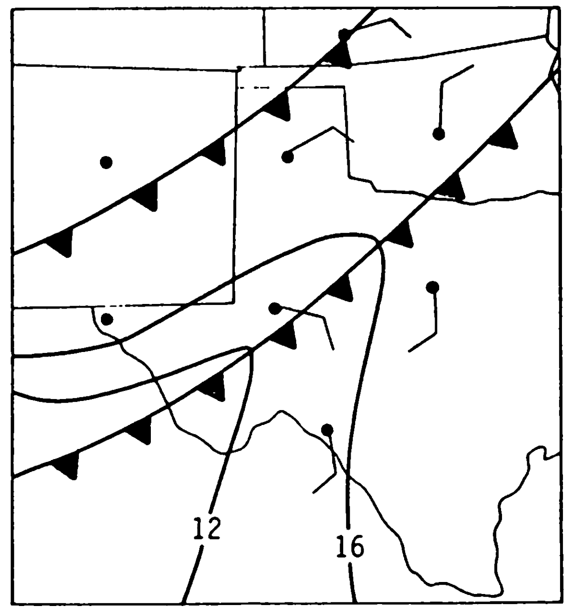


2035 CDT 16-July, 1976

Fig. 7. Echo system Type C.



TYPE C SURFACE



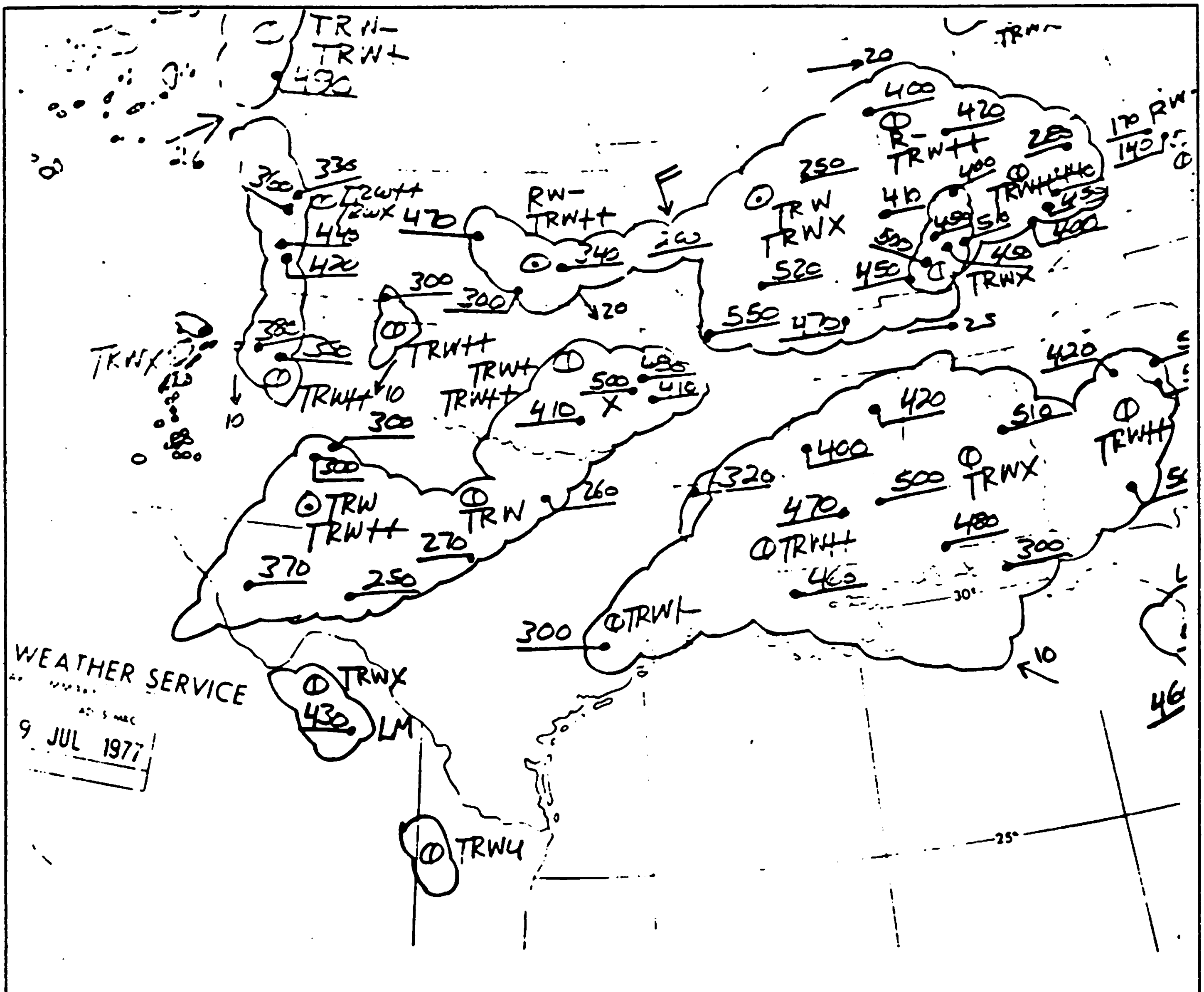
TYPE D SURFACE

Fig. 8. Typical Type C and Type D surface analyses.

southwest. Type D systems accounted for 29 percent of the echo event days and 78 percent of echo event days associated with frontal systems. The advancing frontal echo systems are often preceded by Type A echo regime which usually dissipates before the Type D system occurs. A Type D echo system is illustrated in Figure 9.

As in Type C echo system, the Type D regime has three subclassifications D_1, D_2, and D_3. Again, each subtype refers to prefrontal,frontolytic, and postfrontal echo formation, respectively. Again, Types D_1 and D_3 represent activity ahead and behind the front but Type D_2 needs some further description. Type D_2 is associated with a northeast-southwest stationary front. Frontolysis can occur when east to southeasterly flow at 700 mb and 500 mb advects cooler air ahead of the stationary surface system. As the stationary front dissipates leaving a trough of low pressure another front "appears" to form further north. Analysis at the NWS include two fronts on the surface map and a typical analysis is given in Figure 8.

It should be noted that north-to-south echo lines were not observed in association with north-south fronts in the 1976 and 1977 seasons. The lack of echo occurrence in the HIPLEX region during north-south frontal episodes is primarily due to the formation of the north-south surface trough in the High Plains region. The surface trough associated with the north-south