Heavy Rain Forecasting

SYNOPTIC CHARACTERISTICS OF HEAVY RAINFALL EVENTS IN SOUTH TEXAS

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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., (3). 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. As with the Maddox study 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. Both studies also supported the nocturnal nature of heavy rains, but the monthly distributions differed. Although the surface patterns of the two studies were similar, the upper-air patterns were different. The differences between the two studies emphasizes the importance of identifying and typing local heavy rain events.

1. INTRODUCTION

About four years have passed since Maddox et al., (3), hereafter referred to as M79, classified United States heavy rain events based on attendant synoptic and mesoscale weather patterns. Their analyses indicated that three meteorological patterns were often associated with flash flooding in the central and eastern United States. The three basic types of heavy rain events were identified as a) Synoptic, b) Mesohigh, and c) Frontal.

Although M79 examined meteorological conditions associated with more than 150 intense convective precipitation events, only 7 of the cases occurred over South Texas. However, M79 provides a logical framework for an examination of South Texas heavy rain (HR) events associated with the westerlies and similarities and differences are considered here. Additional discussion of South Texas heavy rains is given by Grice and Maddox (4).

2. DATA SOURCES

The National Weather Service River Forecast Center in Fort Worth, Texas, routinely uses computer plotted, 24 hr rainfall maps. These maps were individually examined for five years of data (1977- 1981) and HR events identified. An HR event was defined as 5 in./24 hr for all of the study area except the Hill Country, where 4 in./24 hr was considered an event (Fig. 1). One-inch isohyets were subjectively analyzed for all HR events. Thirty-three events were eventually studied in detail.

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 parameters. Subjective interpolations were made in time and space to estimate meteorological conditions just prior to the HR event. To aid in these interpolations, hourly enhanced IR satellite images were examined for all events.

3. GENERAL CHARACTERISTICS

All but 2 of the 33 HR events in South Texas 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 not common in South Texas. However, 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 HR areas for the 19 mesohigh and 12 frontal events studied. Ten events exhibited multiple isohyet centers, and each center where HR criteria were exceeded was plotted. (Because of this, the number of plots exceeds the number of events.) Frontal events occasionally occur over all of South Texas; mesohigh events display a distinctive pattern with most of the centers in a narrow band over the northern portion of the area. However, were HR events considered for all of Texas the narrow band would merely be near the southern limit of mesohigh events. Mesohigh events were associated with weak middle-and-upper tropospheric short waves. The absence of mesohigh HR events over extreme South Texas is probably the result of weak lifting, associated with the short waves, being unable to destroy a strong and dominant subtropical inversion. Further north, where the inversion is weaker, thunderstorms can be initiated.

Figure 2 shows the monthly distribution of HR events from the M79 study and also for South Texas. Although M79 found heavy rains over the United States most frequent during the months June-August, in South Texas heavy rains were most frequent in April-June. Heavy rains associated with the westerlies did not occur in July and August in South Texas. The nocturnal nature of HR is apparent in Figure 3. A distinct maximum is observed at night (in both studies) with a minimum during the day; however, mesohigh events in South Texas, which are closely related to approaching short waves, are more evenly distributed during the day.

Figure 4 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 contrasted with similar means for the United States from the M79 study. For both frontal and mesohigh types, winds at and above 700 mb are slightly more southerly for the South Texas HR event. This is probably an indirect result of the proximity of the Mexican Plateau. Middle-level westerly winds usually advect very warm and dry air eastward from the Plateau inhibiting convection. All HR events occurred within a deep moist layer which extended westward to near the Mexican Plateau.

Vertical wind shears in the upper troposphere are also stronger than observed in the M79 study, which is not surprising, since HR events tend to occur earlier in the year over South Texas. Significant veering occurs between 850 and 300 mb. All the HR events were associated with polar and/or subtropical jet streams - note the strong winds at 300 mb. With one exception, temperature and dewpoint values were remarkably similar between the two studies. At 500 mb, temperature/dewpoint differences were considerably higher with the South Texas HR event. Only 45% of the cases had differences of less than 6° C while 35% of the cases exhibited spreads of greater than 15° C. However, deep convection can rapidly modify the 500 mb moisture field during HR events. Mean winds at 850 mb were southeasterly with the frontal type, and southerly with the mesohigh. This contrasts with the prevailing south-southwesterly direction for the sample studied by M79. South to southeast winds are required in South Texas to bring moisture inland. Farther north and east this need not be the case.

