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SEVERE THUNDERSTORMS--TWO CASE STUDIES:

Severe Weather in Northwesterly Flow

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July Thunderstorm Produces Large Hail in Miami, Florida

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Richard E. Hallgren, Director

Editor's Note: The two reports combined in this publication come from offices that represent the climatic extremes that exist in the Southern Region, Yet both reports describe the same basic weather phenomenon--a severe thunderstorm. Even though some of the characteristics of thunderstorms may differ from the arid mountains of New Mexico to the tropical beaches of South Florida, the results can be as potentially dangerous in either location. These two reports prove that point and also emphasize the important role a good, solid foundation in severe storm meteorology plays in predicting the weather regardless of location or climate.

SEVERE WEATHER IN NORTHWESTERLY FLOW - A CASE STUDY

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1. INTRODUCTION

During the afternoon and evening of June 26, 1982 reports of large hail, strong winds, heavy rain and one tornado were received from northeast and east-central New Mexico. One unusual report was of six-and-one-half-inch hail near Maxwell (MX). While several attempts were made to verify the diameter of the hail in the report, none were successful. Since the report came from a highway crew on Saturday afternoon, we have assumed that they were called out to clear hail from the highway which had accumulated to a depth of six and one-half inches; this occurs a few times during the spring and summer. It was evident from radar and satellite data that all the severe weather reports were related to a southward-moving convective complex, see Fig. 1. The north-south distance from the first event, a tornado at 2100 GMT, to the last event, marble-sized hail at 0415 GMT, was 175 miles. The maximum 24-hour precipitation total along the storm track was 2.16 inches at Bell Ranch (BR), with 1.20 inches reported at Roy (RY). Fig. 2 is a reference of cities and terrain features referred to in this paper.

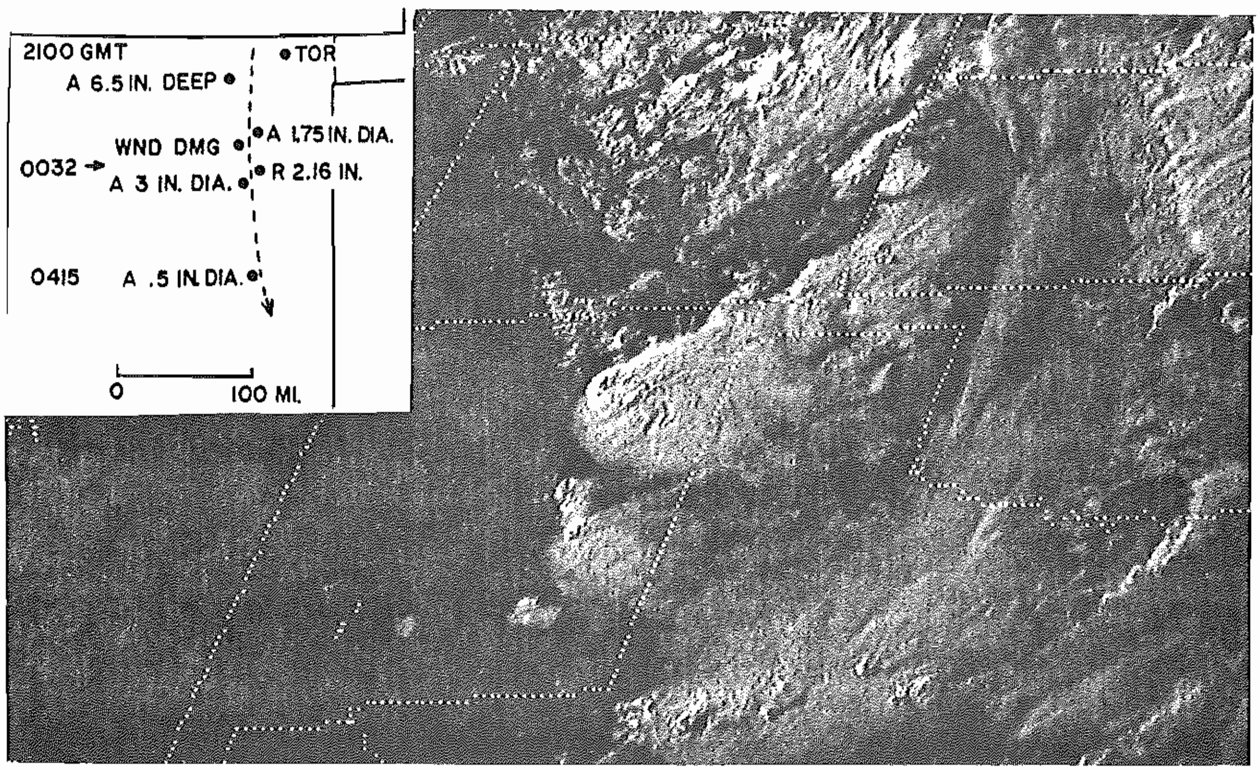

Fig. 1. Satellite picture for 0032 GMT June 27, 1982. Note the overshooting tops over northeastern New Mexico. The cell in southwestern Kansas produced the tornado at 2100 GMT. Inset - center-line track of the precipitation core as observed by radar and the observed events produced by the convective complex.

2. SYNOPTIC FEATURES

At 1200 GMT on the 26th a nearly stationary front extended from the lower Great Lakes, through a weak low in northeastern Oklahoma, across north-central Texas and curved northwestward into northeastern New Mexico. A weak ridge extended from southwestern Wyoming into southwestern Kansas. A trough extended from eastern Wyoming into southwestern Nebraska. A broad thermal low extended from southwestern Arizona into south-central New Mexico. Dew points in the 60s were observed over western Texas and eastern New Mexico as far north as Tucumcari (TCC). A dry-line was located along the western slopes of the Sangre de Cristo Mountains extending south through the mid-Rio Grande Valley into southwestern New Mexico. Upper-air features were a moist maximum wind axis at 850 mb extending south to north along the eastern border of New Mexico. A weak 500 mb gradient was evident over the central U.S.. A vigorous 500 mb low was centered near 45N 135W over the eastern Pacific with the attendant trough extended south to near 25N. The long-wave ridge was over the eastern U.S. near 115W. The long-wave trough extended from the western shore of Hudsons Bay south along 95W into the central U.S..

At 0000 GMT on the 25th a weak 500 mb low was located over central Kansas and a short-wave was moving out of the eastern Pacific system and was over the California coast. The Kansas low weakened and moved northeast. The short-wave over the western U.S. moved through the long-wave ridge and strengthened as it approached the long-wave trough by 1200 on the 26th. Fig. 3 is a composite of the available data prior to the convective development on the 26th. Note the cold pool at 500 mb over northwestern Texas in Fig. 4.

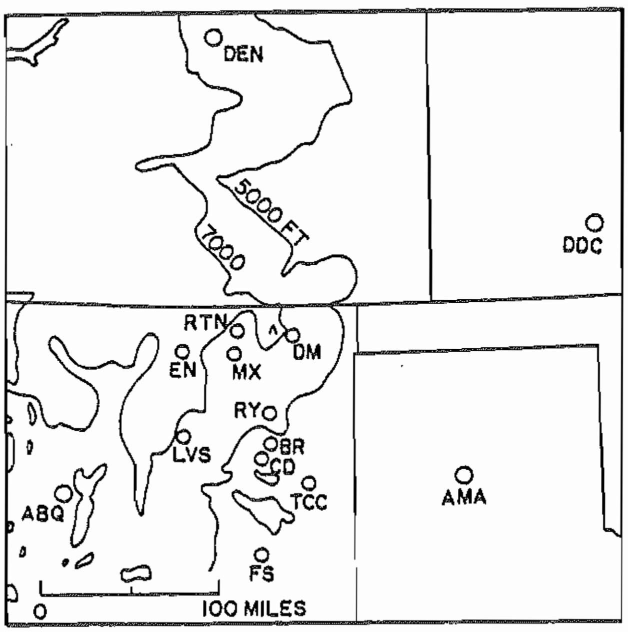

Fig. 2. Reference map for this paper. The Capulin Mountain area is indicated by the inverted V.

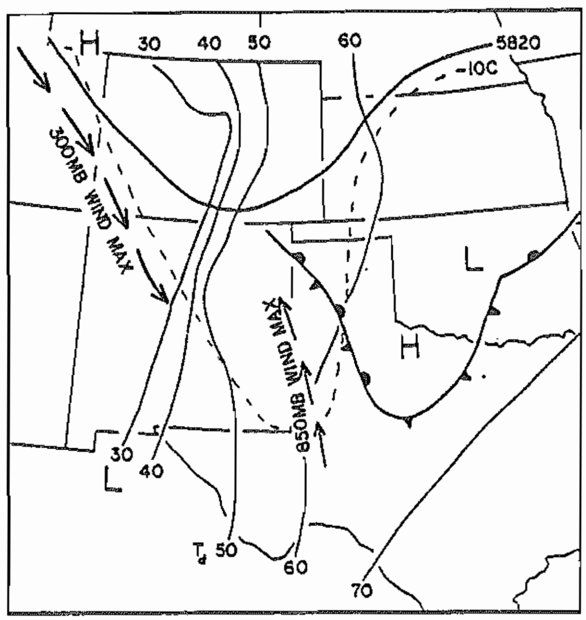

Fig. 3. A composite of the 1200 GMT upper-air and 1800 GMT surface features which influenced convective development on June 26.