frontal system, switches the surface and 850 mb wind direction to southwesterly or even westerly, thereby cutting off the moisture supply from the Gulf of Mexico. Echo systems form north of the HIPLEX region and remain north where the low-level air mass trajectory traces the air mass origin back to the southeast, east of the HIPLEX region, back to the Gulf. Often north-south echo systems formed ahead of the advancing front, but these systems fall within the A type of classification and dissipate just prior to the approach of the north-south front. Table 2 lists the meso-α days classified.



1935 CDT July 9, 1977

Fig. 9. Echo system Type D.

Table 2

MESO-α ECHO TYPE CLASSIFICATIONS
JUNE 1976

Operational Day	Day 1000-1000 (CDT)	Event Day	Vicinity Day	No Echo Day	Event Occurrence			Event Duration (Hours)	Event Beginning Hour (CDT)
					Daytime 1000-2200 (CDT)	Night 2200-1000 (CDT)	Day and Night		
Yes	1-2	C_3			X			2	1000
	2-3		A_1S					-	-
	3-4		A_1S					-	-
	4-5			NE				-	-
	5-6			NE				-	-
	6-7		C_2					-	-
	7-8		B_3					-	-
Yes	8-9		B_1					-	-
Yes	9-10	A_1S					X	11	1600
Yes	10-11	A_1N			X			6	1700
Yes	11-12	A_1S-D_1					X	15	1700
Yes	12-13		D_1-D_3					-	-
Yes	13-14	D_3				X		5	2200
Yes	14-15		A_1N					-	-
	15-16			NE				-	-
	16-17			NE				-	-
	17-18			NE				-	-
	18-19		D_2					-	-
	19-20		D_2					-	-
Yes	20-21	A_1S					X	10	2100
Yes	21-22	A_2S					X	19	1500
Yes	22-23	A_2S					X	24	1000
Yes	23-24	A_2S					X	18	1000
Yes	24-25	A_2S-D_1					X	20	1000
Yes	25-26	D_1					X	15	1000
Yes	26-27	A_2N			X			6	1600
Yes	27-28	A_2N					X	8	1600
Yes	28-29	D_2				X		3	2300
	29-30		D_2					-	-
Yes	30-1	D_2					X	13	1500