4. FRONTAL HR PATTERNS

The surface and upper-air patterns for typical frontal HR events, from both studies, are shown in Figs. 5 through 7. The 300 mb pattern for South Texas HR event is presented in Fig. 8. Although the surface patterns are reasonably similar, the 850 mb and 500 mb patterns are different. The 850 mb flow in the M79 study was southwesterly (mean direction 200°) over the potential heavy rain area but southeasterly (mean direction 150°) in South Texas. The southeast low-level flow over South Texas is required for advection of low-level moisture. Both studies showed the greatest HR potential to be near the 850 mb band of maximum winds and moisture ridge. The angle of intersection between the maximum winds and the synoptic front appears important in the development of heavy rains; an angle of 90° appeared optimum with smaller angles decreasing the HR potential. 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.

Frontal heavy rains with the M79 study occurred near the 500 mb ridge line in advance of an approaching weak short wave, whereas frontal HR in South Texas were located near the inflection point ahead of a strong and deep trough. These events typically occurred within a split-flow 500 mb pattern. The split was usually over the northwest United States with a pronounced trough present in the southern stream. Winds at 500 mb over South Texas apparently must be from directions south of 230° to prevent advection of dry air off the Mexican Plateau. Winds more westerly than 230° rapidly advect dry air over the area inhibiting convection. Mean 500 mb wind directions were 220° over South Texas in contrast to 250° in M79.

Upper-level jet streams are apparently important in development of HR in South Texas. Frontal type HR occurred beneath the right rear quadrant of a polar jet streak (Fig. 8) in an area usually characterized by upper-level divergence. Indirect circulations attending the jet streak support upward motion in this quadrant (5, 6).

5. MESOHIGH HR PATTERNS

Surface and upper-air patterns for typical mesohigh events are depicted in Figs. 9 through 11. The 300 mb pattern for South Texas HR is presented in Fig. 12. In both studies, heavy rains occurred to the south or southwest of a mesohigh pressure center. The mesohighs over South Texas were usually present as elongated ridges rather than closed pressure centers (as depicted in the M79 study). Although about half of the events examined by M79 occurred east of a slow moving large-scale frontal system, a front was not present with most of the mesohigh events in South Texas. The mesohigh can be produced by thunderstorms prior to the onset of HR or may form in conjunction with the initial HR convection.

The mesohigh HR event is similar to the frontal type since it tends to occur near the intersection of a distinct outflow boundary and the 850 mb maximum winds. With both types, winds intersect the surface boundary at nearly right angles. As with the frontal type, 850 mb winds were more southwesterly with the M79 study (mean direction 205°) than with the HR events in South Texas (mean direction 179°). The South Texas HR area was near the 500 mb inflecton point while the M79 heavy rains were near the large-scale ridge. A weak short wave was present in both studies. With South Texas HR events the weak short wave was usually embedded in nearly zonal flow. For South Texas mesohigh HRs the 300 mb map (Fig. 12) frequently 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.

6. CONCLUDING REMARKS

Meteorological conditions associated with 31 heavy rain events in South Texas have been compared with the results of Maddox et al. (3). Using the classification of Maddox et al. (3), it has been determined that primarily frontal and mesohigh type heavy rains affect South Texas. This study supports the premise that most heavy rains occur at night. However, the monthly distribution showed that heavy rains (associated with the westerlies) were most frequent in April-June over South Texas.

Since South Texas heavy rains occur earlier in the year than over much of the United States, vertical shears and upper-tropospheric winds are generally stronger. Synoptic patterns are usually more pronounced. A polar and/or subtropical jet streak is generally present. Winds at all levels are more southerly to southeasterly than those shown in Maddox et al. (3) with South Texas heavy rains. This southerly or southeasterly component is essential; otherwise, dry air from the high Mexican Plateau is advected out over Texas.

It is important to note that many details of South Texas synoptic and meso-patterns are considerably different than the generalized models presented by Maddox et al. (3). Accordingly, this synoptic climatology for South Texas may have limited applicability to nearby areas. The importance of identifying and typing local heavy rain events cannot be overemphasized for operational weather forecasting applications.