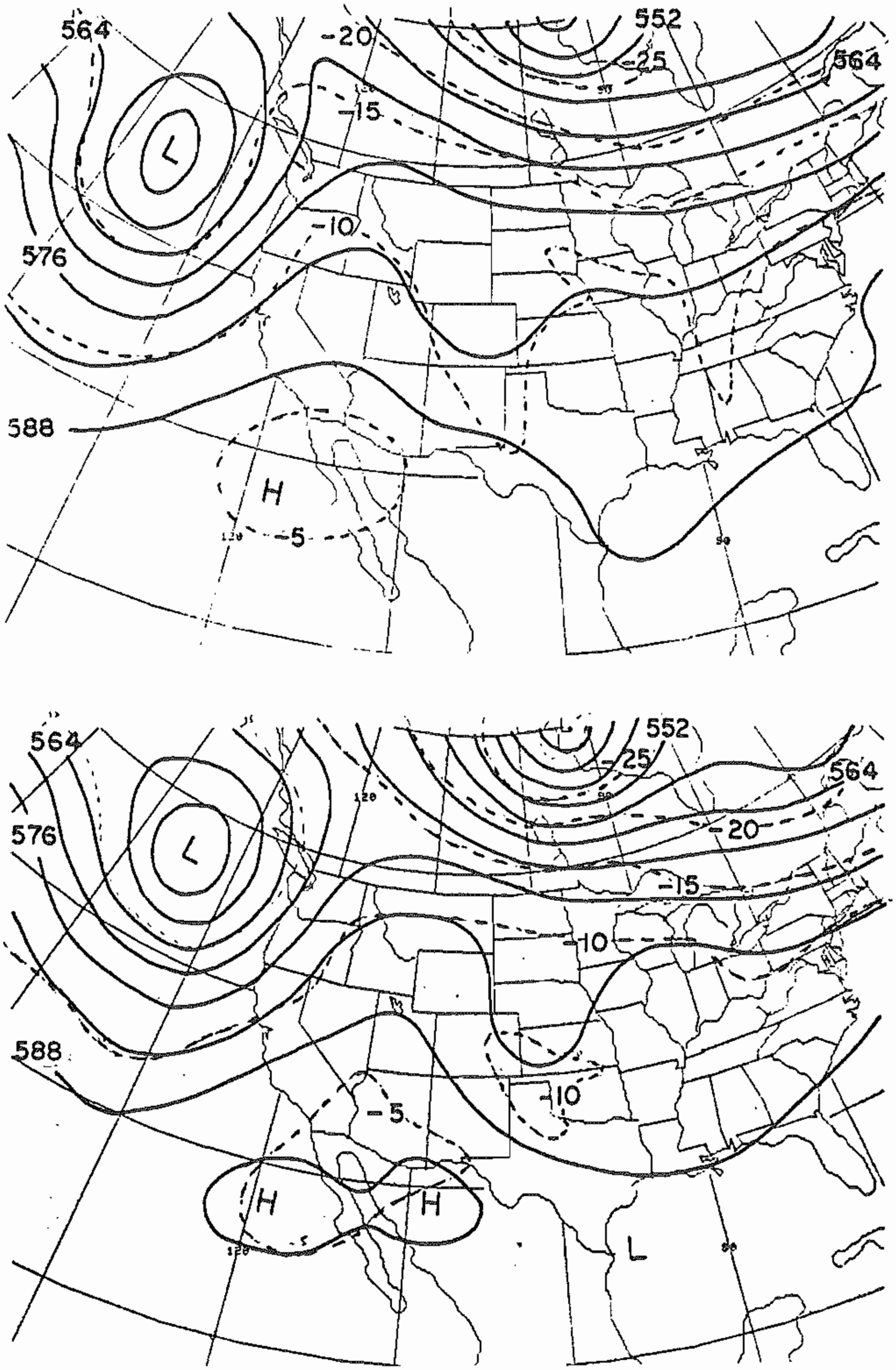

Fig. 4. 500 mb charts, 1200 GMT June 26, 1982 (top), 0000 GMT June 27, 1982.

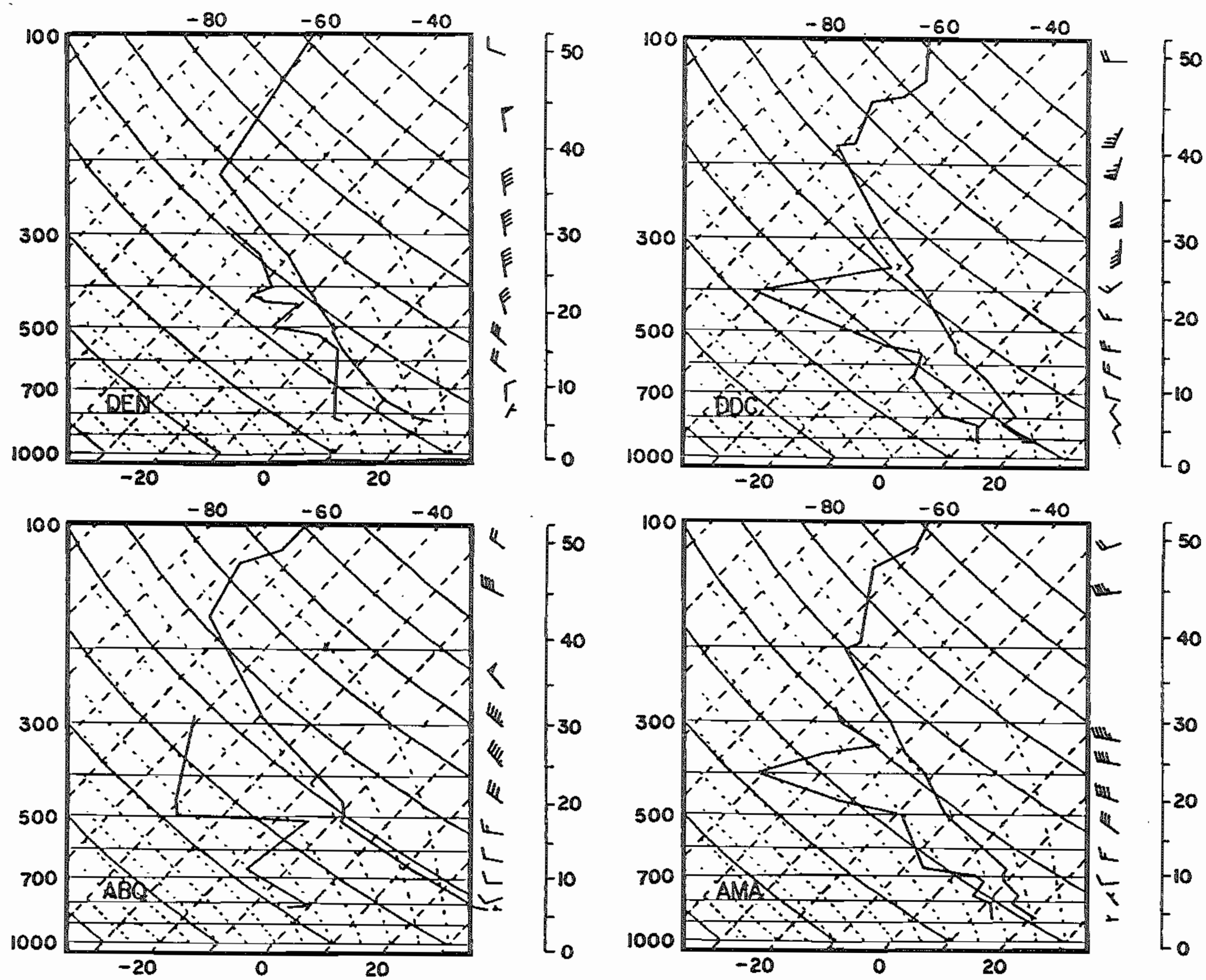

Fig. 5. Upper-air soundings at 0000 GMT June 27, 1982 for Denver, CO (DEN), Dodge City, KS (DDC), Albuquerque, NM (ABQ) and Amarillo, TX (AMA).

3. STABILITY CONSIDERATIONS

One of the destabilizing events evident in Fig. 3 is the southward push of cold air at 500 mb directly over the 850 mb moist maximum wind axis. The vertical stability features can be seen in the plotted soundings in Fig. 5 for Denver, CO (DEN), Dodge City, KS (DDC), Albuquerque, NM (ABQ) and Amarillo, TX (AMA) at 0000 GMT June 27, 1982. Fig. 6 is a composite sounding for early afternoon over northeastern New Mexico near the area of convective development. Insolation at the surface was consumed in evaporating the moisture from the overnight precipitation and heating of the boundary layer. Maximum temperatures at the non-mountain locations of Raton (RTN) and Des Moines (DM), elevations near 6600 feet, were in the low 70s. However, in the mountains southwest of RTN at Eagle Nest (EN), elevation 8260 feet, the maximum temperature was 75 degrees. EN is about the same elevation as the Capulin Mountain area (Λ), which includes Johnson Mesa, Serria Grande and Laughlin Peaks, east of RTN.

Showalter stability indices on the 0000 GMT soundings of the 27th for AMA and DDC were minus 2 and zero respectively. Accompanying mixing ratios of 10 to 12 grams per kilogram were present in the lower atmosphere to feed the convection. Afternoon maxima were such that the level of free convection was not generally attained over the Plains of eastern New Mexico and the western Panhandle area. However, a temperature of only 65 degrees at 8000 feet in the Capulin Mountains would provide sufficient energy to propel a parcel to 38,000 feet. While the cloud bases would be near 12,000 feet MSL, low-level convergence would aid in the entrainment of the moisture-rich boundary layer into the developing convection. Since other convection in the area was retarded, the latent heat stored in the boundary layer moisture was available to nourish and sustain the southward moving convective complex. The vigor of the convection was further enhanced by cold advection at upper-tropospheric levels and by the strong upper-tropospheric wind shear observed between DEN and DDC which would aid in the high-level divergence and cyclonic rotation. Dry mid-tropospheric air was also available for entrainment to enhance the evaporative cooling.

4. STORM DEVELOPMENT

Convection resulting from the surface heating of the boundary layer was limited over the Plains of New Mexico and the western Panhandle area, and for the most part did not mature sufficiently to produce precipitation. This lack of convective venting of the moisture-rich boundary layer provided a potent latent heat source for the few convective storms which did mature. Convection was induced by the nearby mountains which provided a heat source and orographic lifting for the moist low-level flow. the customary pattern of convection south and east of a short-wave was

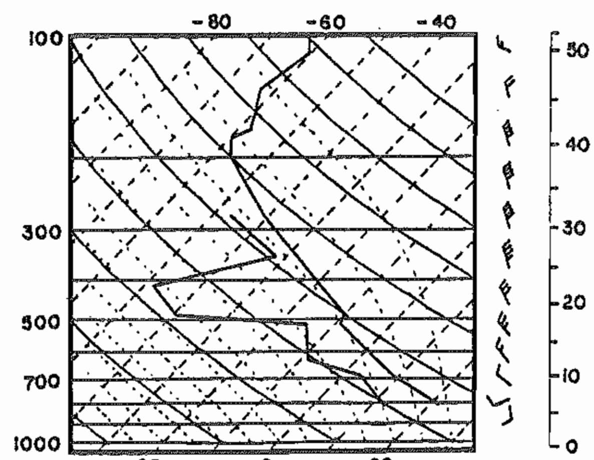

Fig. 6. Composite sounding over the northeastern Plains of New Mexico during the afternoon.

present over the eastern Panhandle and north-central Texas area extending north into Nebraska.

By 1900 GMT convection had developed over east-central Colorado and adjacent mountains, the Capulin Mountain area, and over the southeastern slopes of the Sangre de Cristo Mountains near Las Vegas, NM (LVS). Radar was detecting precipitation in these areas of convection on the 1930 GMT observation.

By 2000 GMT the embryonic convection area east of RTN had grown rapidly with propagation taking place on the eastern flank. Rapid development of the new cells continued, and the first reported severe weather occurred about 2100 GMT - a tornado touch down northeast of DM. The cell which produced the tornado broke away from the convective complex and moved east-northeast and continued to regenerate, apparently in response to the development of the upper-tropospheric low which by 0000 GMT on the 27th was centered over the juncture of Nebraska, Kansas and Colorado.

Following the spinoff of the cell, convection became very vigorous on the western flank of the convective complex. This activity produced the hail hear MX about 2200 GMT which accumulated to a depth of six and one-half inches. Aircraft reported tops at this time of 42,000 feet.

The southward-moving convection which developed over east-central Colorado reached the Capulin Mountain convective complex and was consumed. The southward speed of the complex increased, and hail and strong winds hit the RY area about 0000 GMT. Heavy rain fell at BR and baseball-size hail fell near Conchas Dam (CD) between 0100 and 0200 GMT. The maximum radar top of 51,000 feet was reported on the 0110 GMT special radar observation from AMA.