Table 2

MESO-α ECHO TYPE CLASSIFICATIONS
(Continued)
JULY 1976

Operational Day	Day 1000-1000 (CDT)	Event Day	Vicinity Day	No Echo Day	Event Occurrence: Daytime 1000-2200 (CDT)	Event Occurrence: Night 2200-1000 (CDT)	Event Occurrence: Day and Night	Event Duration (Hours)	Event Beginning Hour (CDT)
	1-2	D_2			X			3	1500
	2-3	A_1S			X			3	1500
	3-4		A_1S					-	-
	4-5		A_1S					-	-
	5-6		A_1S					-	-
	6-7		D_2					-	-
Yes	7-8	D_2			X			4	1600
Yes	8-9	D_2-D_3					X	17	1000
Yes	9-10	D_3-D_2			X			8	1300

Table 2

MESO-α ECHO TYPE CLASSIFICATIONS
(Continued)
JUNE 1977

Operational Day	Day 1000-1000 (CDT)	Event Day	Vicinity Day	No Echo Day	Event Occurrence: Daytime 1000-2200 (CDT)	Event Occurrence: Night 2200-1000 (CDT)	Event Occurrence: Day and Night	Event Duration (Hours)	Event Beginning Hour (CDT)
	1-2			NE					
	2-3	A_1N				X		7	2200
Yes	3-4	A_2N					X	8	1600
	4-5	A_2N					X	24	1000
	5-6	A_2N			X			12	1000
	6-7	A_2N			X			7	1200
	7-8	A_2N-A_1S			X			9	1200
	8-9	A_2N			X			6	1300
Yes	9-10		A_1S					-	-
	10-11		A_1S					-	-
Yes	11-12	A_1S			X			5	1600
	12-13			NE				-	-
	13-14	A_1S			X			7	1500
	14-15			NE				-	-
Yes	15-16		D_3					-	-
	16-17			NE				-	-
	17-18	A_1S-D_1					X	12	1300
	18-19		D_3					-	-
	19-20		D_3						
	20-21	A_2N					X	2	0800
	21-22	A_2N					X	16	1000
Yes	22-23	A_2N-A_1S-D_1					X	22	1000
Yes	23-24	D_1					X	15	1000
	24-25	D_3					X	7	1700
Yes	25-26	A_1S					X	7	1900
	26-27	B_3					X	5	2100
	27-28	B_2			X			8	1400
Yes	28-29		C_1					-	-
	29-30	C_2				X		8	2300
	30-1	C_2					X	10	1500

Table 2

MESO-α ECHO TYPE CLASSIFICATION
(Continued)
JULY 1977

Operational Day	Day 1000-1000 (CDT)	Event Day	Vicinity Day	No Echo Day	Event Occurrence: Daytime 1000-2200 (CDT)	Event Occurrence: Night 2200-1000 (CDT)	Event Occurrence: Day and Night	Event Duration (Hours)	Event Beginning Hour (CDT)
Yes	1-2		C_2					-	-
	2-3	A_1S-D_1					X	18	1600
Yes	3-4	D_1-D_3			X			11	1000
	4-5	D_3					X	10	1500
	5-6	D_3			X			13	1000
	6-7			NE				-	-
	7-8			NE				-	-
Yes	8-9	B_2				X		3	0700
	9-10	B_2-B_3					X	23	1000
Yes	10-11	B_3-B_2					X	24	1000
Yes	11-12	B_2-B_1					X	24	1000
Yes	12-13	B_1					X	18	1000
	13-14	B_1					X	24	1000
	14-15	B_1					X	24	1000
	15-16	B_1-C_1					X	23	1000
	16-17	C_1-C_3					X	14	1000