ACKNOWLEDGMENTS

Without the help of a number of people, this study would not have been possible. Dr. A. Thompson of Texas A & M University was kind enough to allow the use of the University's map and satellite library. Special thanks are extended to G. Ely, J. Ward, W. Read, M. Nanney and others at WSFO San Antonio for their encouragement and participation in many stimulating discussions. Finally, the authors thank D. Smith, Southern Region Headquarters, for his comments and suggestions.

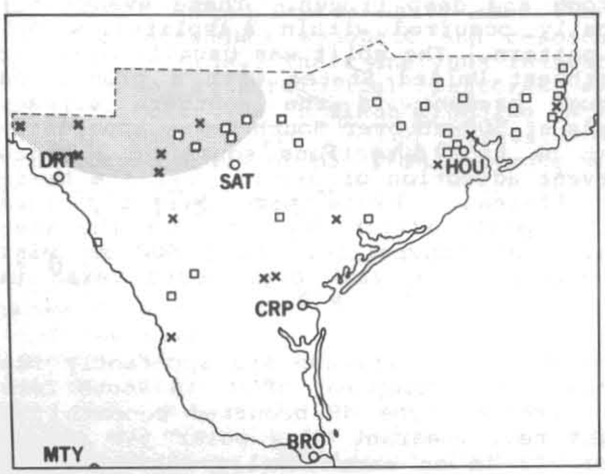
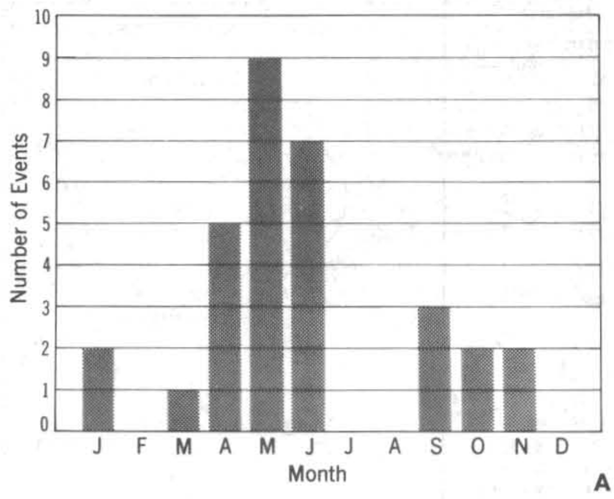


Figure 1. Locations of centers of heavy rains for frontal events (denoted by X's) and mesohigh events (denoted by squares). The dashed line represents the northern border of the study area and the shaded region indicates the Hill Country.



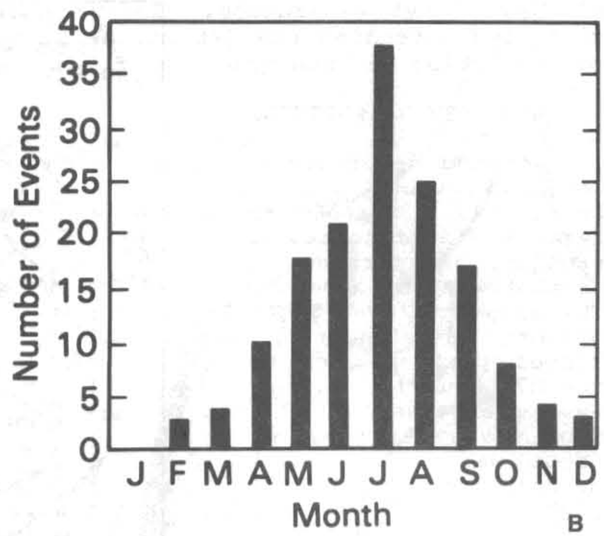
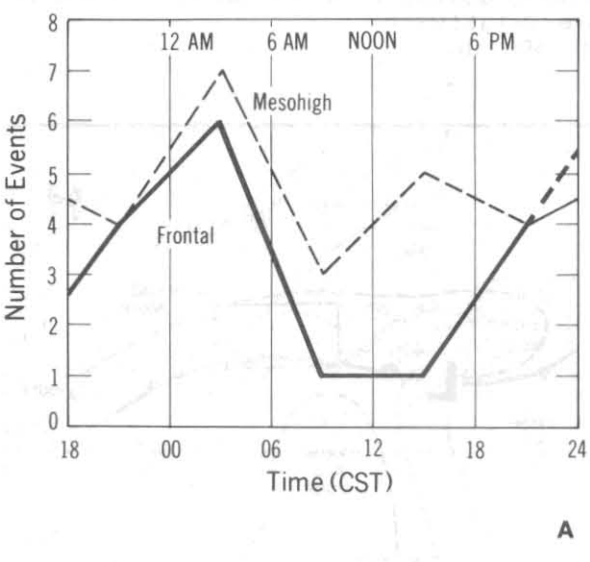


Figure 2. Monthly distribution of heavy rain events for South Texas (a), and for United States from M79 (b).