The low-level convergence was maintained during the afternoon by an increasing thermal gradient as temperatures climbed into the mid-90s in the Rio Grande Valley. The convection from the LVS area moved southeast during the afternoon. The Capulin Mountain complex continued to move south and began to weaken after 0200 GMT. Outflow from this complex interacted with the convection spawned near LVS which continued to regenerate while moving southeast. As in the previous instance when convection overtook an active complex, the southern complex dominated. Active convection developed in the northwestern portion of the LVS complex. This convection produced the marble-sized hail reported near Fort Sumner (FS) about 0415 GMT. Outflow from the Capulin Mountain complex reached ABQ at 0500 GMT with a gust of 36 knots and a dew point temperature jump from 29 to 52 degrees. The merged complex moved southeast into Texas by 0800 GMT.

5. DISCUSSION

Severe weather associated with south and southeast moving storms has been previously documented by other investigators, first by Galway (1958) and more recently by Johns (1982). Johns took the tornado data set developed by Fujita and Pearson for the period 1930-1974 and screened the data for tornado occurrences in which the path was oriented from northwest to southeast, his figure is included here as Fig. 7. Note the number of tornado occurrences east through south of the Capulin Mountain area in northeastern New Mexico and the northwestern Panhandle area.

Terrain-induced south and southeast moving convective storms occur almost annually during the summer over much of New Mexico and Arizona. However, we seldom receive reports which meet the criteria used to identify severe weather, i.e., 3/4-inch hail and/or 50-knot winds. This may be due to the limited boundary layer moisture, but another factor is the sparse population.

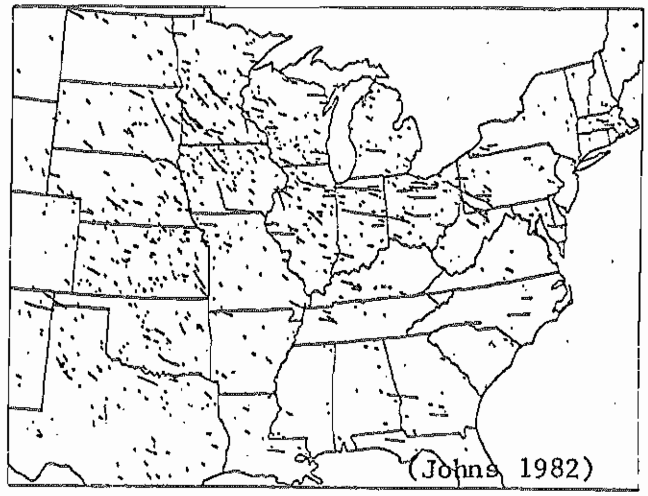

Fig. 7. Tornado tracks with a northwest—southeast orientation.

Johns (1982) noted that severe weather associated with convection in northwesterly flow at mid-tropospheric levels occurs mainly from late May through August. The diurnal heating cycle controls the convective development with the first reports of severe weather coming between noon and 6 PM local time with most outbreaks lasting from 4 to 14 hours. The severity of the storms is modulated by the available low-level moisture, but mid-tropospheric instability in concert with orographically induced convection play an important role as evidenced by the high frequency of severe weather reported on the Plains east of the Rockies. These latter factors are also important in the southward-moving high-based thunderstorms over New Mexico and Arizona which often produce strong winds and blowing dust but little precipitation.

6. SUMMARY

Severe weather does occur when the mid-tropospheric flow is northwesterly. Researchers have identified several conditions which are favorable to the formation of convection which produces severe weather in northwesterly flow, these are shown schematically in Fig. 8. The conditions are: a moist boundary layer with surface dew points in the mid-50s or above, a tropospheric short-wave trough moving from the long-wave ridge position into the long-wave trough and strengthening (maximum wind axis on the west side of the short-wave) with cold advection at mid- and upper-tropospheric levels, a surface low southwest and a surface high northeast of the severe weather area to provide low-level convergence. Orographic features favoring convective development should be considered when locating possible areas of severe weather development as they frequently provide the embryo of the convective storm.

Acknowledgments. My thanks to R. H. Johns of the National Severe Storms Forecast Center, Kansas City, MO for his assistance. A special thank you to N. J. Ropar and the staff of WSFO, Albuquerque for their comments and suggestions.

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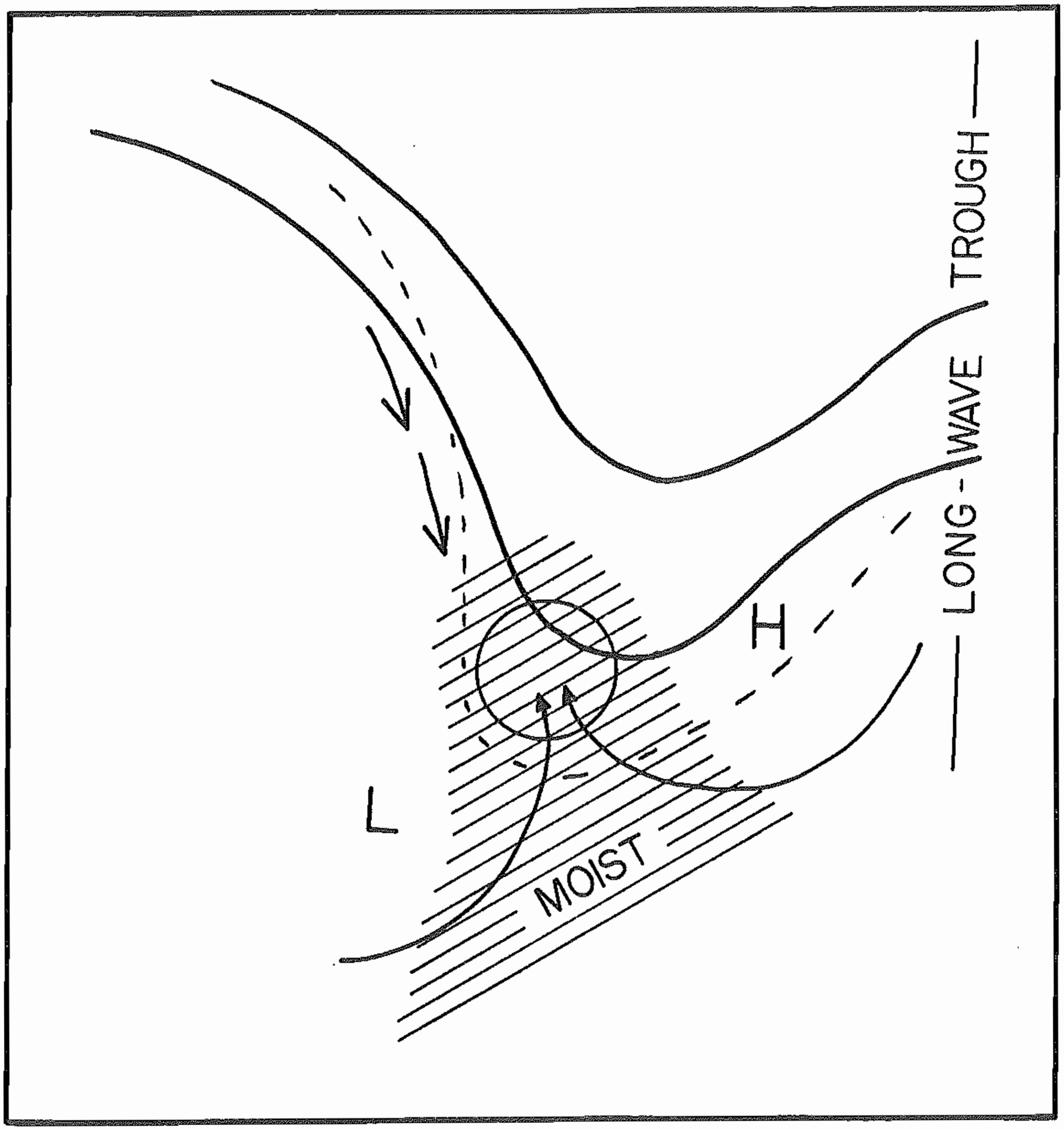

Fig. 8. Schematic of conditions which favor the development of severe weather in northwesterly flow aloft.

July Thunderstorm Produces Large Hail in Miami, Florida

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1. Introduction

The occurrence of hail in any season of the year is quite rare in south Florida; the observation of large hail, over one inch, is even less common. A hailstorm in March was studied by Neumann (1965), which is probably the most complete study on a particular storm. However, this was in the spring season. A couple of reasons for the scarcity of hail during the summer are the warm temperatures aloft and the lack of "supercell" thunderstorm development.

During the first two weeks or so of July, 1983, Florida had been experiencing a dry spell following a wet June. A large high pressure area had settled in over the southeastern states, producing a stagnant air mass situation. In fact, Miami WSFO issued it's first air stagnation advisory ever for north Florida on the 11th. By the 18th, the axis of the surface ridge was across south Florida. Temperatures aloft over south Florida at 500 MB were uniformly warm. At West Palm Beach the temperature was -7 to -8 Celsius. As a result of the stable atmosphere, thunderstorm activity was at a minimum. In fact, very little convection was evident over the weekend of the 16th and 17th -- a very rare phenomenon for south Florida in the summer in itself. This type of observation was hindered by the amount of haze obscuring the sky. Daily maximum temperatures were reaching the lower 90s. In all, conditions were very similar to northeastern heat waves, which were indeed occurring that weekend. Temperatures well up into the 90s were roasting the entire eastern half of the nation, even up into New England.

Then, on Monday, July the 18th, changes took place in the atmosphere causing very unstable conditions which resulted in the development of several large thunderstorms on the sea breeze front along the southeast Florida coast. At least one of these storms produced hail in the Miami area which, by Florida's standards, would be classified as large hail.

The purpose of this paper is to point out the features that were indicators of possible hail on that particular day.

2. Synoptic Situation

At 8:00 P.M. EDT on the 17th, the surface ridge was across south Florida (Fig. 1a). At 500 MB the ridge was across north Florida and Georgia. An important feature was a cold low at 500 MB to the east of the northern Bahamas (Fig. 1b). The LFM prognostic package run from the 0000Z data on the 18th forecast the low to move west southwest. An 08 absolute vorticity center was associated with this low center. The axis of higher absolute vorticity extended west southwest over the Florida Straits. At higher levels, this low center was also apparent. At West Palm Beach, the morning atmospheric sounding on the 18th showed that the wind veered with height from southwesterly at the surface to northeasterly above 850 MB (Fig. 4). The 500 MB temperature was -8 Celsius at that time.

At 8:00 A.M. EDT on the 18th, there was no change in the surface pattern (Fig. 2a). The weak gradient which would be conducive for a sea breeze front to develop was still present. The cold low at 500 MB had moved west southwest during the past 12 hours and was approaching the northern Bahamas. The ridge at 500 MB had drifted southward (Fig. 2b). The 500 MB height at West Palm Beach had lowered 30 meters, and the temperature decreased 2 degrees Celsius during that 12 hours. It was now -10 Celsius at 500 MB -- a rather cold July reading for south Florida.