4. MESO-β ECHO CLIMATOLOGY

An analysis of the mesoscale classification showed that all mesoscale echoes observed in the 1976 and 1977 Texas HIPLEX operational seasons were either isolated (Type I) or line (Type L) systems. Further subclassification in each of these mesoscale character groups resulted in identification of two echo character groups. These echo groups are isolated cell conditions or echo complex conditions. Furthermore, the isolated cell conditions could be subclassified as either having some orientation or not having orientation. In addition, the cell complexes could be subclassified as to whether their component cells had line organization or not. Figure 10 illustrates, in block diagram form, the possibilities for one meso-α and one meso-β type. The arrows indicate the classification path for an echo system associated with an east - west front (Type C) that consisted of line formation (Type L) of echo complexes with line organized internal cells (Type A).

4.1 Isolated System Type I

Slightly less than half of the total number of days involved in the meso-β classification were Type I days and half of the total number of meso-β events were Type I events. Most of these isolated systems were not associated with well defined synoptic features (e.g. fronts) and thus were classified as meso-α Type A or Type B days.

The lack of a synoptic scale dynamic influence (e.g. frontal lifting or upper level trough) appears to be an important factor in preventing organization of the convective activity. The absence of a triggering synoptic dynamic effect implies that vertical convective instability, a favorable environmental shear, and an adequate moisture supply are sufficient for convective development and growth in the West Texas region or that mesoscale dynamic processes are occurring, or both. A possible mesoscale dynamic process is gravity-wave induced vertical motion. Gravity waves produced by a rapidly developing cumulus cell or cell complex are a documented phenomenon. A description of the effects of this perturbation on development and orientation of new systems is given by Chen, et al (1978). In addition, Chen, et al (1978) discuss the importance of convective instability, environmental shear, and adequate moisture flux as they relate to meso-β echo systems and to each other.

Isolated mesoscale systems can exist prior to development of a line organized system. Type I systems can also occur after decay of a Type L line system. Frequently, synoptic and mesoscale conditions