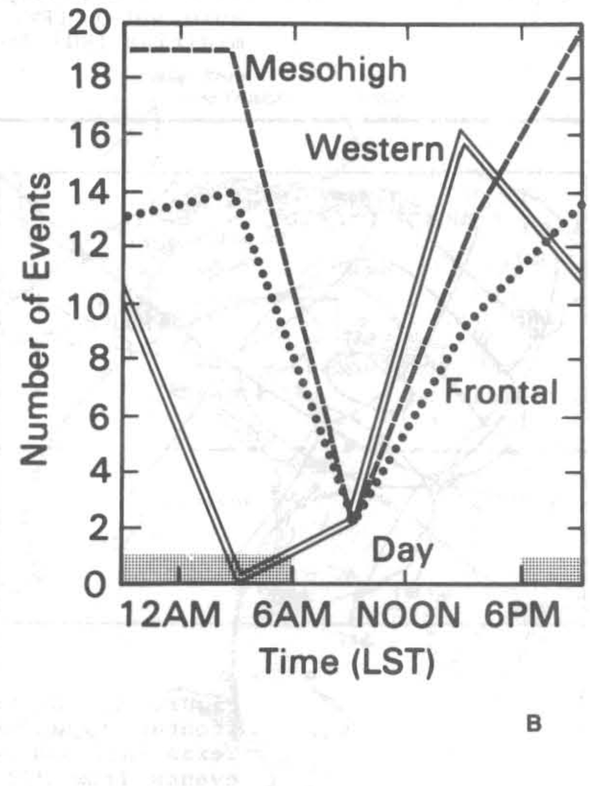


Figure 3. Timing of the onset of heavy rains for South Texas (a), and for United States from M79 (b).

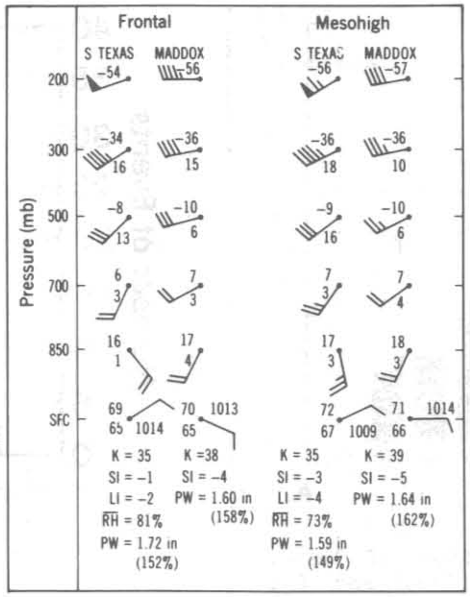


Figure 4. Mean values of wind, temperature and temperature-dewpoint depression at selected levels for heavy rains in South Texas and for United States flash flood events from M79. Winds are in knots with full barb = 10 kt and flag = 50 kt. Also included are K Indices (K), Showalter Indices (SI), Lifted Indices (LI), Precipitable water (PW), and average Relative Humidities (RH) from surface to 500 mb.

