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SYNOPTIC ASPECTS OF HEAVY RAIN EVENTS IN SOUTH TEXAS ASSOCIATED WITH THE WESTERLIES

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ABSTRACT

Meteorological conditions associated with 33 heavy rain events in South Texas have been examined. The results were compared with a study of over 150 events by Maddox et al. (1979). Analyses of surface and standard level upper-air data revealed 31 of the 33 heavy rain events to be associated with either the frontal or mesohigh type patterns. Some geographical stratification appears to exist since the mesohigh events occur most frequently over south central and southeast Texas. Although the middle and upper troposphere create a favorable environment, instability and low-level moisture convergence appear to be necessary precursors for heavy rain. The area of maximum rainfall was found to be located near the intersection of the 850 mb maximum winds and the surface front or thunderstorm outflow boundary. The angle of intersection of these features is an important factor in the formation of heavy rains. Typical synoptic and mesoscale patterns are developed for the two heavy rain types and temporal distributions presented.

1. Introduction

Forecasting locally heavy rains is one of the most challenging operational weather forecast problems in South Texas. Experience indicates that exceptionally heavy rainfalls are not uncommon in this region. For example, in each of the past four years, events have occurred in which 24 h rainfall exceeded 20 in.! The remains of tropical storm Amelia produced a 24 h rainfall of at least 31 in. over the Hill Country in 1978 (Caracena and Fritsch, 1981) with 21 in. falling during a 12 h period (NOAA, 1979). In 1979 tropical storm Claudette produced 43 in. of rain near Houston in only 22 h (Freeman et al., 1980). The remains of tropical storm Danielle caused over 20 in. over the Hill Country with a second 20 in. maximum near Beaumont in 1980; and in 1981, the remnants of a tropical depression resulted in rain amounts near 20 in. across portions of south central Texas.

Twenty inch rains, which are not always associated with tropical storms, can apparently be expected to average one a year with several events falling in the 10 to 20 in. category; however, 24 h rainfalls over five inches are much more common. Indeed, during 1980 South Texas reported almost three times the number of flash flood events as were recorded in any other part of the country (NOAA, 1981). The frequency and impact of heavy rains in South Texas requires a tailored, detailed study of these events.

At the National Weather Service Forecast Office in San Antonio, a multifaceted approach is being brought to bear on the heavy precipitation forecast problem. A local quantative precipitation forecast (QPF) study is underway. This effort is following an approach similar to that successfully employed by Belville et al. (1978) and Mortimer et al. (1980) for West Texas. Other studies have been designed to detect common meteorological features for South Texas heavy rainfalls. In such studies, events have been classified as "westerly" (associated with the polar westerlies at 500 mb) or tropical. This paper presents results of the investigation of westerly heavy rain events (HR events). Maddox et al. (1979, hereafter referred to as M79) considered 151 intense, non-tropical, flood-producing precipitation events and identified important synoptic and mesoscale mechanisms that act to intensify and focus precipitation events over specific regions. Although only 7 of these 151 cases occurred over South Texas, the study provided a logical framework for a more detailed examination of South Texas HR events.

2. Data Sources

For the past 5 years (1977-1981) the South Texas Service Hydrologist (WSFO staff member) has archived computer plotted, 24 h rainfall maps produced at the River Forecast Center in Fort Worth, Texas. One-inch isohyets were subjectively analyzed and HR events identified. An HR event was defined as $\geq$ 5 in./24 h for all of the study area except the Hill Country - see Fig. 1 - where 4 in./24 h was considered an event. An attempt was made to identify those situations where HR affected significant areas and extremely localized rain events were not included. Thirty-three events were eventually selected for detailed study.

Data packages were assembled for each of these cases. Included were twice daily charts for the standard levels 850, 700, 500, 300, and 200 mb and 3 hourly surface maps. Also available were twice daily charts of stability and atmospheric moisture content. Subjective interpolations were made in time and space to estimate meteorological conditions just prior to the HR. To aid in these interpolations, hourly enhanced IR satellite images were examined for all events. Film from the NWS WSR-57 radar at Galveston was available for 17 events; however, Hondo radar films were not available.

3. General Characteristics

All but 2 of the 33 HR events fit either the frontal or mesohigh categories described by M79. The remaining two events appeared to be hybrid synoptic-frontal types. Synoptic events (as defined by M79) are rare in South Texas. However, this should be expected since this type of event is triggered by a slow moving front oriented north to south, a combination that occurs infrequently over South Texas.

Figure 1 shows the approximate locations of the HR areas for the 19 mesohigh and 12 frontal events studied. Ten events exhibited multiple isohyet centers and each center was plotted where HR criteria were exceeded. (Because of this, the number of center plots exceeds the number of events.) Orographic lifting may have played an important role with the frontal events that occurred over the western part of the area. Mesohigh events show a more distinctive pattern. Eighty-two percent of these HR centers fall within a narrow band extending from just northwest of San Antonio (SAT) eastward to the Louisiana border. This region lies along the northern boundary of the study area and were heavy rain events considered for all of Texas the narrow band would merely be near the southern limit of mesohigh events.

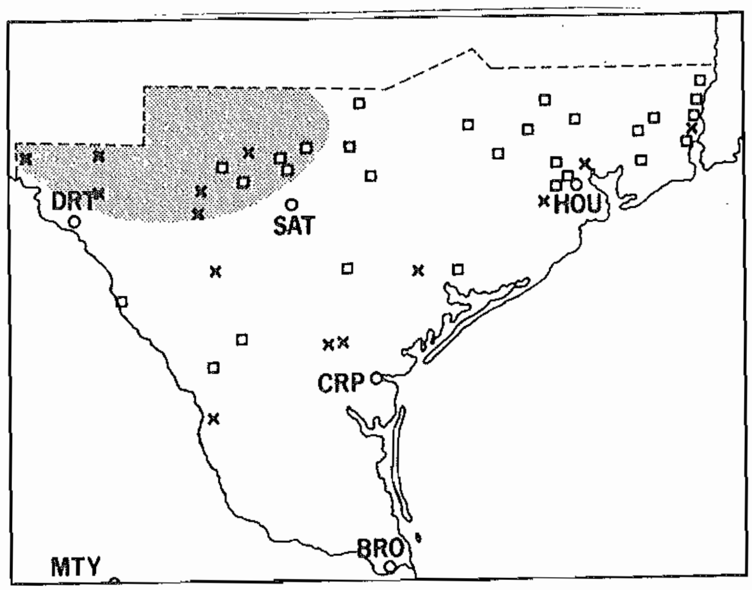

Figure 1. Locations of centers of heavy rains for frontal events (denoted by X's) and mesohigh events (denoted by squares). Dashed line represents northern border of study and shaded area shows approximate location of Hill County.