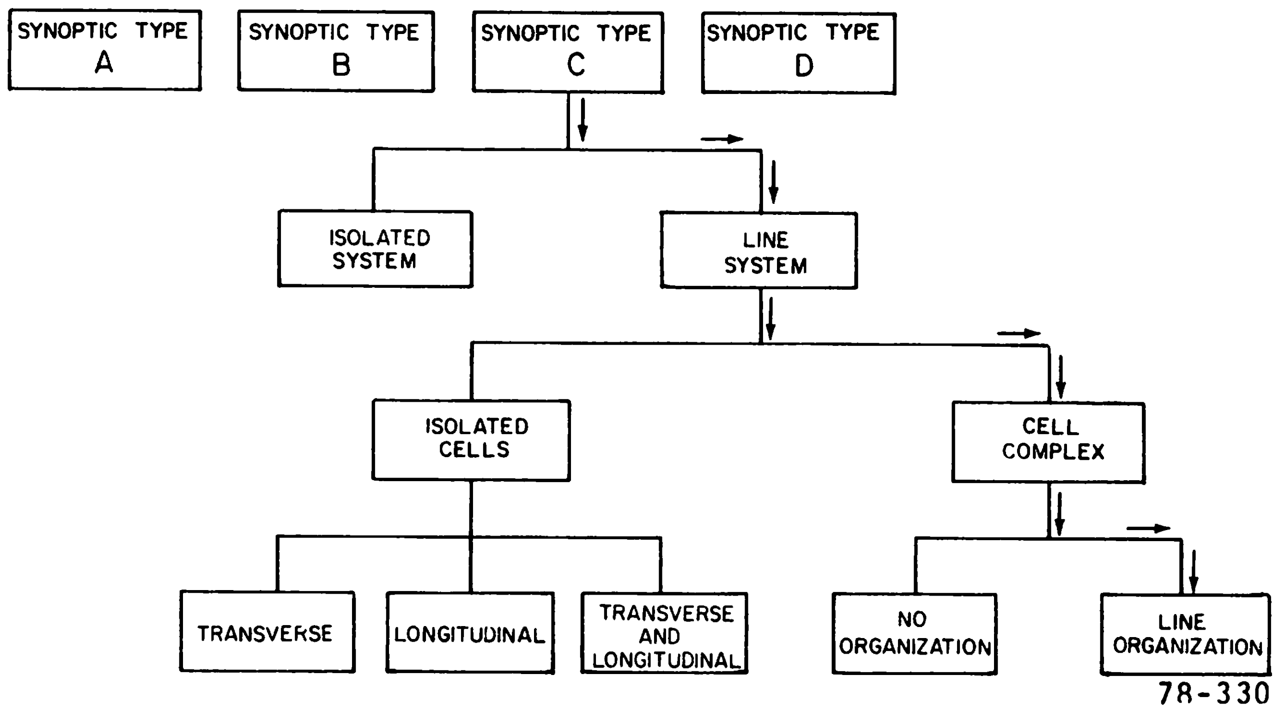


Fig. 10. One possible route to classify a mesoscale radar echo system.

change during the course of an isolated event or day. Favorable changes in available moisture, vertical shear structure, or vertical motion can act to organize and intensify convective systems. Conversely unfavorable changes in these variables result in a decay in organization and an isolated system is possible. Furthermore, mesoscale spatial variability of the above can be large enough to permit isolated and line systems to coexist within detection distance of the Snyder radar (about 300 km in diameter).

Four distinct cloud-scale echo characters are possible in a mesoscale isolated system. They are:

1. Isolated cells with no orientation with respect to environmental (850 - 500 mb) wind shear.

2. Isolated cells with orientation with respect to environmental wind shear.

3. Cell complexes without line organization of internal cells.

4. Cell complexes with line organization of internal cells.

Mesoscale isolated systems composed of isolated cells with no orientation were not observed in either the 1976 or 1977 Texas HIPLEX operational seasons. These isolated echoes with no orientation develop and exist in very weak vertical wind shear conditions with a minimum of available moisture and when no mesoscale or synoptic forcing is apparent. The cells are widely spaced and compete for what little moisture is available and thus are limited in size.

Mesoscale isolated systems composed of isolated cells with definite orientation with respect to the environmental vertical wind shear accounted for all the isolated days classified and 70 percent of the isolated cell events observed. The two modes of orientation identified are:

a. <u>Transverse</u> - Individual cells are aligned along a line normal to the vector 850 - 500 mb wind shear.

b. <u>Longitudinal</u> - Individual cells are aligned along a line parallel to the vector 850 - 500 mb wind shear.

Both of the above modes can exist at the same time and furthermore, the orientation of the wind shear vector can change both in time and across the mesoscale network. This results in extremely complex classification problems. If it is assumed that the Midland 1200 GMT or 0000 CDT vector wind shear, obtained from the soundings at those respective times, is representative of the environment for some hours before or after the sounding, then a unique wind shear can be associated with each echo event. Caution must be exercised when interpreting results obtained from an analysis utilizing these shears. As long as echo systems are reasonably close to Midland and near the sounding times, representative analyses can be made with complete confidence. A detailed account of the mesoscale dynamics associated with the orientation of convective echoes and why it is important to development is given by Chen, et al (1978).