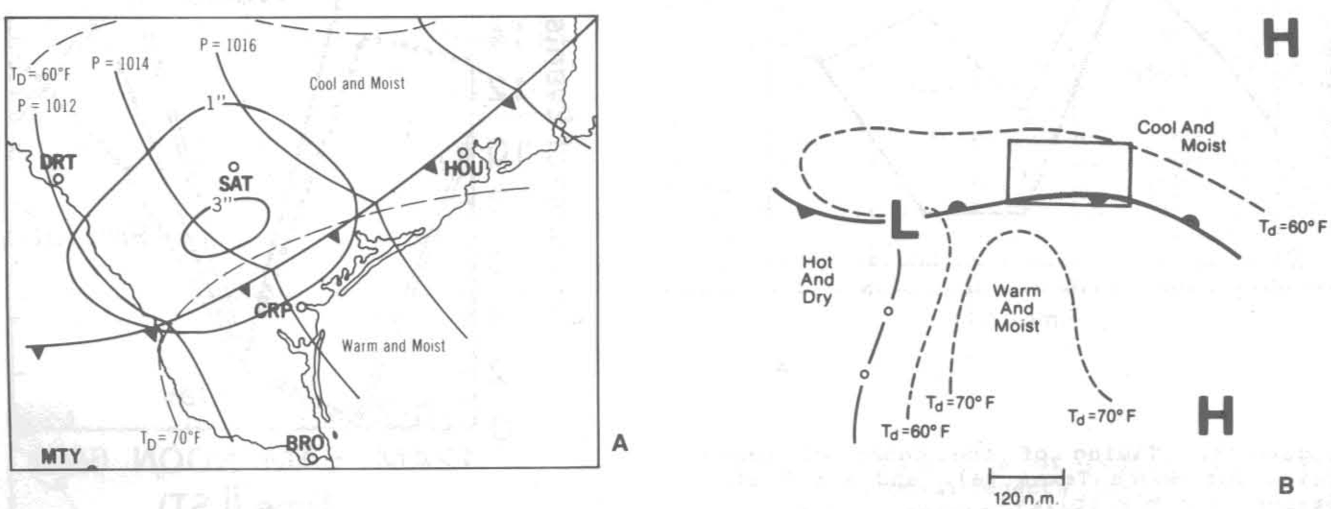
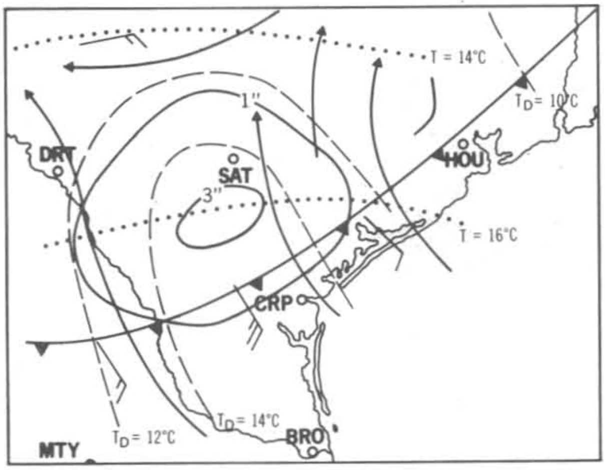
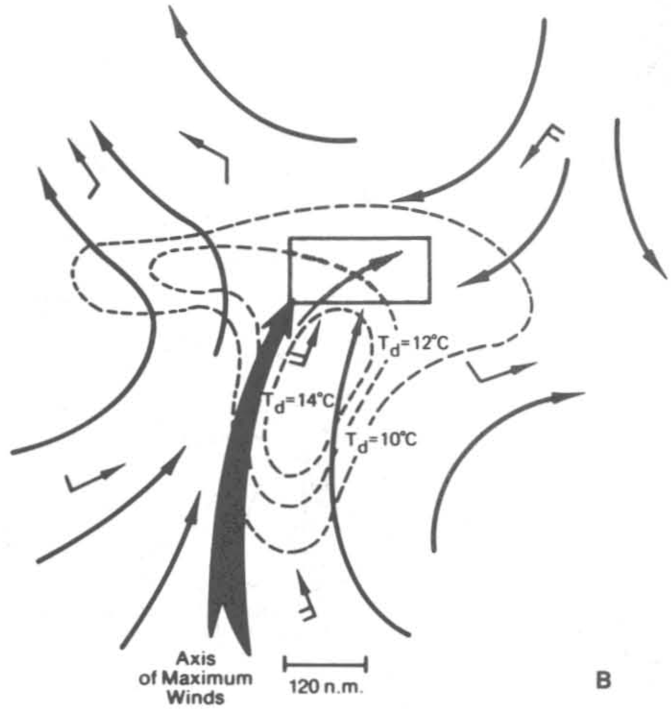


Figure 5. Surface patterns for a typical frontal type heavy rain event for South Texas (a), and for U.S. frontal flash flood events from M79 (b). Isolines labeled 1" and 3" (a) represent 24-h isohyets. Shaded box (b) represents area of potential heavy rains and flash flooding.