The absence of mesohigh HR events over extreme South Texas is probably the result of two synoptic factors. Climatologically, mesohigh HR show a distinct peak during late spring and early summer. This is just the time of year when the subtropical high is frequently well established over the Gulf of Mexico and Texas with the ridge line often lying in the vicinity of Brownsville (BRO) or Corpus Christi (CRP). The associated subtropical low-level inversion effectively supresses convection. Within this synoptic setting only strong middle and upper-level short waves can effectively break the inversion and trigger thunderstorms. However, strong, well-organized systems and their attendant convection generally move rapidly across the region, resulting in lower rainfall amounts. Weak middle and upper tropospheric short waves cannot destroy the strong inversion near the subtropical ridge but are apparently capable of causing thunderstorms further north where the inversion is weaker.

Figure 2 shows the monthly distribution for the combined frontal and mesohigh HR events (the two types were combined since individual distributions were similar). Heavy rains in South Texas are most frequent during the late spring and early summer months of April through June - remember that "tropical" heavy rains have not been considered in this study. Sixty-eight percent of the events occurred during these three months, and a more detailed examination shows the HR to be concentrated from the last two weeks in April through the first two weeks in June. Although the sample is small, forecast experience shows that the period from April 15th through June 15th is a critical time for "westerly" heavy rains over South Texas. During this period, the westerlies usually remain over the middle United States with much of Texas along the southern border of the westerlies. Short waves traversing the Central Plains can bring weak cold fronts into South Texas. This period is also one of transition, characterized by the strengthening subtropical high in the Atlantic. As the influence of the high extends into the western Gulf of Mexico, influxes of tropical moisture move across South Texas and interact

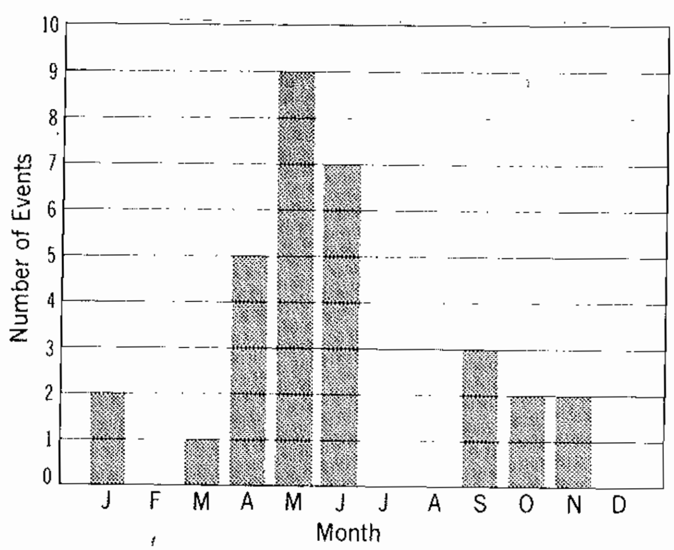

Figure 2. Monthly distribution of heavy rain events studied.

with weak surface fronts and short waves in the westerlies. July and August are typically dominated by the subtropical high and no HR associated with the westerlies occurred during these months.

Many flash floods occur at night (M79), and Hoxit et al. (1978) examined possible mechanisms that contribute to the development of intense convection after sunset. Figure 3 shows the time of onset of the two types of HR under consideration. The nocturnal nature of frontal type rains is apparent with the distribution closely following that shown by M79. A distinct maximum is observed at night with a minimum during the day. The distribution for mesohigh events also shows a maximum at night but the minimum during the day is not as pronounced. Frontal type HR events may be related to the formation of a low-level nocturnal wind maximum (Hoxit et al., 1978); whereas, mesohigh events appear to be more closely related to an approaching short wave and are more evenly distributed during the day.

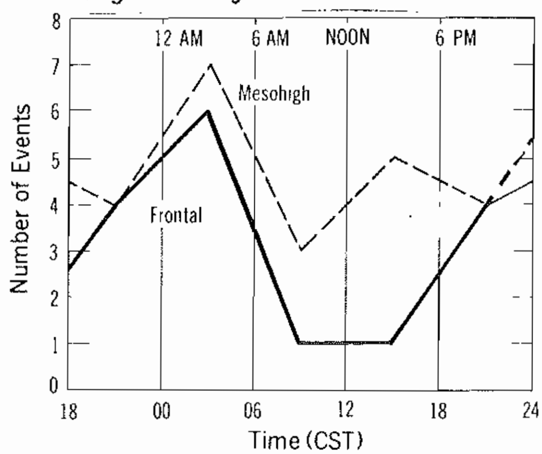

Figure 3. Timing of the onset of heavy rains for the frontal and mesohigh events.

Figure 4 shows maximum rainfall amounts for the cases studied. (Rainfall maxima are rounded to next lowest full inch.) 58% of the events produced 4 to 6 in. maxima; rainfall with 33% of the cases resulted in 6 to 7 in. The peak at 6-7 in. and the sharp drop for 7-8 in. rains primarily reflect using the 4 in. criteria over the Hill Country. Maximum rain amounts with 42% of the mesohigh cases were 6-7 in. but none fell in the 7-8 in. range, although higher rainfall amounts were often associated with the mesohigh events (33% of the cases $\geq$ 8 in.).