Mesoscale isolated systems comprised of echo complexes without line organization of their internal cells were observed in two of the 10 isolated events. No days could be classified as having echo complexes as their dominant characteristic. Echo complexes are defined as multiple cells with radar contours greater than or equal to 35 dbZ enclosed by a single 25 dbZ contour. Echo complexes in isolated systems are representative of the mature stage of isolated convective system development. Initially isolated cells develop, then certain cells are enhanced through favorable orientation with the wind shear. As more and more cells grow they merge into cell complexes. The physical mechanisms involved in this complex formation are still unknown. During dissipation of complexes the isolated cells are again evident and then they also disappear.

A mesoscale isolated system with cell complexes having line organization of their internal cells was observed in only one event and no days had this characteristic as their dominant feature. This echo character is very similar to the previous example in that it is a temporary stage in the life cycle of the convective system. Some evidence indicates that the shear direction and magnitude differences may be important in differentiating between cell complex events with organization and those without.

Figure 11 shows an example of a typical PPI display for each meso-β echo character.

4.2 Line System Type L

Fifty-four percent of the meso-β days classified were line systems. Half of the meso-β events were also line systems. Most line events were associated with synoptic-scale dynamic influences. Fronts and upper level troughs are important in organizing and maintaining these line systems. There were cases, however, where line systems were observed and no major synoptic influence was evident. In these cases, mesoscale dynamic processes such as the gravity waves already mentioned can organize and maintain convective