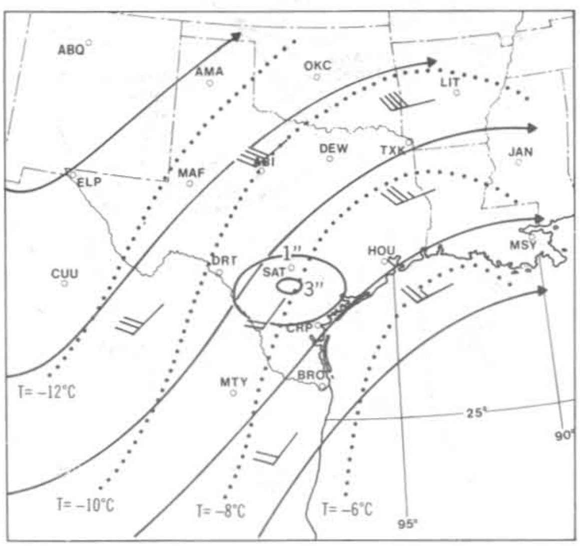


A



B

Figure 6. Corresponding 850 mb flow patterns for a typical frontal type heavy rain event for South Texas (a), and for U.S. frontal flash flood events from M79 (b). Surface frontal position is indicated in (a).



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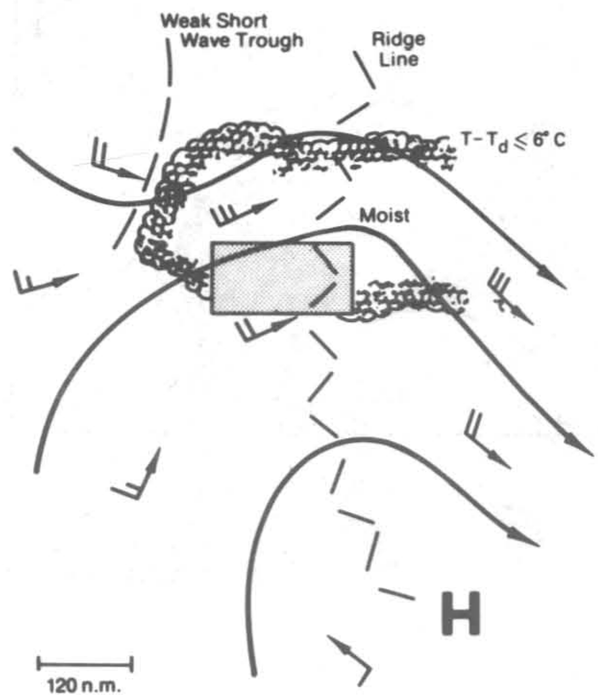

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Figure 7. Corresponding 500 mb flow patterns for a typical frontal type heavy rain event for South Texas (a), and for U.S. frontal flash flood events from M79 (b).

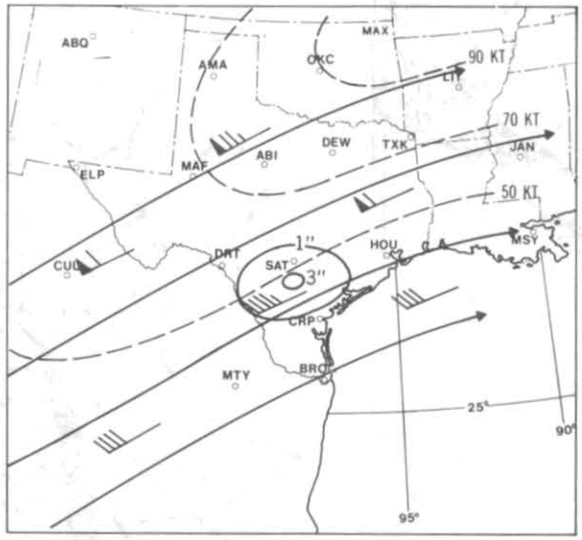


Figure 8. Flow pattern at 300 mb for a typical frontal type heavy rain event in South Texas.