Maddox (1980) has shown that well-organized Mesoscale Convective Complexes (MCCs) occur frequently over the United States and Fritsch et al. (1981) estimated that during a typical summer, MCCs produce 50 to 60% of the rainfall in the Midwest. Table 1 shows a classification of the South Texas HR events using hourly enhanced infrared satellite images and Maddox's (1980) MCC definition (nearly circular systems as viewed from satellite with a cloud shield colder than -32°C that is larger than 100,000 km^2). Only 34% of the frontal events were associated with MCCs but 47% of the mesohigh cases involved MCCs. Since MCCs present such a well-defined and characteristic signature in satellite imagery, these events should be easily detected and monitored once an MCC actually develops. However, HR were more often (58% of

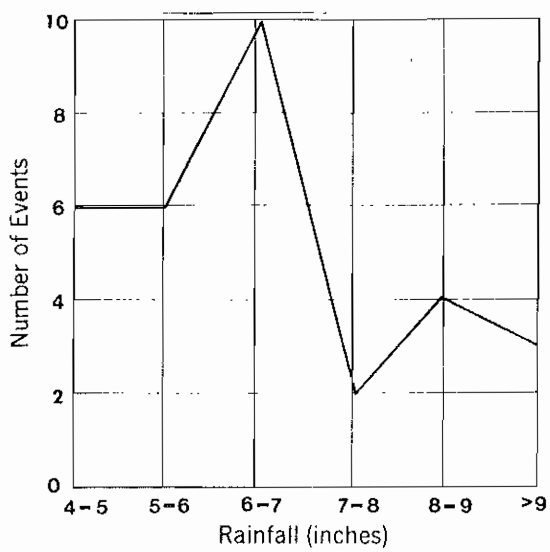

Figure 4. Maximum rainfall amounts reported with the heavy rain events.

the cases) not clearly associated with organized mesoscale convective systems, at least, insofar as was detectable from satellite imagery. These events appeared to be the result of a few strong thunderstorm cells imbedded within regions of weaker showers. In a number of cases, HR fell when satellite imagery seemed to indicate innocuous showers (i.e., IR cloud top temperatures warmer than -52°C). Obviously, these events pose a great forecast challenge and emphasize the importance of identifying the meteorological settings within which they are likely to occur.

Table 1. Classification of South Texas HR with respect to MCC criteria.

	MCC	Non MCC
Frontal type	4	8
Mesohigh type	9	10
Total	13	18

Maddox and Deitrich (1981) examined 11 simultaneous severe thunderstorm/heavy rain (SS/HR) events. They concluded that, although such events are relatively rare, they are very important because they represent an extreme challenge to the operational forecaster. Table 2 shows the distribution of severe thunderstorms associated with heavy rains in South Texas.

Table 2. Classification of South Texas HR with respect to severe thunderstorms.

	Severe	Non Severe
Frontal type	4	8
Mesohigh type	5	14
Total	9	22

Only 29% of all HR events studied were associated with severe thunderstorms. These SS/HR cases were generally characterized by:

1. Conditional instability greater than mean values associated with HR events.
2. Stronger wind shears than the typical HR event.
3. Being more closely linked to upper-tropospheric jet streaks than the typical HR event.

Most of the SS/HR events occurred during the late afternoon and evening as opposed to the nonsevere episodes which occurred more frequently at night. Because the differences between HR and SS/HR events are subtle, it will be extremely difficult for the forecaster to accurately differentiate, well in advance, between a developing HR and SS/HR event.

Figure 5 shows the means of temperature, wind, and temperature-dewpoint depression for the standard levels just prior to HR events in South Texas. Also shown are mean stability and moisture values. These are compared with

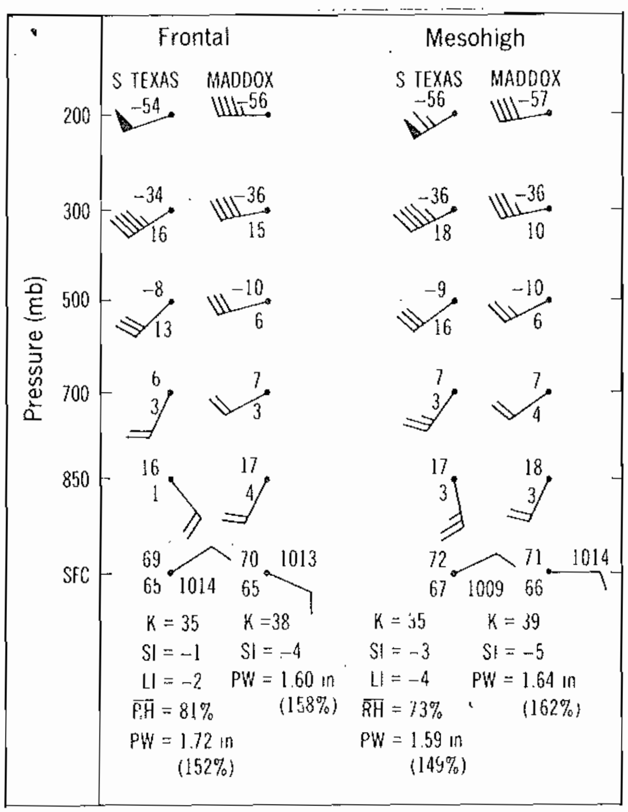

Figure 5. Mean values of wind, temperature, and temperature-dewpoint depression at selected levels for heavy rains in South Texas and flash flood events by M79. Winds are in knots with full barb = 10 kt and flag = 50 kt. Also included are K indices (K), Showalter indices (SI), Lifted indices (LI), Precipitable water (PW), and average Relative humidities (RH) from surfce to 500 mb.

similar means from the more general M79 study. For both frontal and mesohigh types, winds at and above 700 mb are slightly more southerly for south Texas heavy rains. This is probably an indirect result of the proximity of the high Mexican Plateau. Middle-level westerly winds usually advect warm and dry air eastward from the Plateau inhibiting convection. All the HR events occurred within a deep moist layer over South Texas which extended west to near the Mexican Plateau.

Vertical wind shears are also stronger than the means in M79, which is not surprising since HR events tend to occur earlier in the year over South Texas than they do over much of the rest of the country. The difference in wind speeds between 850 mb and 200 mb is 35 kt (M79--25 kt) for the frontal type and 40 kt (M79--20 kt) for the mesohigh. Significant veering occurs between 850 and 300 mb. All the HR events were associated with the polar and/or subtropical jetstream which is reflected in the stronger winds at 300 and 200 mb than were found by M79.

With one exception, temperature and dewpoint values are remarkably similar between the two studies. At 500 mb, temperature-dewpoint differences are considerably higher with the South Texas HR. Only 14 (45%) of the cases had differences of less than 6°C whereas 11 (35%) of the cases contained differences of greater than 15°C. However, convection can rapidly modify the 500 mb moisture field during HR events.

Mean winds at 850 mb were southeasterly (148°) with the frontal type and southerly (179°) with the mesohigh. This contrasts with the prevailing south-southwesterly direction of the cases studied by M79. South to southeasterly flow is required in the study area to bring moisture inland. Farther north and east this need not be the case.