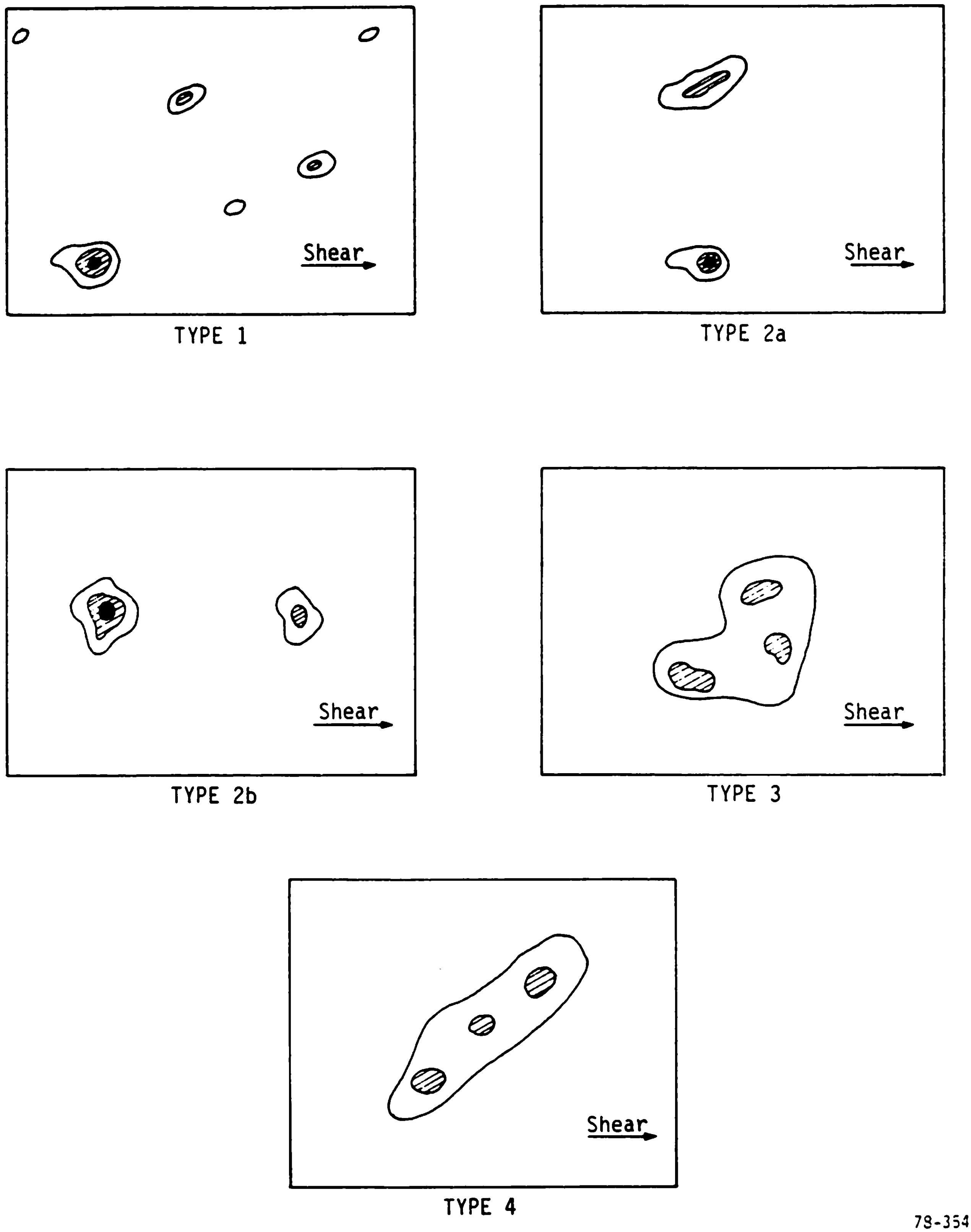


Fig. 11. Meso-β echo characters.

activity. Regardless of the convective triggering mechanism, line systems result from intense development of isolated cells along one mode. Whether the mode is transverse or longitudinal depends on the orientation of the moisture convergence field, convective instability, and other features as detailed by Chen _et al_ (1978).

The four cloud-scale echo characters possible in an isolated system are also possible for a line system.

Line systems composed of isolated cells with no orientation were not observed in either of the two HIPLEX experiments as was the case for isolated cells in isolated systems. The absence of isolated cells without orientation implies that some dynamic processes are necessary for development of convective systems.

Two events and one day were characterized by line systems composed of isolated cells with orientation in either the transverse or the longitudinal mode. Frequently, intensive development in one of the modes resulted in the squall line itself, however, when environmental conditions were unfavorable for intensive development the isolated cell conditions persisted throughout the day.

As the isolated cells continue to develop and grow along a favorable mode of orientation they merge into cell complexes. The cell complexes while forming along a line may have no line organization of their internal cells. This process was observed in three events and two days could be described as having this feature dominate.

In some instances the line feature is so dominant that even the cells comprising an echo complex are line oriented. This was the most frequent of the line systems observed with four events and three days being classified.

Table 3 is a summary of the meso-β echo climatology and Table 4 is the detail of the meso-β classification.

Table 3

MESO-β ECHO CLIMATOLOGY

Mesoscale Character	Echo Character	No. Days	Total Days (%)	No. Events	Total Events (%)
I		6	46	10	50
	1	0	0	0	0
	2	6	46	7	35
	3	0	0	2	10
	4	0	0	1	5
L		7	54	10	50
	1	0	0	0	0
	2	1	7.7	2	10
	3	2	15.4	3	15
	4	4	30.8	5	25

Code Key:

I - Mesoscale Isolated System

L - Mesoscale Line System

1 - Isolated cells (no orientation)

2 - Isolated cells (transvefse and longitudinal)