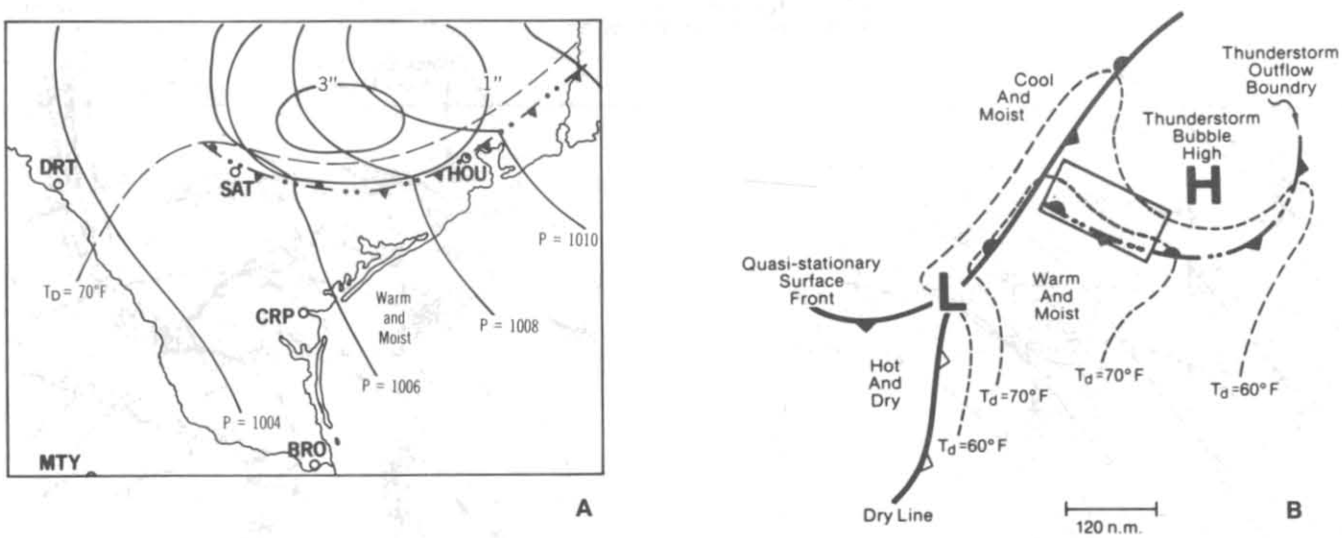
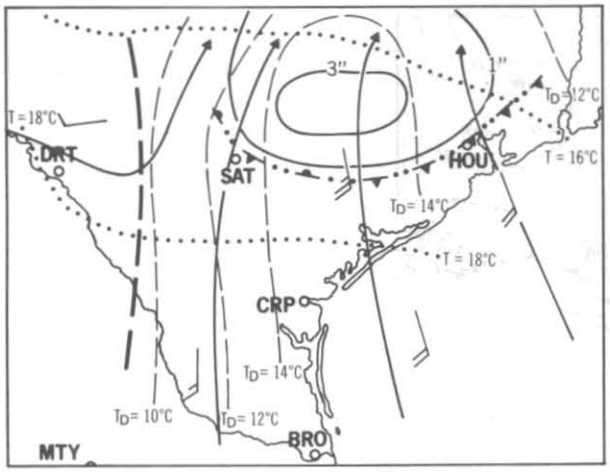


Figure 9. As in Fig. 5 except for meso-high type heavy rain event.



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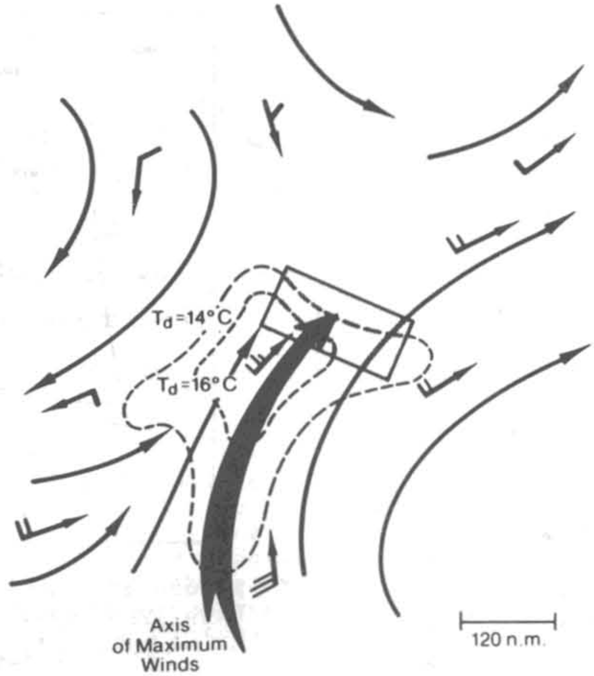