It appears from Figure 5 that greater atmospheric instability is associated with mesohigh type HR events than with Frontal types. Both the Showalter (SI) and lifted indices (LI) are lower for the mesohigh type although the K-indices (K) are the same. The presence of a synoptic scale frontal zone allows for continued forcing of the convection. Since many of the frontal events occurred in the western part of the area (Figure 1), the higher terrain may also have contributed. With the mesohigh type event, greater instability allows the initial convection, needed to establish a well-defined thunderstorm outflow boundary, to develop.

Precipitable water for each event was compared to the monthly normals presented by Lott (1976). For both types the average precipitable water was about 150% of the mean climatological value. The mean relative humidity from the surface to 500 mb was not exceedingly large--81% for frontal and 73% for mesohigh. The forecaster, rather than relying on observed values, should closely monitor trends. The proximity of the Gulf of Mexico can, given the proper synoptic setting, result in rapid increases in moisture and corresponding decreases in stability (Smith, 1978).

4. Frontal Synoptic Patterns

The surface and upper-air patterns for a typical frontal type HR event are depicted in Figures 6 through 10. The areas enclosed by the 24-h isohyets are averages of the 12 cases. Although the area within the one-inch isohyet varied greatly, the location of the area bounded by the three-inch line was quite consistent relative to the synoptic features. Tables 3 and 4 list the mean values and ranges for temperature, wind, stability, and moisture. Although Figures 6 through 10 depict a typical synoptic pattern, Tables 3 and 4 reveal that the individual events showed significant variance.

The frontal event is characterized by a nearly stationary front (oriented southwest to northeast - see Figure 6). The front is usually quite shallow and its intersection with the 850 mb level occurs over North and West Texas (Figure 7). Heavy rains occur in the cool air within about 75 miles of the surface front. However, if the cool air mass is very shallow, the HR may be displaced farther north of the surface front and may require greater instability to develop. The surface front can be extremely weak and discernable only by small contrasts in the thermodynamic fields. However, development of thunderstorms along the weak front can produce dramatic strengthening of the thermal and moisture gradients. During the late spring and early summer months, it is imperative that continuity be kept of all frontal locations, even if the supportive thermal and moisture fields are seemingly insignificant.

Table 3. Temperatures and winds associated with frontal type HR events.

Level		T	T_d	Wind Direction	Wind Speed
Surface* 1014 mb	Mean	69°F	65°F	NE	10 kt
1010-1020	Range	60° - 75°	58° - 70°	N-E	7-15
850 mb		16°C	14°C	148°	18 kt
		13° - 18°	11° - 18°	130°-184°	15-25
700 mb		6	4	186	16
		2 - 10	0 - 8	130-230	10-25
500 mb		-8	-21	219	28
		-13 - -5	<-42 - -7	170-230	15-55
300 mb		-35	-50	233	45
		-29 - -30	<-69 - -38	180-250	25-70

*Surface pressure reduced to sea level.

Mass convergence near the surface has been shown to be associated with convection (Hudson, 1971; Miller, 1972; Scoggins et al., 1979). Strong low-level moisture convergence appears to be very important for HR in South Texas. An angle of ~90° between the maximum winds and the surface front is most desirable, with smaller angles decreasing the HR potential. Usually the moisture ridge and the low-level jet were coincident; however, three cases occurred with broad areas of high moisture content positioned south of the front.

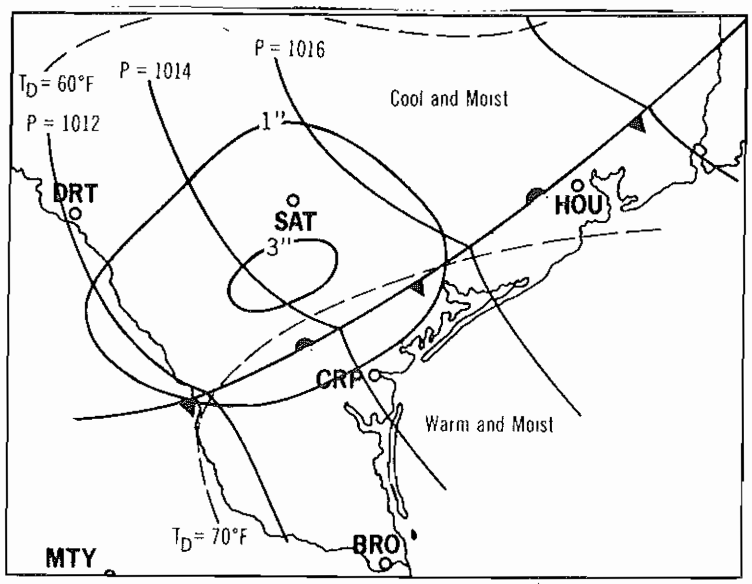

Figure 6. Surface pattern for a typical frontal type heavy rain event. Isolines labeled "1" and "3" represent 24-h isohyets.

Table 4. Stability and moisture associated with frontal type HR events.

Parameter	Mean	Range
Showalter index	-1	-4 - +3
Lifted index	-2	-4 - 0
K index	35	30 - 40
$\overline{RH}$ sfc-500 mb	81%	65% - 93%
Precipitable water	1.72 in.	1.29 in. - 2.30 in.
Percent of normal	152%	109%-207%

The occurrence of strong low-level convergence is frequently reflected on the surface chart by an increase in the easterly pressure gradient to the north and in the southerly pressure gradient to the south of the front (Figure 6). This packing of the surface isobars can be of significant help in locating the region of strong low-level convergence, especially between sounding times. It was often found that the ≥ 1 in. rain area was characterized by about a 4 mb gradient (both north to south and east to west) with weaker gradients throughout the surrounding environment.

The 700 mb level (Figure 8) is characterized by a large, nearly stationary trough over northern Mexico with southerly flow over South Texas. The southerly, or even southeasterly, flow at this level does not bring Mexican Plateau dry air over South Texas. The slow movement of the trough also allows continued advection of moist air northward across South Texas. In two of the cases, heavy rains occurred under an east-west 700 mb ridge; however, the mid-tropospheric winds were less than 10 kt, low-level forcing was strong, and stability quite low. The data (Table 3) indicate that heavy rains are unlikely with 700 mb wind directions west of about 230°. A moisture ridge prevailed over the heavy rain area in all but one of the events. However, the absence of significant moisture at 700 mb should not always be construed as a factor against HR because of the rapidity with which moisture can be transported vertically through the middle troposphere.