At both times, a northeasterly wind maximum of 20 to 25 knots was across central Florida at 300 MB and above (Figs. 1c & 2c). Light cyclonically curved winds were present over south Florida.

The 500 MB LFM analysis at 8:00 P.M. EDT on the 18th indicated an 08 absolute vorticity center just off the southeast coast of Florida (Fig. 3b). The 500 MB data would indicate that a low center was located just east of Key West, Florida. Extreme south Florida, Miami in particular, would be in an area of positive vorticity advection prior to this time, or when the thunderstorm activity was occurring in that area.

3. <u>West Palm Beach Sounding</u>

The 8:00 A.M. EDT sounding on the 18th at West Palm Beach showed every indication that thunderstorm development was probable that day (Fig. 4). The lifting condensation level (LCL) was less than 1000 feet, and the level of free convection (LFC) was at 3500 feet. This air mass was a good example of conditional instability. The small negative area near the surface would soon disappear, and the large positive area above the LFC would vigorously support convective currents. The various indices of stability all pointed to a favorable day for thunderstorms. The K Index was 30; the Lifted Index, -7; the Stability Index, -4; and the Total Totals, 51.

The sounding also showed high moisture content in the lower levels and a dry layer in the middle troposphere. The precipitable water calculated from the sounding was 1.69 inches.

The wet-bulb freezing level was at 11,000 feet, which according to Fawbush and Miller (1963), correlated rather well with 1/2 inch to 1 inch hail occurrences in the Plains.

4. Thunderstorm Development and Weather Events

One lone thunderstorm was detected over south Florida at 8:32 A.M. EDT on the Miami radar the morning of the 18th. This cell was just west of Jupiter. It had a VIP 4 intensity and a top of 40,000 feet. This thunderstorm during the next 5 hours moved southwest at 20 knots reaching the southwest coast of the Florida Peninsula by 1:32 P.M. EDT. During it's life cycle, this thunderstorm was a VIP 5 intensity at different times and had a maximum tope of 46,000 feet. Throughout the entire morning, this cell was the only echo over south Florida. Figure 5 shows this isolated cell during a five hour period from 8:30 A.M. until 1:30 P.M.

By 2:00 P.M., the sea breeze front had developed as indicated by radar and satellite (Fig. 6). Also quite evident on the satellite photograph was the cloudiness and convective activity over the Bahamas associated with the cold upper low center.

At 2:33 P.M., the thunderstorm which eventually produced the hail in Miami was just west of Fort Lauderdale with a top of 52,000 feet (Fig. 7). The intensity was at the VIP 5 level. A special weather statement and radar summary written at that time indicated the very heavy thunderstorms with the possibility of small hail along with strong gusty surface winds.

By 3:00 P.M., the thunderstorms along the sea breeze front had continued to intensify with four or five main cells becoming the dominant thunderstorms (Fig. 8). The hail producer was just west of Hollywood at that time with a top of 51,000 feet and an intensity of VIP 5. At this time the first report of marble-size hail at Miami Lakes, north of Miami International Airport, was received. This prompted a severe thunderstorm warning for eastern Dade County. From 3:00 P.M. until 3:40 P.M., six additional reports of hail up to golf ball size, or 1 1/2 inches, were received along and just to the left of the track of the thunderstorm cell (Table 1).

Figure 9 shows the 3:10 P.M. and the 4:00 P.M. location of the central core of the thunderstorm along with the location of the reports and size of the hail. The cell moved from 30 degrees at 22 knots during that 50 minutes.

A special radar observation was taken at 3:10 P.M. (Fig. 10). VIP levels 2, 3, and 5 are contoured on the overlay. An interesting feature is noted here. The reports of hail, 4 reports marked by ⓧ, received between 3:00 P.M. and 3:25 P.M., fall within the VIP 2 contour. It is suggested that the protrusion southeast of the main core and the isolated VIP 2 over Sweetwater was hail return. The hail was spewed out of the top of the thunderstorm and carried to the south by the upper winds.

At 2:52 P.M., Opa-Locka Airport, just east of the location of the initial hail report, observed a wind gust of 50 knots with the thunderstorm. From the 8:00 A.M. sounding at West Palm Beach, using

Fawbush's and Miller's (1953) method of estimating the peak gust from potential temperature drop, a gust of 75 knots could be obtained. This was computed by bringing the wet-bulb temperature at the wet-bulb freezing level (675 MB) down to the surface moist adiabatically. This gives a potential temperature of 63 degrees Fahrenheit. Petterssen (1956) says that the lowest temperature to be expected during a downdraft would not be very different from the potential wet-bulb temperature corresponding to the zero wet-bulb. Next, the maximum temperature was estimated from the sounding. A conservative estimate would be 90 degrees Fahrenheit. This is also the convective temperature--the temperature when free convection would begin. The temperature drop (90F minus 63F) of 27 degrees would give a potential peak gust of 75 knots (Fawbush & Miller, 1953). A more realistic maximum temperature forecast would be 94 degrees which would indicate a peak gust of 80 knots.

The thunderstorm brushed by Tamiami Airport, passing west of that location, causing the temperature to drop 25 degrees, 97 degrees to 72 degrees. This is close to the temperature drop, 27 degrees, computed above. The temperature at Miami International Airport dropped from 95 degrees to 80 degrees as a result of the outflow from the thunderstorm.

5. Conclusion

Experience has shown that following a dry spell in the summertime, the first active thunderstorm day is usually characterized by only a few large thunderstorms which grow to great heights and are quite intense. These thunderstorms frequently produce severe weather, as was the case on the 18th.

The West Palm Beach morning sounding definitely indicated that convection was likely, and the large positive area above the LFC would support vigorous upward motion to great heights as soon as the small negative area was wiped out by the initial morning's temperature rise.

The falling height at 500 MB and the temperature drop of 2 degrees Celsius were indicators of the decrease in stability and of the approach of the cold upper low center. Experience has shown that a 500 MB temperature of -10 Celsius or colder during the summer is favorable for intense thunderstorm activity, especially after a period of warmer temperatures.

The low level winds at West Palm Beach were light westerly near the ground which would produce low level convergence near the coast when the sea breeze started, thus enhancing the vertical development.

The presence of the cold low and the forecast movement of the low toward south Florida was also suggestive of active thunderstorms. In actuality, the low moved just south of the Florida Peninsula with the area of positive vorticity advection passing directly over south Florida during the afternoon.

In the past, it has been observed that intense thunderstorms occur over south Florida when the upper wind flow is from the north or the northeast. This flow pattern places the upper level trough to the east of the state. In this instance, the 300 MB and 200 MB trough was across the Bahamas and the Florida Straits.

This was a classic hailstorm for south Florida.

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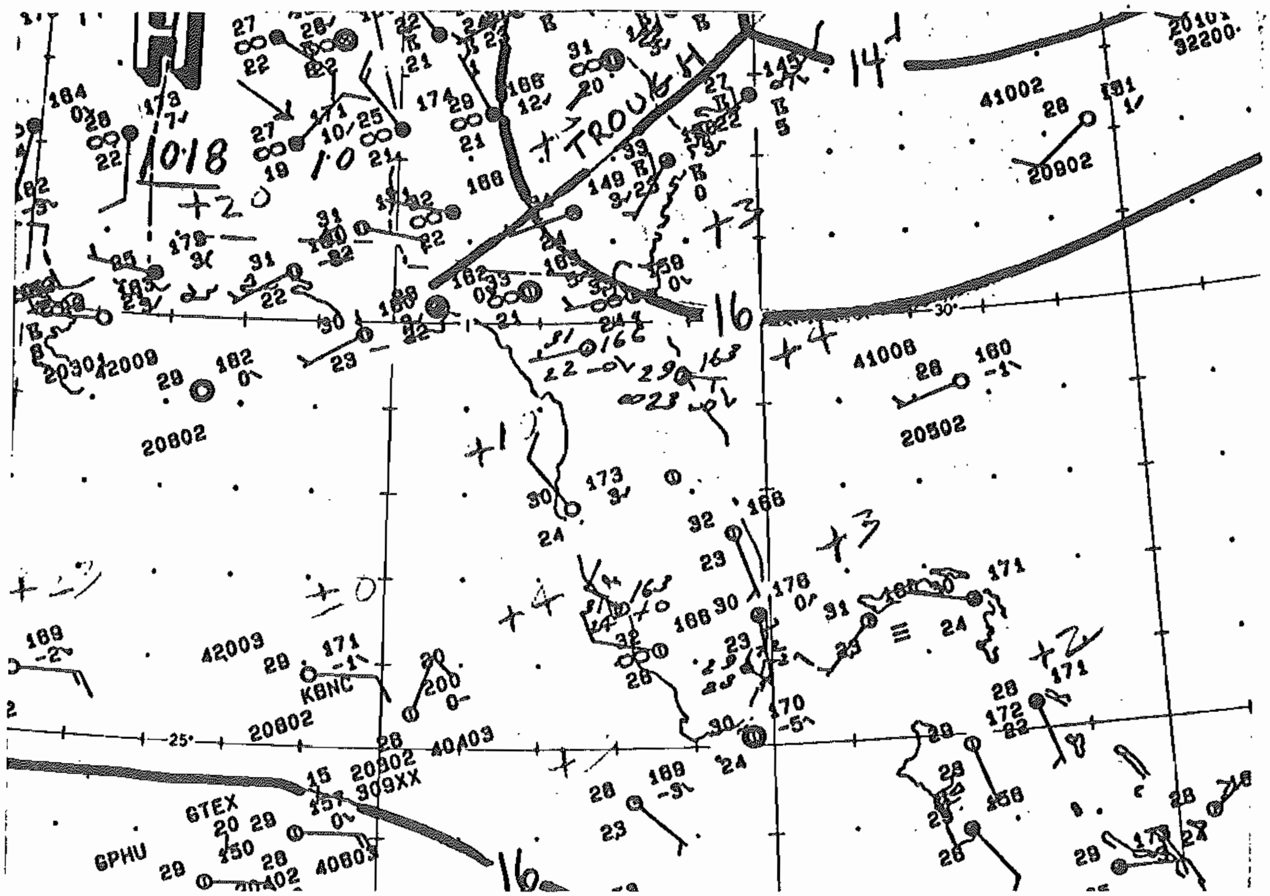


Figure 1a. 8:00 P.M. EDT, July 17, 1983
Surface Analysis

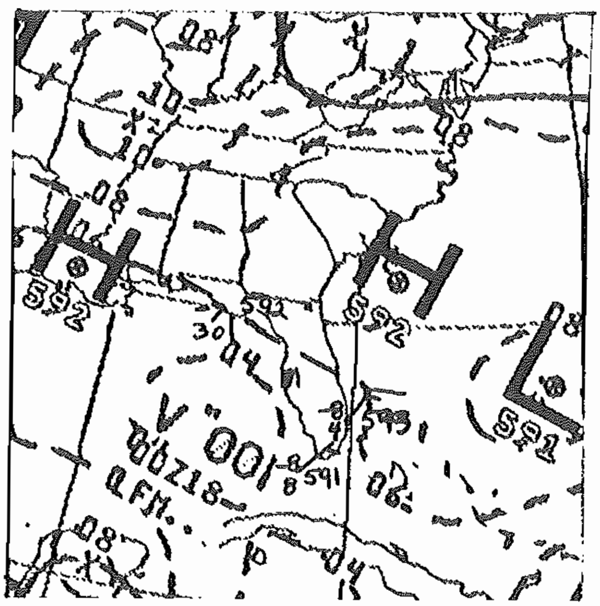


Figure 1b. Initial LFM 500MB Analysis. 8:00 P.M. July 17.