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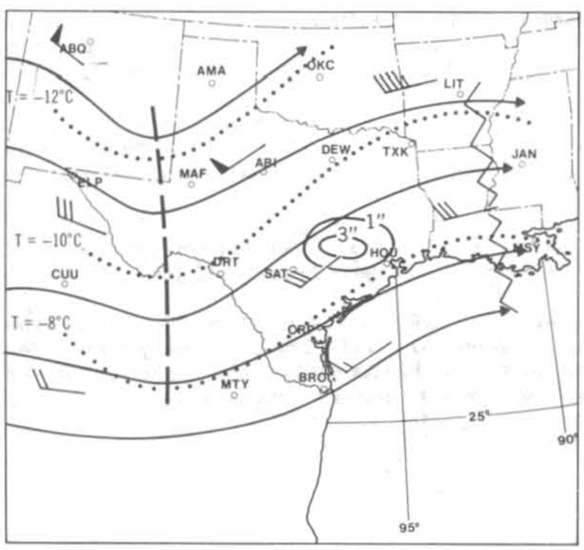
Figure 10. As in Fig. 6 except for meso-high type heavy rain event.



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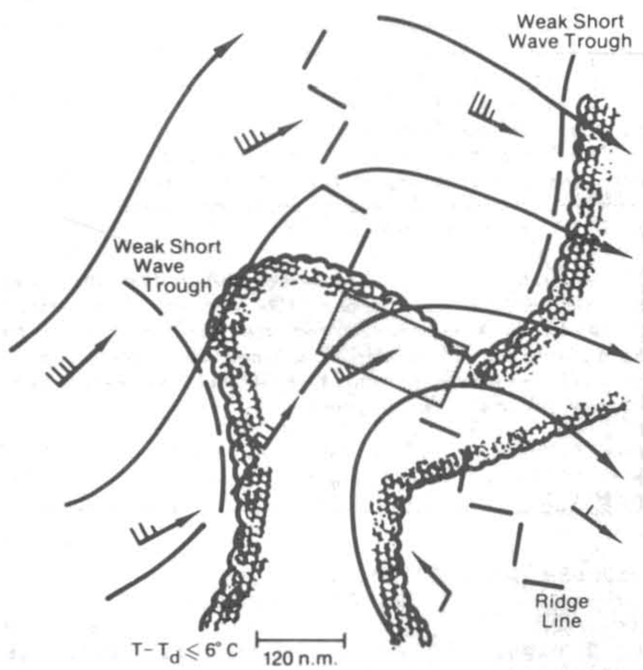

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Figure 11. As in Fig. 7 except for meso-high type heavy rain event.

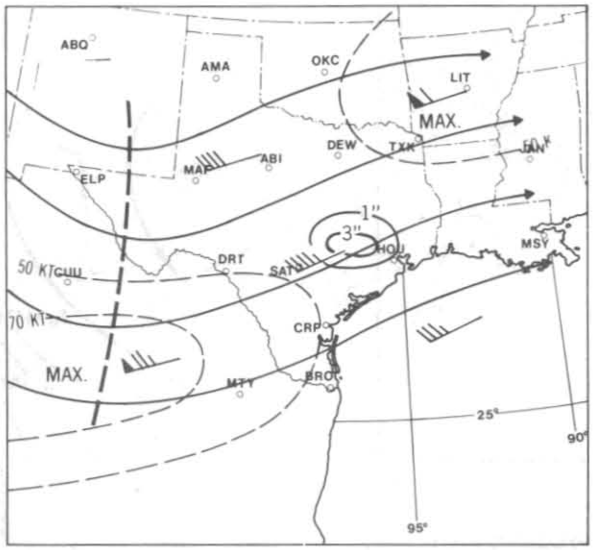

Figure 12. As in Fig. 8 except for meso-high type heavy rain event.

REFERENCES AND FOOTNOTES

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