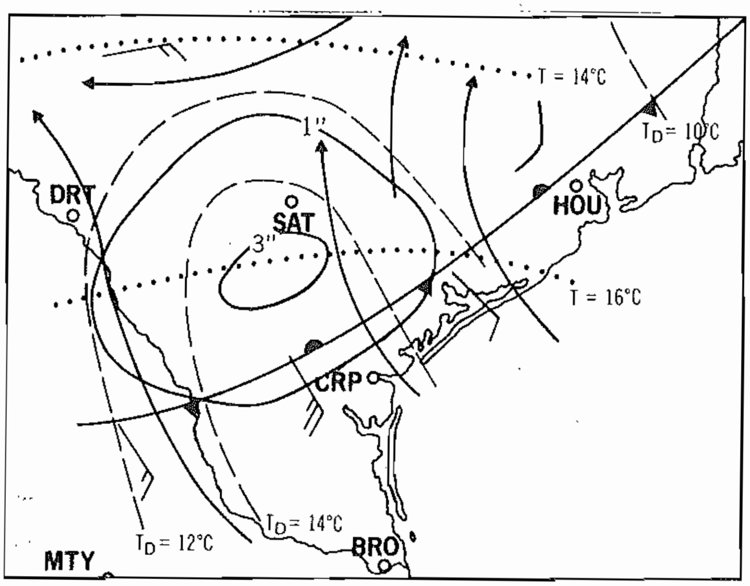

Figure 7. Corresponding 850 mb flow pattern for a typical frontal type heavy rain event. Surface frontal position from Figure 6 is shown.

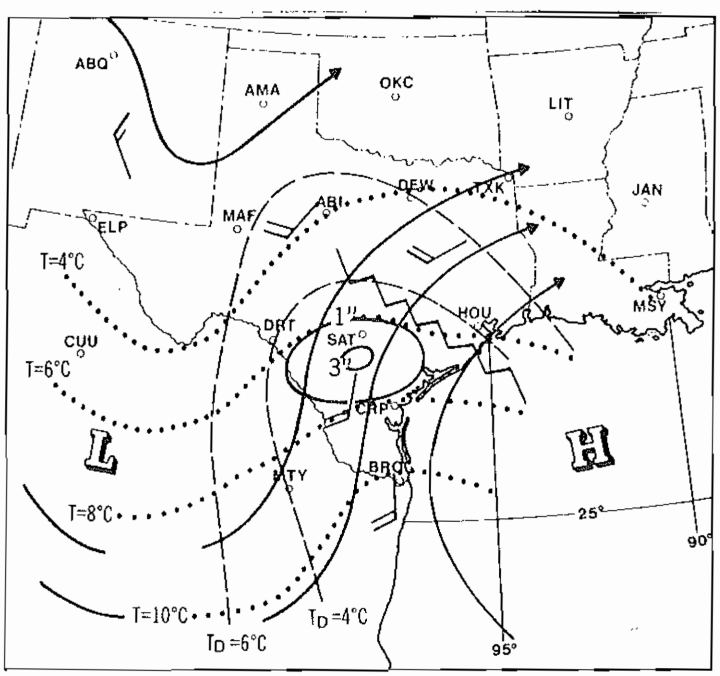

Figure 8. Corresponding 700 mb flow pattern for a typical frontal type heavy rain event.

Pronounced warm advection occurs at 700 mb (Figure 8) in conjunction with weak to moderate warm advection at 850 mb (Figure 7). Recently, it has been emphasized (Maddox and Doswell, 1982a and b) that pronounced lower tropospheric warm advection can be an important mechanism, because of the associated upward motion, in the release of conditional instability. With this in mind, the forecaster should closely monitor low-level thermal advection fields, especially when the mid-level westerlies weaken in the late spring and early summer.

At 500 mb (Figure 9) a trough is located over northern and western Mexico with south to southwest flow over Texas. As at 700 mb , the prevailing south to southwest component impedes advection of dry air off the Mexican Plateau. Winds at 500 mb are almost always more southerly than 230° (Table 3) during HR events.

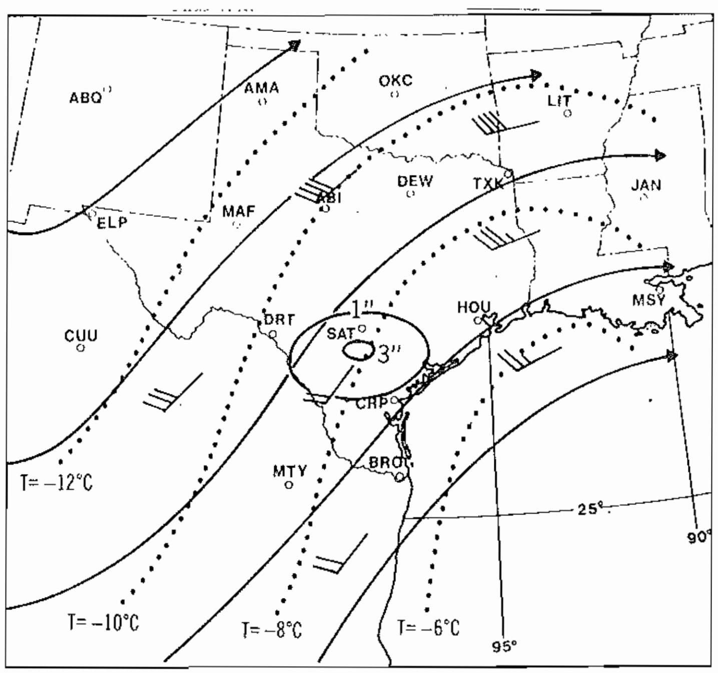

Figure 9. Corresponding 500 mb flow pattern for a typical frontal type heavy rain event.

In 10 of the 12 frontal HR cases, the 500 mb flow split over the Great Basin. A progressive short wave was located over the midwestern United States with a separate, nearly stationary trough sheared off over northern Mexico. Only three of the events were directly associated with short waves, which again emphasizes the importance of the low-level patterns. The traveling short wave in the Midwest often acts to push the cold front into Texas. In response to the trough over northern Mexico, low-level winds in South Texas become southeasterly resulting in strong moisture convergence along and north of the surface front. Two of the cases exhibited a positive tilt trough from the midwestern U.S. into northern Mexico. With this synoptic pattern, upper air winds were much lighter over south Texas and the features less apparent. However, the effects were similar to the split flow regime.