3 - Cell complex without line organization

4 - Cell complex with line organization

Table 4

MESO-β ECHO TYPE CLASSIFICATIONS

Date	Echo Type	Beginning Hour (CDT)	Ending Hour (CDT)	Mesoscale Character	Echo Character	MAF 850-500 Wind Shear Direction (°)	MAF 850-500 Wind Shear Speed (mps)	MAF Stability $\Delta\theta_e$ 850-500 (°K)
1976								
June 3-4	A_2N	1600	0000	I	2	298.3	7.7	15.0
June 4-5	A_2N	1000	1000	I	2	321.2	10.1	NA
June 22-23	A_2N	1735	0300	L	4	376.7	6.3	9.9
July 10-11	B_3B_2	1000	1000	L	2	310.4	4.5	11.3
July 10-11	B_3B_2	1000	1000	L	4	310.4	4.5	
1977								
June 1-2	C_3	1000	1200	L	3	159.2	5.6	12.8
June 9-10	A_1S	1600	0300	I	2	348.7	5.32	5.8
June 9-10	A_1S	1600	0300	I	3	348.7	5.32	
June 11-12	A_1S, D_1	1700	0800	L	4	304.5	5.37	14.2
June 20-21	A_1S	2100	0700	L	3	306.8	8.85	NA
June 21-22	A_2S	1500	1000	I	2	037.6	0.73	9.2
June 22-23	A_2S	1000	1000	I	2	256.7	3.28	4.1
June 22-23	A_2S	1000	1000	I	3	256.7	3.28	
June 23-24	A_2S	1000	0400	L	4	273.1	5.34	
June 23-24	A_2S	1000	0400	L	3	273.1	5.34	13.0
June 23-24	A_2S	1000	0400	I	2	273.1	5.34	
July 8-9	D_2, D_3	1000	0300	L	4	256.0	5.77	0.4
July 8-9	D_2, D_3	1000	0300	L	2	256.0	5.77	
July 9-10	D_3, D_2	1300	2100	I	2	071.6	5.37	16.5
July 9-10	D_3, D_2	1300	2100	I	4	071.6	5.37	

5. CONCLUSIONS

The following conclusions resulted from analysis of the meso-α and meso-β radar echo classification and climatology.

Meso-α

- 48 percent of all days had echo patterns not associated with frontal systems
- 19 percent of all days had widespread echoes associated with moisture advection through a deep layer in the atmosphere
- 8 percent of all days had echo patterns associated with east-to-west fronts
- 25 percent of all days had echo patterns associated with southwest-to-northeast fronts

Meso-β

- 47 percent of radar echo systems were isolated in nature
- 54 percent of radar echo systems had line organization
- Both isolated and line systems could be composed of isolated cells existing in transverse and longitudinal modes,or cell complexes
- No mesoscale systems were seen to have isolated cells without orientation as their major feature

6. RECOMMENDATIONS

Although the major emphasis of this research is on the development and interpretation of a M-33 radar climatology based on analysis of the classified radar data, relationships between the radar categories and certain mesoscale environmental variables become apparent during this effort. As mentioned briefly in the text, the vector 850-500 mb wind shear at Midland was tabulated for most meso-β days. Also tabulated was the change in equivalent potential temperature between the same two layers. An average of each variable for all days for each mesoscale and echo character was computed as is given in Table 5. Although the sample size was extremely small (13 total days), significant stratification was evident between groups. The following is a list of the interesting features;

- Line systems have a higher magnitude of wind shear and a more westerly direction than do isolated systems.

- Line systems have a larger convective instability than do isolated systems.

- The more organized a system the more westerly the shear. For example, isolated cells with orientation and complexes with line organization are more westerly than are complexes without organization.

- Echo organization increases with increasing convective instability, i.e., isolated cells, complexes without line organization and complexes with line organization represent, respectively, ascending degrees of both organization and convective instability.

It is strongly recommended that these statistics be computed using a larger data base. If it can be shown that the above relationships are true, then great strides can be taken in forecasting seeding conditions and implementing seeding hypotheses in the Texas HIPLEX region.

Table 5

ECHO CHARACTER SUMMARY

Mesoscale Echo Character	Cloud Scale Echo Character	Direction ($^\circ$)[c]	Windshear[a] ($m\ sec^{-1}$)	Ave. $\Delta\theta_e$[b] ($^\circ K$)
I		252	5.43	8.53
L		271	5.93	12.83
	1	N/A[d]		N/A
	2	262	5.27	10.32
	3	233	7.23	12.80
	4	289	5.36	13.60

a. Average windshear measured at 0000Z. The shear is defined as the vector difference between 500 and 850 mb winds at Midland.

b. Average equivalent potential temperature difference between 500 and 850 mb measured at 0000 CDT.

c. Windshear is measured from the end of the 850 to the end of the 500 mb wind vector.

d. No data available.

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