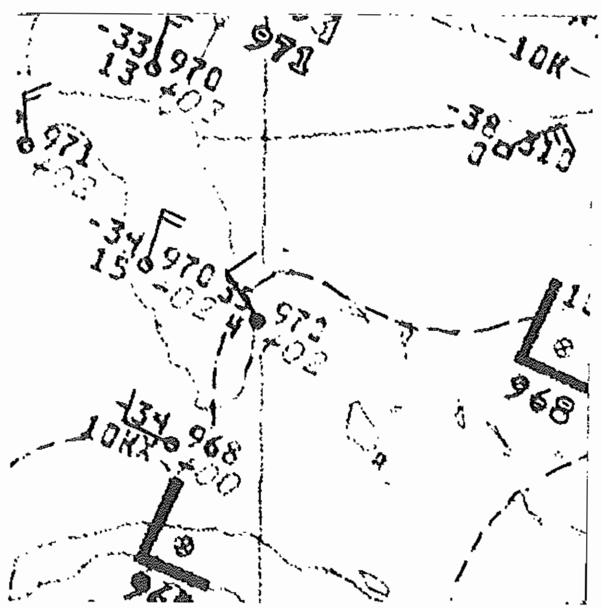


Figure 1c. 300MB Analysis 8:00 P.M. July 17

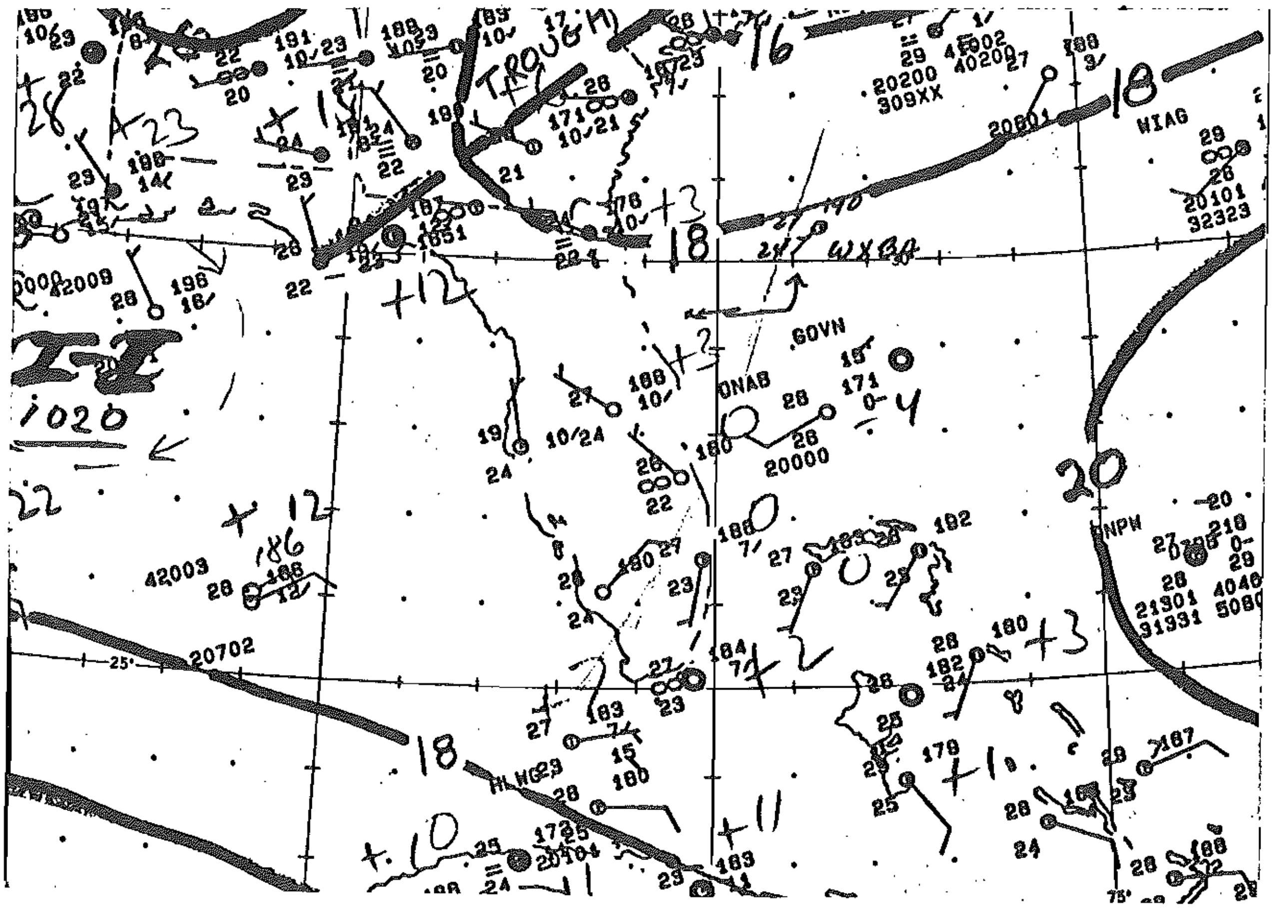


Figure 2a. 8:00 A.M. EDT, July 18, 1983
Surface Analysis

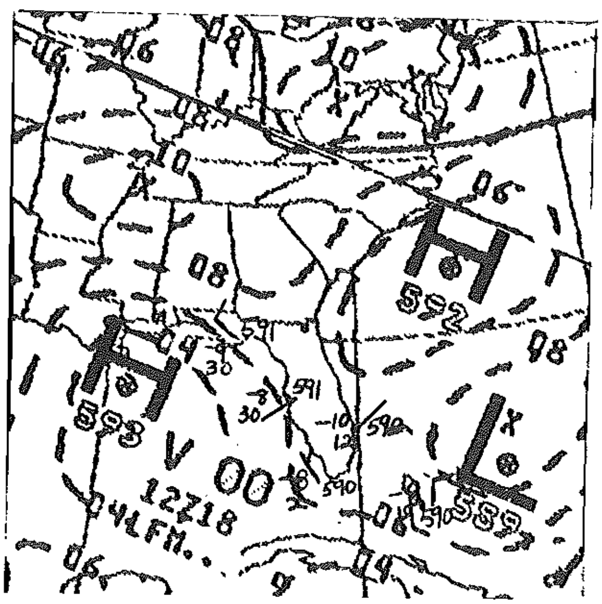


Figure 2b. Initial LFM 500MB Analysis. 8:00 A.M. July 18.

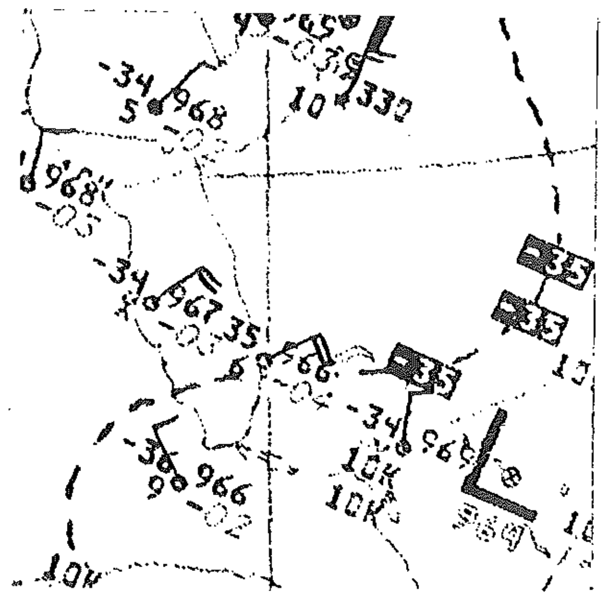


Figure 2c. 300MB Analysis 8:00 A.M. July 18.