The 300 mb analysis (Figure 10) shows the location of the upper-level jet stream in relation to the HR area. Ten of the events were located in the right rear quadrant of a polar jet streak with the remaining two cases in the left front quadrant of the subtropical jet streak. The indirect circulations attending the jet streak support upward motion in these two quadrants (see Reiter, 1963; Uccellini and Johnson, 1979).

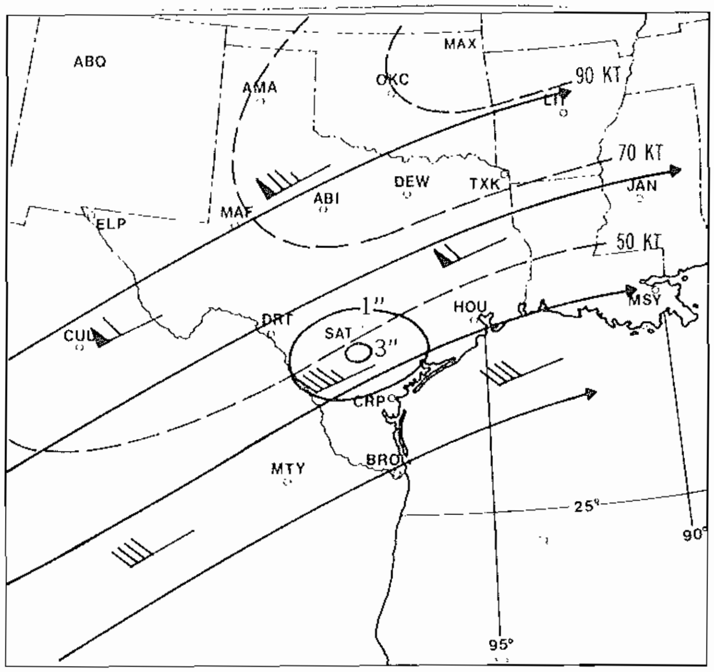

Figure 10. Corresponding 300 mb flow pattern for a typical frontal type heavy rain event.

Frontal type HR in South Texas should be least difficult to anticipate. Limited-Area Fine-Mesh (LFM) 500 mb, 700 mb, and surface prognostications handle the important synoptic features delineated in this study quite well. This should help alert the forecaster to a developing HR event. However, as the situation evolves, the thermodynamics of the lower levels should be given special attention. Frontal type HR pose the greatest threat when low-level forcing and atmospheric instability are both strong. Although contributions are made by upper tropospheric circulations, it often appears that analyses at and below 700 mb are most useful in delineating the possible location of the HR.

5. Mesohigh Events

Figures 11 through 15 show the surface and upper air patterns associated with the typical mesohigh type HR event in South Texas. Table 5 lists the mean values and ranges of temperature and wind while Table 6 contains the mean values and ranges of stability and moisture. Tables 5 and 6 reveal significant variance among the individual events.

Heaviest rains occur to the south or southwest of the mesohigh (Figure 11), although the heaviest rain in two events fell on the southeast side. The mesohigh usually manifests itself as an elongated ridge rather than a closed pressure center. The mesohigh can be the result of previous thunderstorms and be present a number of hours prior to the onset of HR or, in some cases, may form in conjunction with the initial thunderstorm. This characteristic makes this type particularly difficult to forecast. Fortunately, all the heavy rains studied were associated with strong, easily identifiable boundaries, suggesting useful forecast clues.

Table 5. Temperature and wind associated with mesohigh type HR events.

Level		T	T_d	Wind Direction	Wind Speed
Surface* 1009 mb 1003-1016	Mean Range	72°F 65°-77°	67°F 62°-72°	NE N-E	10 kt 7-15
850 mb		17°C 13°-20°	14°C 11°-17°	179° 160°-220°	23 kt 15-35
700 mb		7 1-10	4 1-6	219 180-240	23 10-40
500 mb		-9 -14 - -5	-27 -44 - -8	228 190-240	30 15-50
300 mb		-36 -30 - -41	-51 -70 - -35	241 220-250	45 15-75

*Surface pressure reduced to sea level.

Table 6. Stability and moisture associated with mesohigh type HR events.

Parameter	Mean	Range
Showalter index	-3	-7 - 0
Lifted index	-4	-10 - 0
K index	35	30-44
$\overline{RH}$ sfc-500 mb	73%	60-85%
Precipitable Water	1.59 in	1.20 in - 2.10 in
Percent of normal	149%	119% - 171%

The mesohigh HR event is similar to the frontal type in that HR tends to occur near the intersection of a distinct mesohigh outflow boundary and the 850 mb maximum winds. With both types the winds intersected the discontinuity at nearly right angles. The strong low-level convergence is also reflected on the surface pressure analysis (Figure 11) by a packing of the isobars as it was in the frontal situation. Available radar data reveal that as echoes approach this zone of strong moisture convergence, the cells slow, grow, and may merge. An area of higher VIP levels will evolve and become nearly stationary or move slowly in directions that appear independent of the steering winds (700 to 500 mb flow). Smaller cells form to the southwest, strengthen as they move through the high reflectivity area, and then weaken upon exiting to the northeast. Radar messages may indicate a significant cell

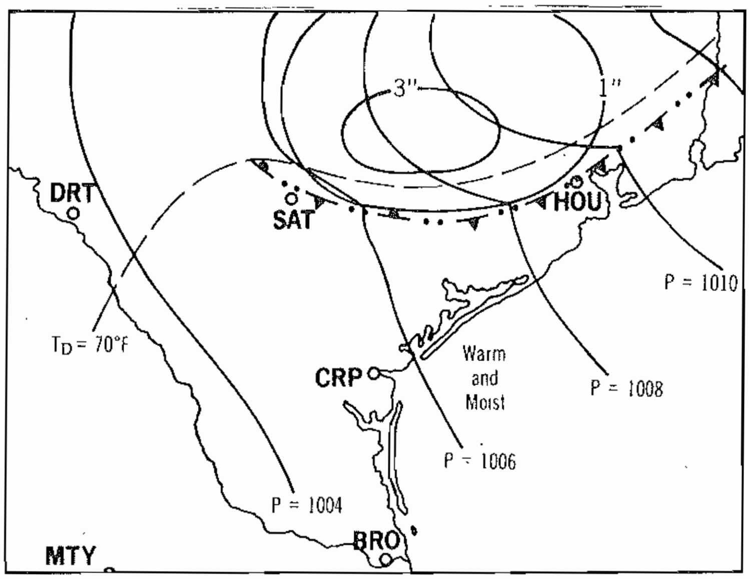

Figure 11. Surface pattern for a typical mesohigh event with details in Figure 6.

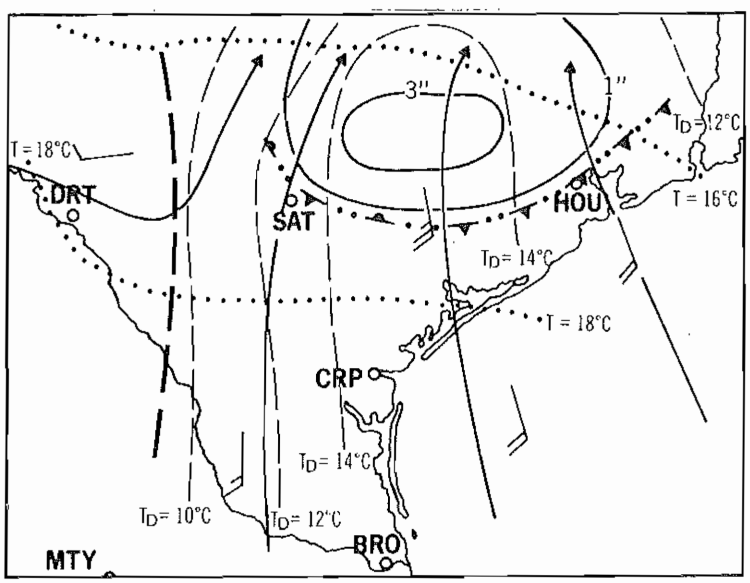

Figure 12. Corresponding 850 mb pattern for a typical mesohigh event. Thunderstorm outflow boundary from Figure 11 is shown.

movement but the HR area may remain almost stationary. This characteristic should be revealed by manually digitized radar (MDR) values (Moore and Smith, 1979; Smith, 1980). This type of continuous reinforcement of the initial mesoscale HR area by new cells has been documented by others (Labas, 1976; Changnon, 1978; Grosh, 1978; Changnon and Vogel, 1980). The low-level inversion south of the outflow boundary may suppress convection and cloudiness thereby allowing increased instability to develop and feed the heavy rainstorms. Conditions during the significant Kansas City flash flood in 1977 (Hales, 1978) were very much like this.

The moisture ridge at 850 mb (Figure 12) is also present at 700 mb (Figure 13); however, the HR area is located beneath or south of the 700 mb moisture maximum. This pattern was exhibited by all but three cases examined. Also, warm air advection was again pronounced at both levels.

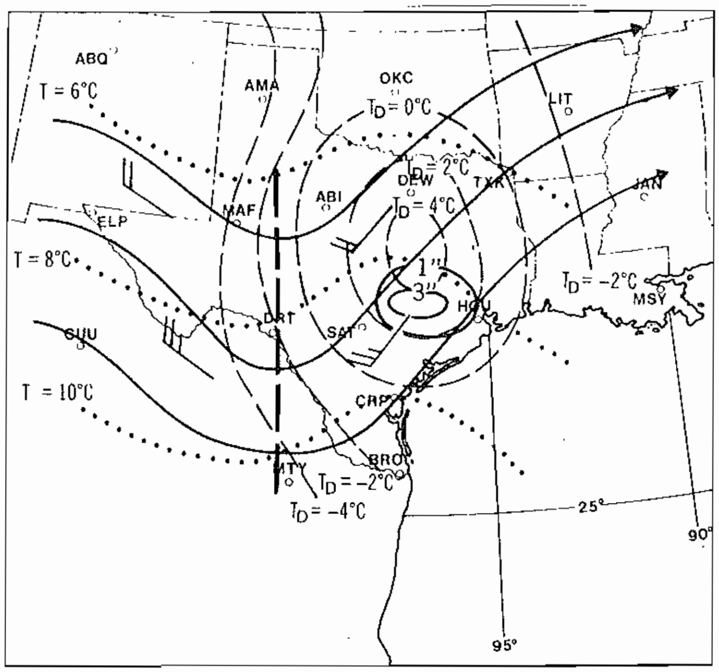

Figure 13. Corresponding 700 mb pattern for a typical mesohigh event.

In all 19 cases a weak 700 mb short wave trough was present over West Texas and northern Mexico. Since this trough was moving, it appears that it helps to initiate and support the convection. Winds at 700 mb were more westerly (Table 5) than with the frontal type (Table 3). The dynamics associated with the short wave apparently compensate for the drying and stabilization associated with the more westerly winds. At 500 mb (Figure 14) the short wave was embedded in nearly zonal flow and extended from New Mexico through northeast Mexico. Thirteen of the events were associated with weak, open waves while cut-off systems accompanied the remaining six cases.

The 300 mb analysis (Figure 15) is characterized by a trough over New Mexico southward into Mexico. This trough was apparent in all 19 cases.

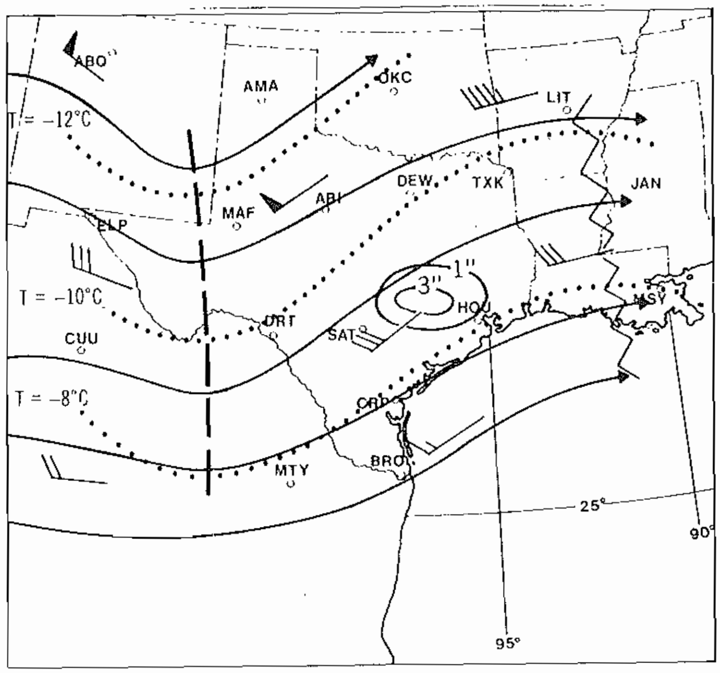

Figure 14. Corresponding 500 mb pattern for a typical mesohigh event.