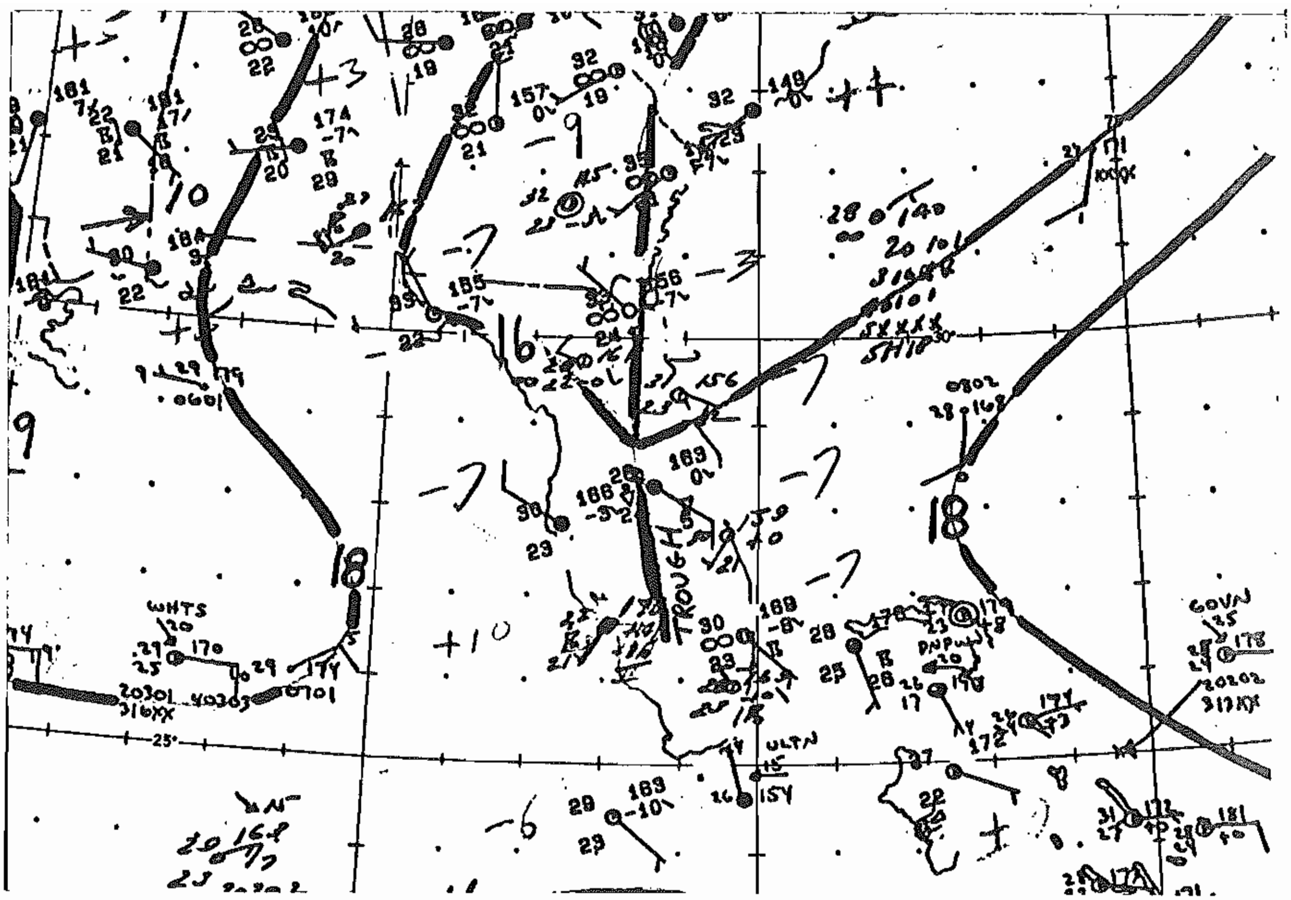


Figure 3a. 8:00 P.M. EDT, July 18, 1983
Surface Analysis

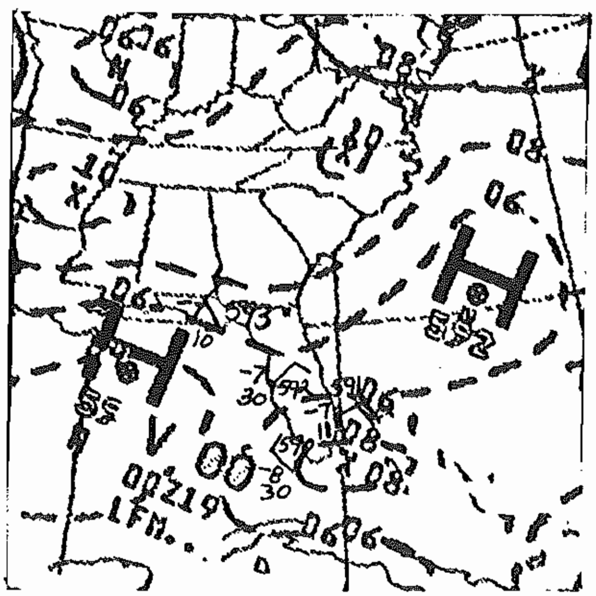


Figure 3b. Initial LFM 500MB Analysis. 8:00 P.M. July 18.

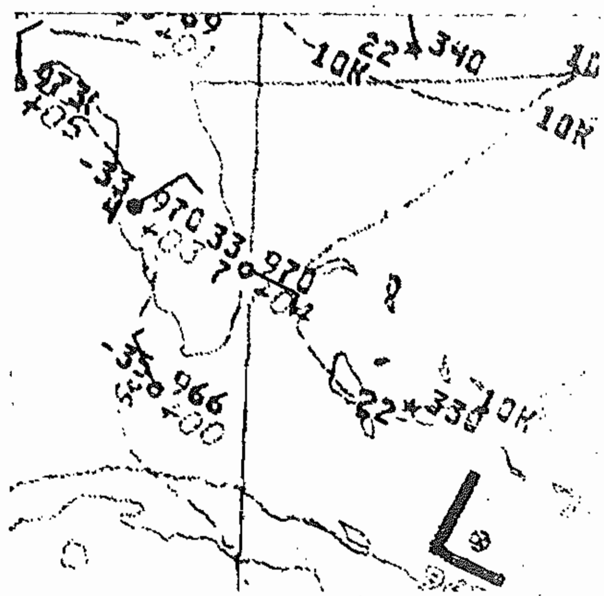


Figure 3c. 300MB Analysis 8:00 P.M. July 18.

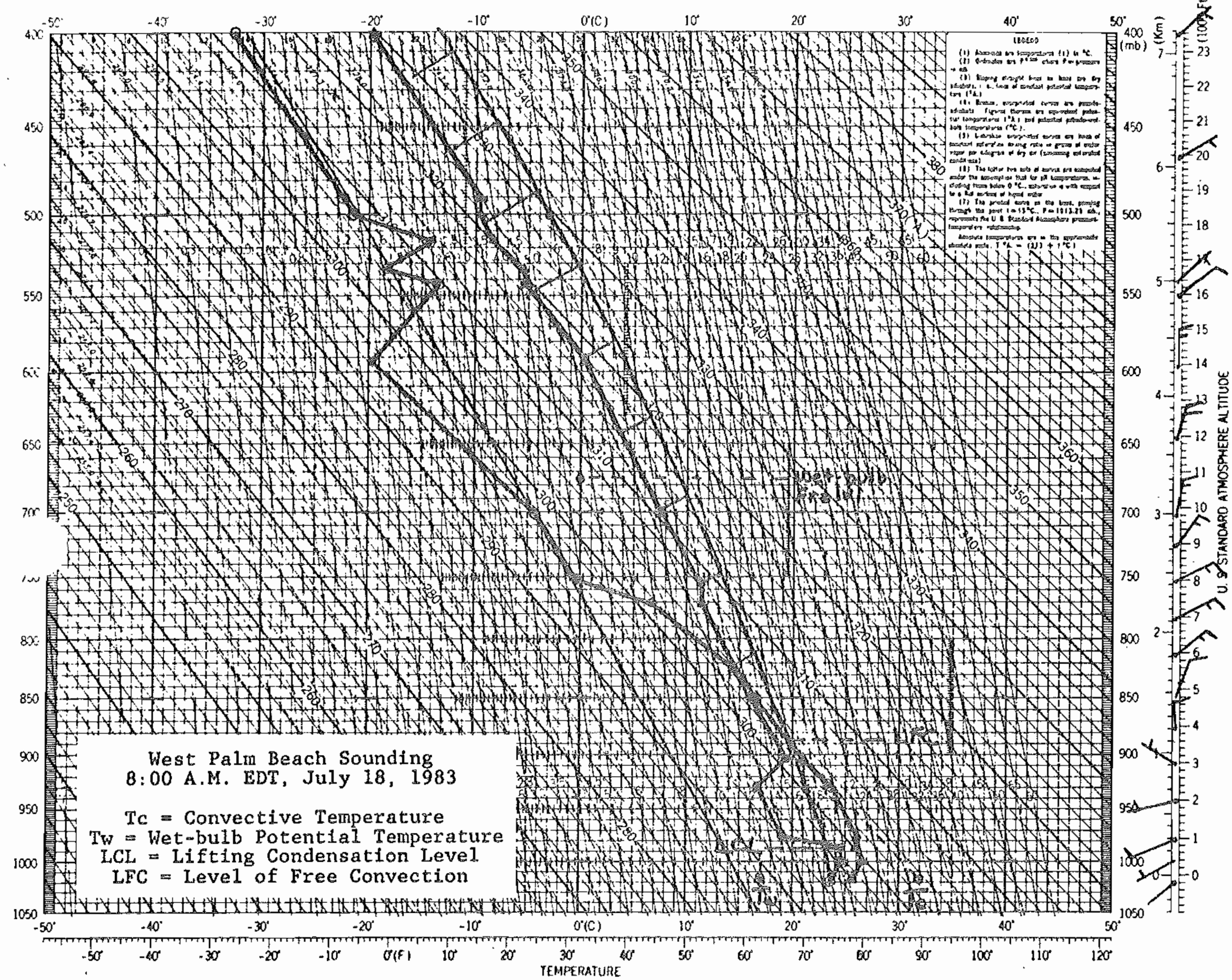
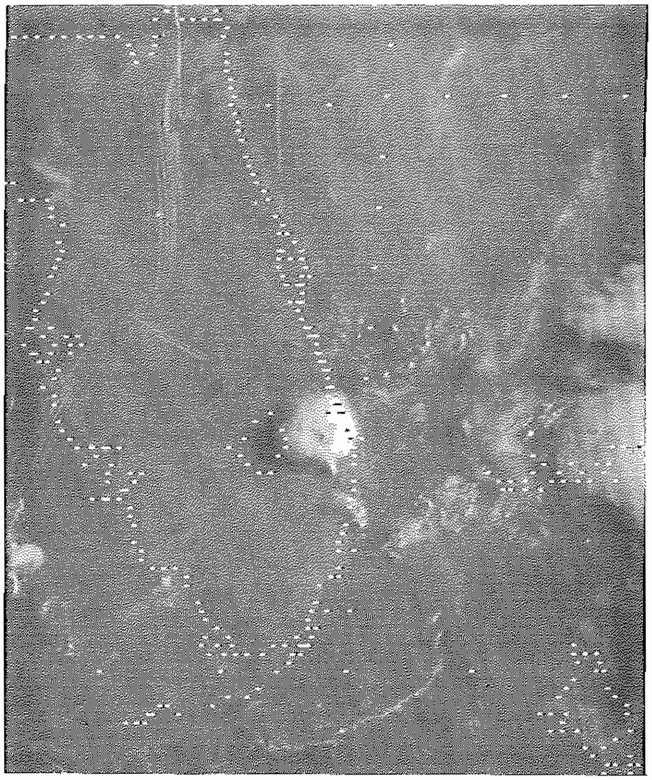
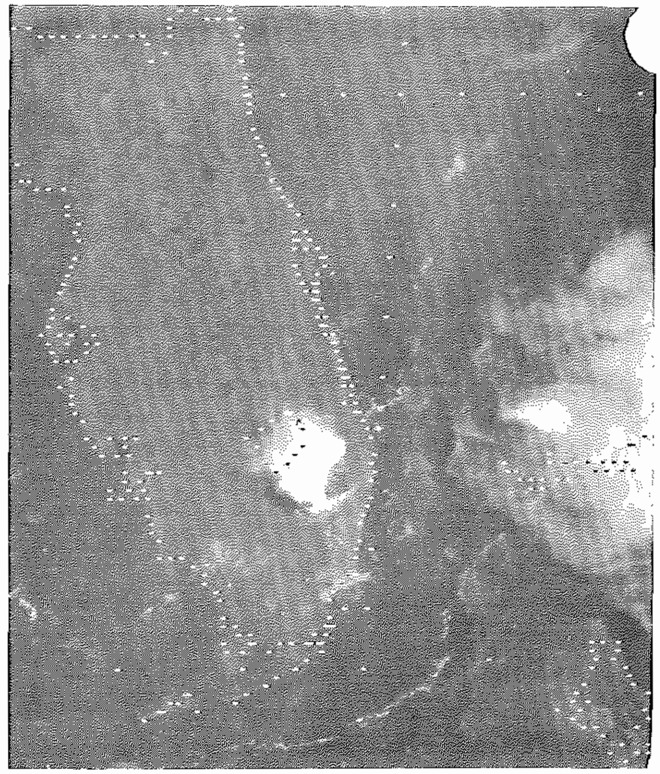

West Palm Beach Sounding
8:00 A.M. EDT, July 18, 1983
Tc = Convective Temperature
Tw = Wet-bulb Potential Temperature
LCL = Lifting Condensation Level
LFC = Level of Free Convection
TEMPERATURE
U.S. STANDARD ATMOSPHERE ALTITUDE

Figure 4.