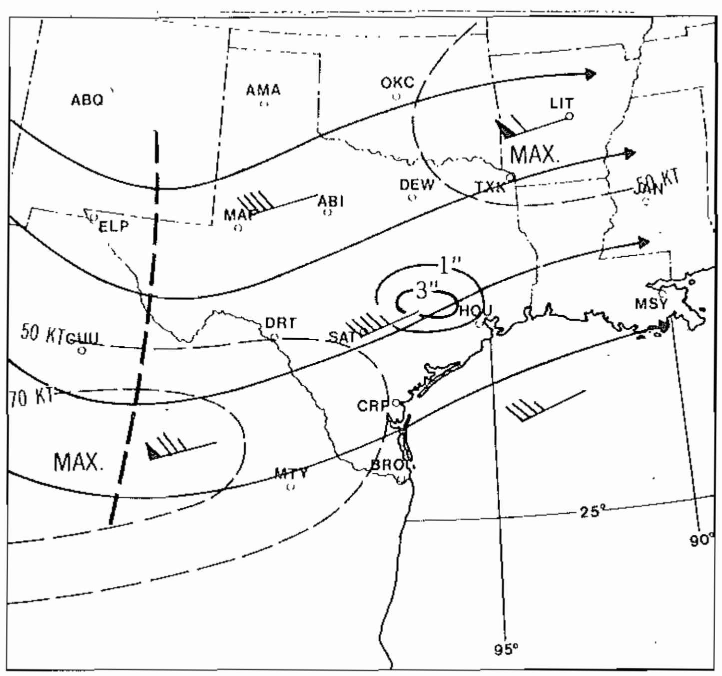

Figure 15. Corresponding 300 mb pattern for a typical mesohigh event.

,324-2655

Fourteen of the events exhibited a pairing of polar and subtropical jet streaks with the HR located between the jet streaks in an area of strong upper-tropospheric positive vorticity advection. The frequency with which this jet streak configuration occurred in this study suggests it may be related to other severe weather events in South Texas.

The mesohigh HR event presents a major problem to the forecaster. Small short waves coming across northern Mexico are not handled well by the LFM. Reanalysis, as advocated by Maddox (1979), and extrapolation are necessary ingredients of the forecast procedure. Stability parameters, which can change drastically in a short time, must be closely monitored. If the upper level analysis and stability and moisture parameters indicate the atmosphere will support intense convection, the forecaster should concentrate on the 850 mb moisture and wind fields and surface winds and pressure fields. Thunderstorm outflow boundaries which become oriented normal to the 850 mb maximum winds and are located near the nose of the moisture ridge should be monitored closely. Hourly surface mesoanalysis can provide significant clues to areas of surface convergence.

6. Concluding Remarks

Meteorological conditions associated with 31 heavy rain events in South Texas have been examined. Using the classification of M79 it has been determined that primarily frontal and mesohigh type heavy rains affect South Texas. The following important features were found to be common to both the frontal and mesohigh types:

1. The 850 mb winds and moisture fields are important ingredients in the production of heavy rains. The strength of the moisture ridge and the orientation of the maximum winds relative to the front or boundary appear especially critical.
2. Low-level convergence is frequently reflected by detailed surface mesoanalysis.
3. Warm air advection is clearly present at both 850 mb and 700 mb.
4. The polar and/or subtropical jet stream is present near the area of heavy rain.

The two types differed in the following ways:

1. Frontal heavy rains are generally associated with split flow in the middle and upper troposphere while mesohigh events are associated with basically zonal flow.
2. Frontal heavy rains occur in conjunction with a large, nearly stationary middle and upper-level trough over the western United States and northern Mexico while mesohigh events form ahead of a weak, traveling short wave.

It is important to note that the details of South Texas synoptic and meso-patterns are considerably different than the generalized models presented by M79. The M79 study can be utilized as a blueprint for the design and execution of successful local investigations. Although the present study analyzed heavy rains over South Texas in detail, the resulting synoptic climatology may have limited applicability to nearby areas. Belville et al., (1980) stressed the need for routine mesoscale analysis during threatening periods and indicated that during a flash flood situation mesoanalysis should be performed on an hourly basis. Maddox (1979) pointed out the necessity of reanalyzing products from the National Meteorological Center and suggested an analysis interval of 2 mb for the surface chart. However, in some of the events of this study, a 2 mb analysis would not have delineated the surface convergence. In some instances, hourly, 1 mb analyses are mandatory.

Reliance should not be placed solely on one level or one parameter. Weaker thermal advection in the lower levels can be compensated by strong positive vorticity advection at middle and upper levels. Conversely, forecasters should not be mislead by weak or non-existant PVA aloft when lower-level features are favorable for heavy rains. Extremely unstable conditions may, on occasion, dominate a number of other unfavorable factors. The entire atmospheric structure must be considered. It is important that the forecaster develop a four-dimensional (current structure plus temporal evolution) mental picture of the meteorological situation (Maddox, 1979).

This study has dealt with particular conditions present during heavy rains. However, to fully understand the processes involved, events must be studied in which a number of the above criteria were present but heavy rain did not develop. A desirable extension of this study would be the development of a concise checklist for HR events. This study is only a partial answer and the results should be used accordingly. The "typical events" considered will not cover all possible synoptic patterns which may combine to create heavy rain. Tables 3 through 6 show the considerable variance which can occur. In closing, we should emphasize the important and most relevant advice of Smith and Younkin (1972):

> "Past experiences with composite models show that forecasters often tend to apply models indiscriminately to situations dissimilar to the developmental data with unsatisfactory results. This practice soon leads to disillusionment and early disenchantment with a valid forecast tool."

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