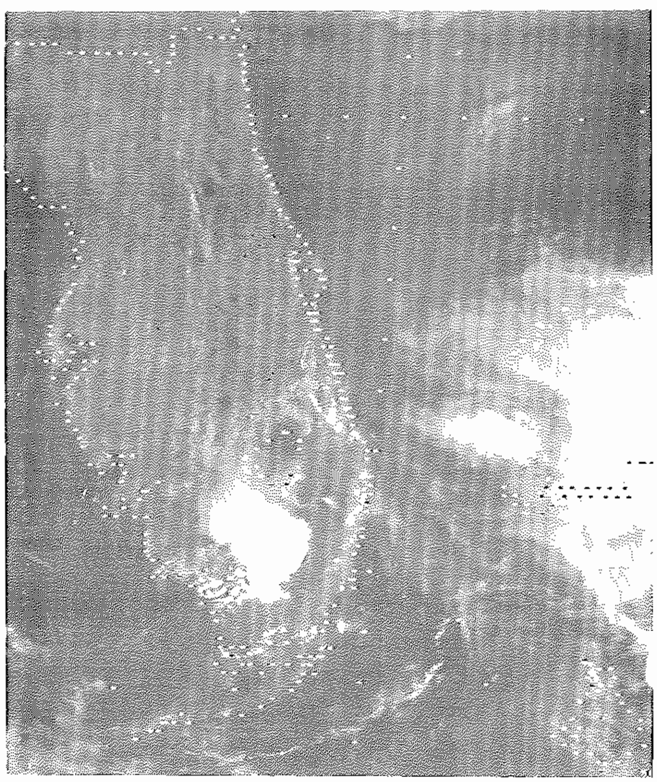
Figure 5. Isolated Thunderstorm Cell, Morning of July 18, 1983.



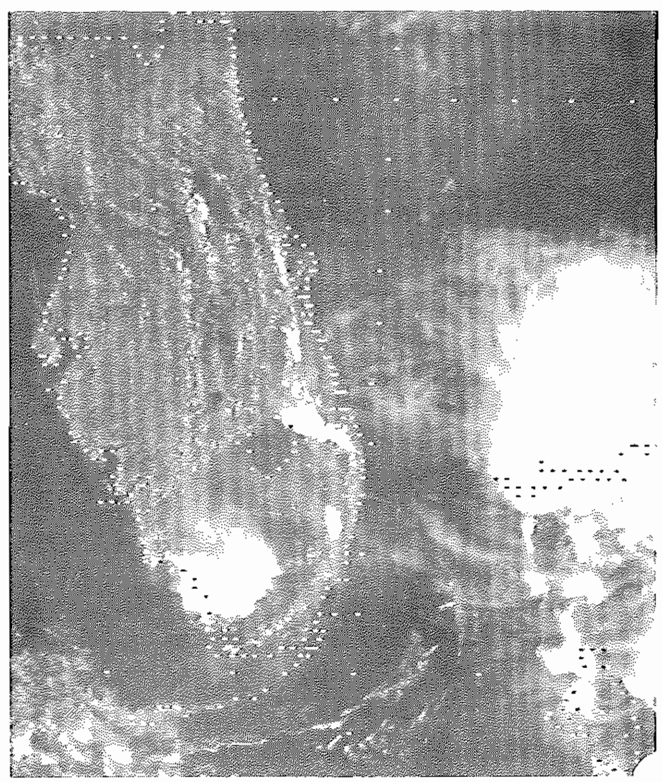
8:30 A.M. EDT



10:00 A.M. EDT



12:00 Noon EDT



1:30 P.M. EDT

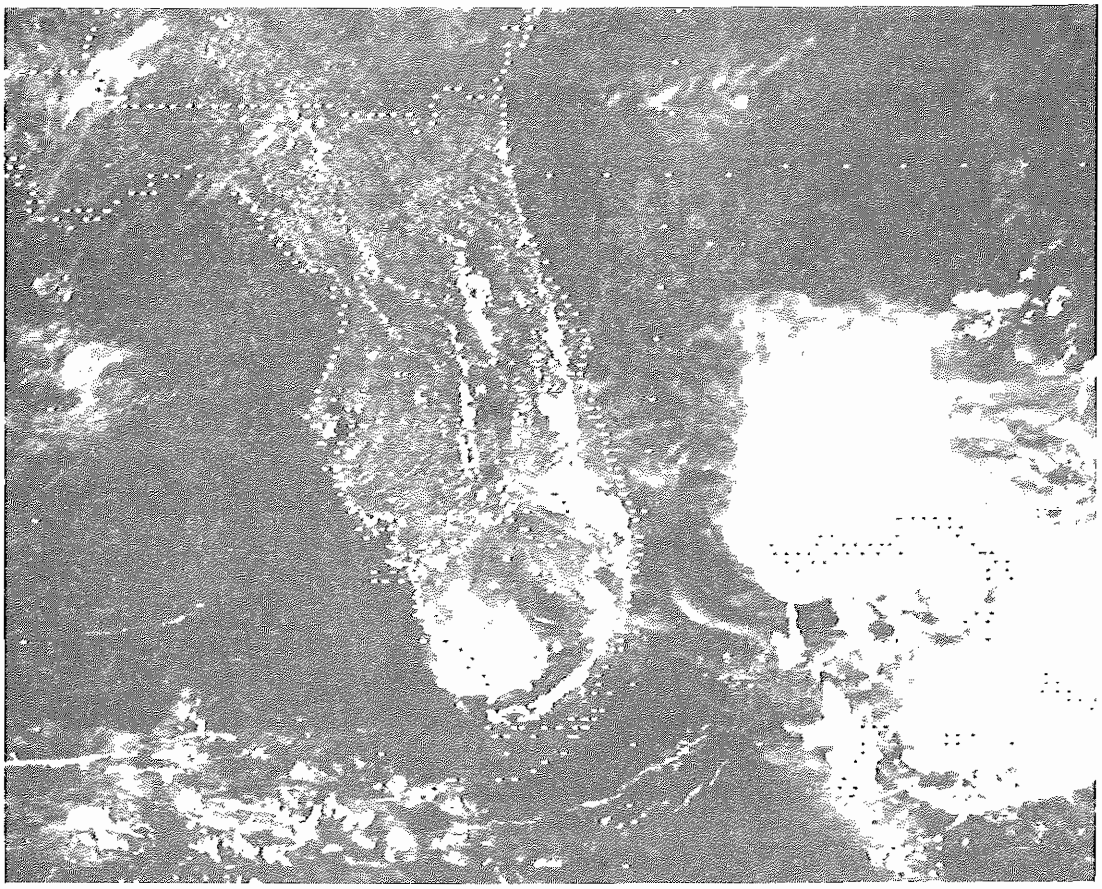


Figure 6. 2:00 P.M. EDT, July 18, Visible Satellite Photo.

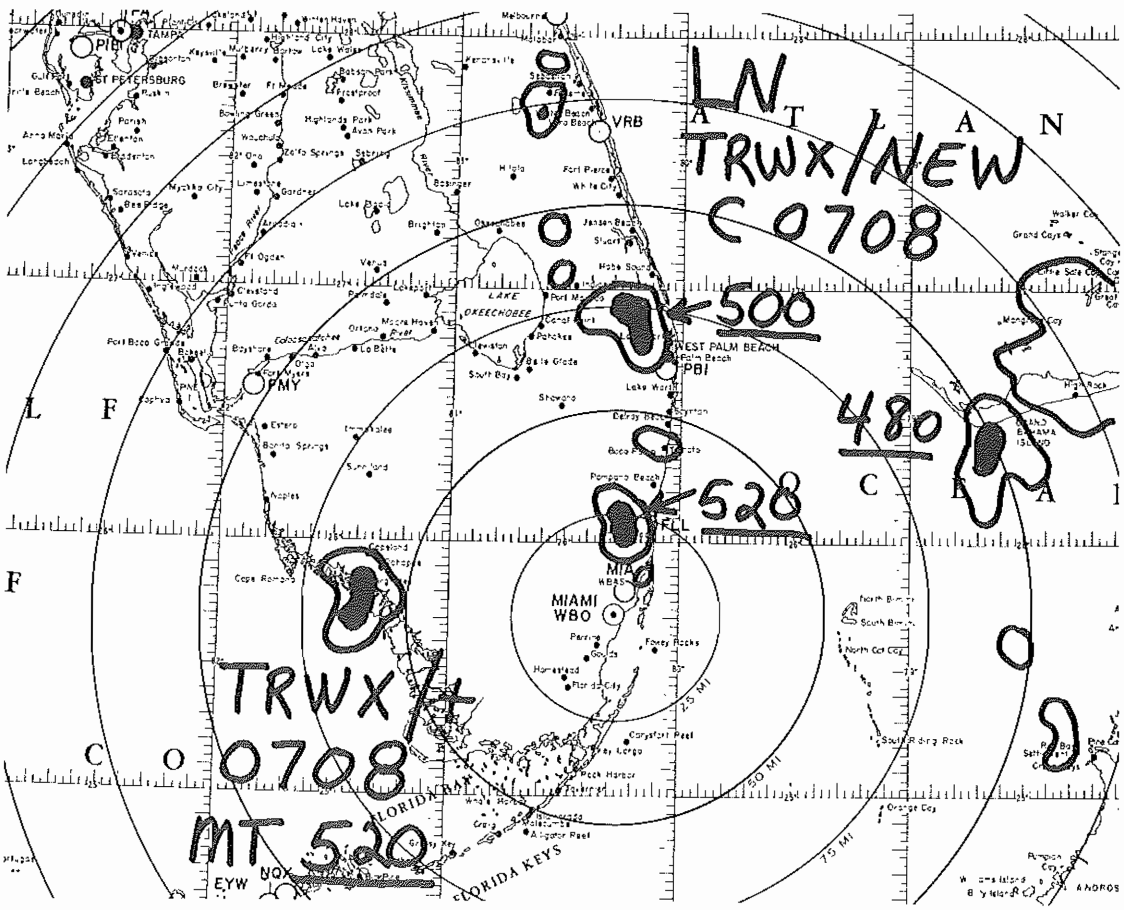


Figure 7. 2:33 P.M. EDT, July 18, Miami WSR-57 Radar Overlay.

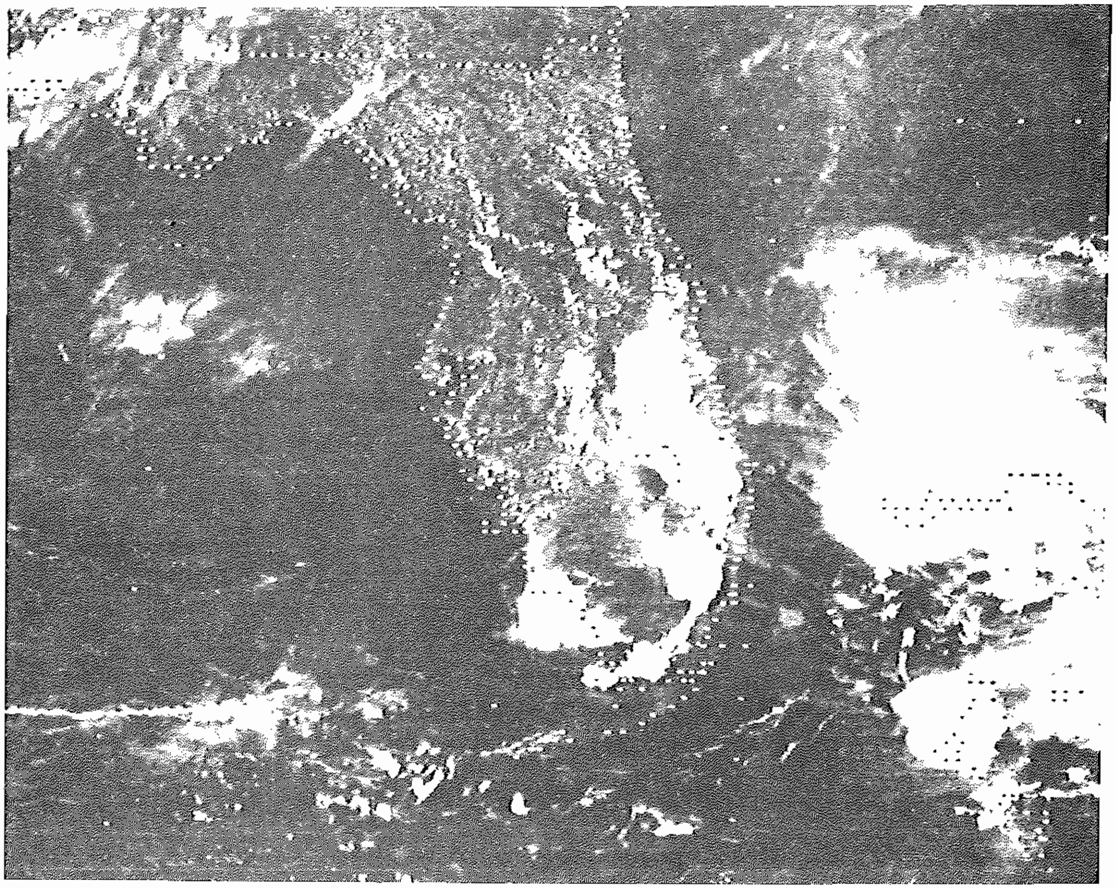


Figure 8. 3:00 P.M. EDT, July 18, Visible Satellite Photo.

Table 1. Local Storm Report

300 PM EDT	Marble size hail Miami Lakes.
315 PM EDT	Marble size hail and power outage Hialeah.
325 PM EDT	Golf ball size hail Sweetwater.
	1-inch hail North Hialeah.
	1 1/2-inch hail South Dade County (S.W. 150 Street and 130 Avenue).
337 PM EDT	Golf ball size hail South Dade County (Bird Road and S.W. 137 Avenue).
340 PM EDT	Large hail...wooden fence damaged...gate blown over... metal support pole bent Kendall Lakes (S.W. 69 Street and 153 Avenue).
355 PM EDT	Unconfirmed tornado Goulds area (S.W. 216 Street and 127 Avenue). Police found no evidence of tornado.

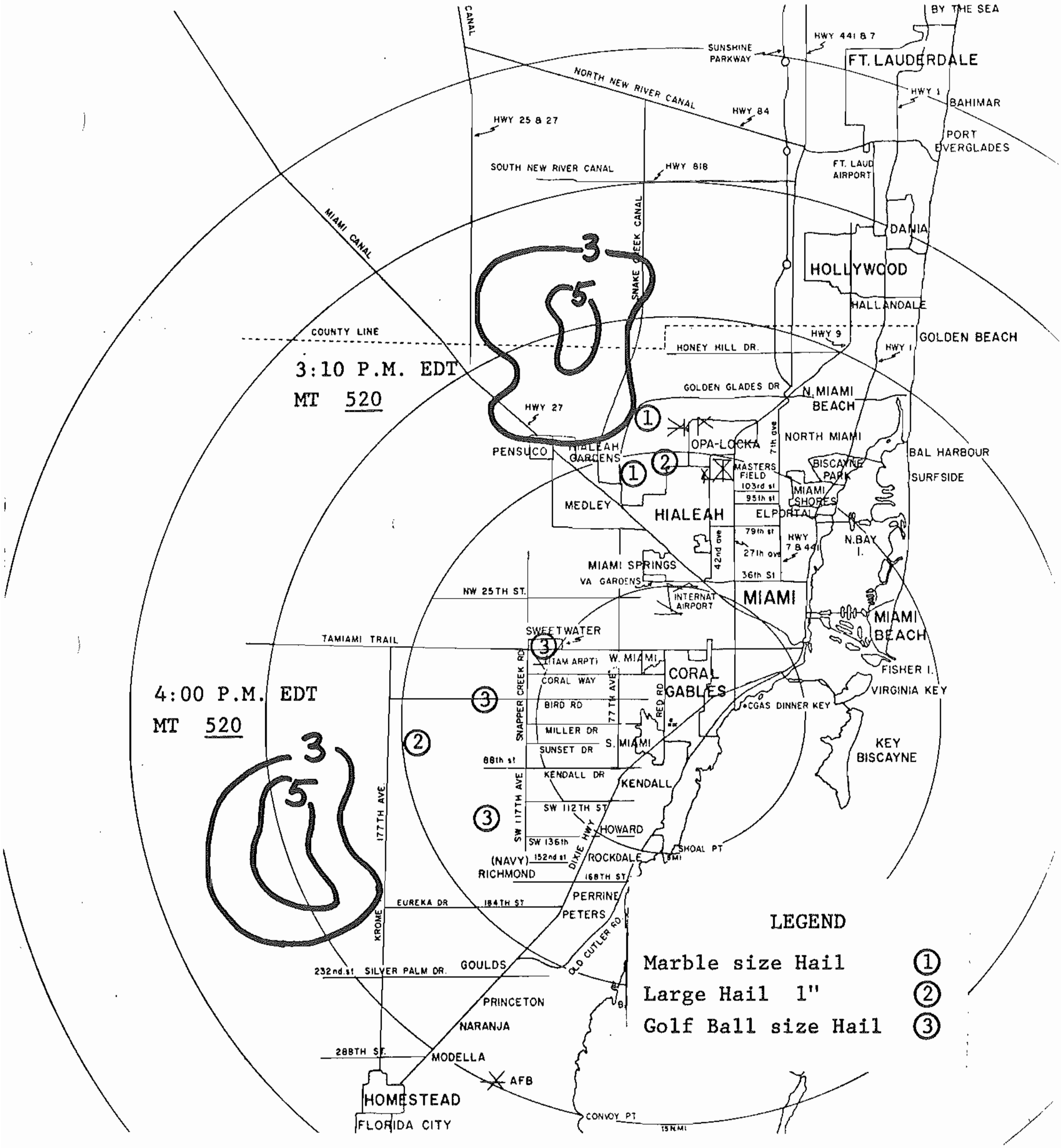


Figure 9. Miami WSR-57 Radar Overlay Composite. July 18, 1983. Vip level 3 & 5 depicted 3:10 P.M. and at 4:00 P.M. MT is Maximum echo top. Circled numbers locate Hail reports and hail size. Table 1 gives more detailed information on hail reports.

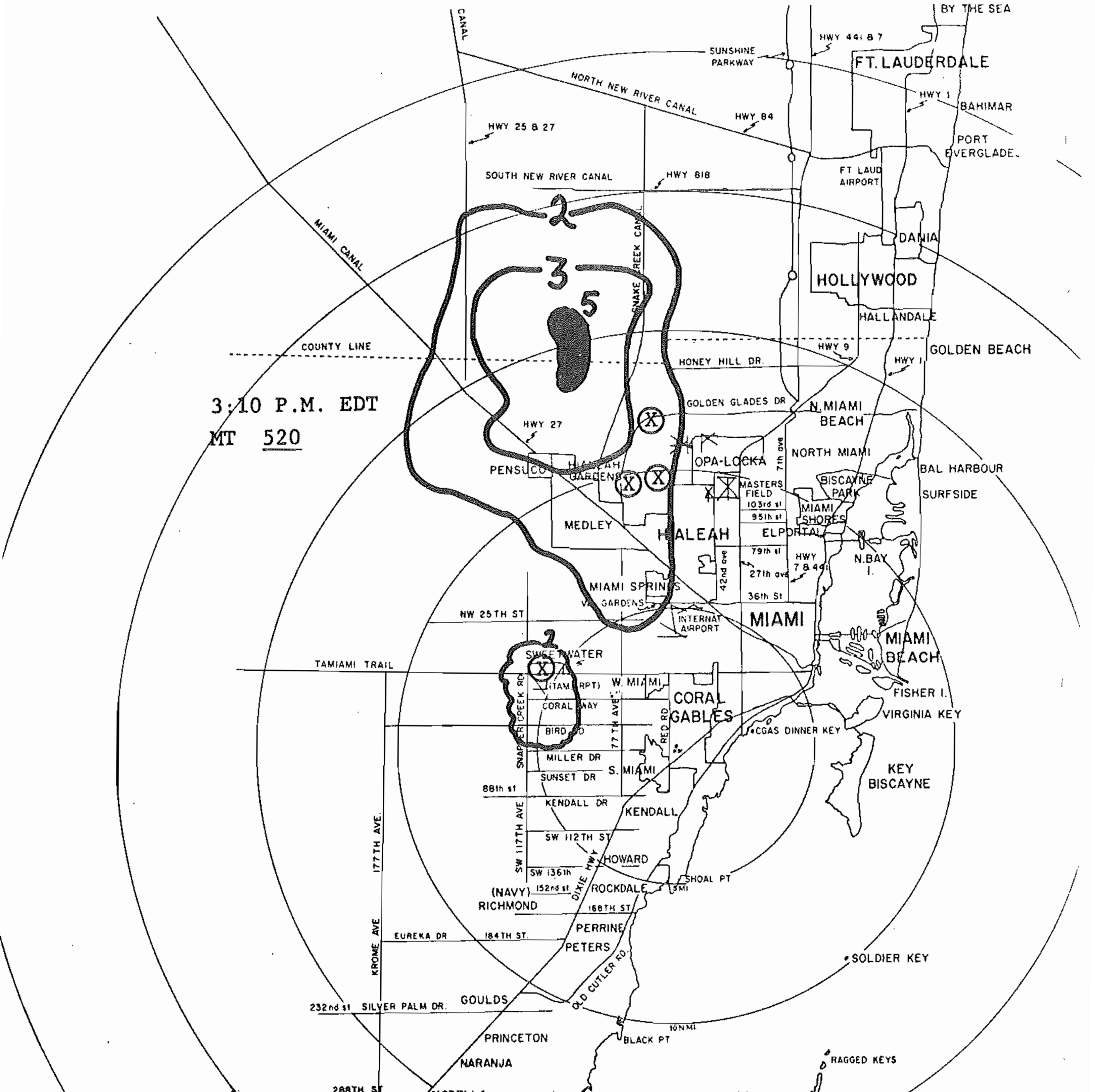


Figure 10. Miami WSR-57 Radar Overlay of Special Observation at 3:10 P.M. EDT, July 18. VIP levels 2, 3, & 5 are contoured showing the core of hail producing thunderstorm. Ⓧ locates hail reports received close to time of observation.