EFFECTS OF EASTERN PACIFIC CYCLONE MOISTURE ON A HEAVY RAIN AND FLOOD EVENT IN TEXAS AND OKLAHOMA

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ABSTRACT

A series of heavy rain events caused devastating floods across portions of north central and southwest Texas into southeast Oklahoma from October 11-14, 1981. The occurrence of both a frontal and mesoscale flash flood pattern and the entrainment of tropical moisture from eastern Pacific Hurricane Norma combined to produce the heavy rainfall. Although the episode persisted over a three day period, the heaviest convective activity was nocturnal in nature. An extensive area with storm totals of 254 to 508 mm stretched from southwest Texas into south central Oklahoma. There were isolated pockets with storm totals in excess of 508 mm. This is a case study examining the meso-scale, upper air and hydrologic aspects which led to the prolonged heavy rain and flood episode.

1. INTRODUCTION

Heavy rains produced by tropical systems moving from the Gulf of Mexico into Texas have been well documented in the past several years (3,4,5,6). Hale (7) discussed the effects of tropical moisture from the eastern Pacific into the southwestern U.S. However, little has been written regarding the entrainment of eastern Pacific tropical moisture across the Sierra Madre Mountains of Mexico into Texas and Oklahoma (8).

During October 1981, the remnants of three eastern Pacific hurricanes (Lidia, Norma and Otis) moved across the Mexican highlands into Texas. These three storms interacted with synoptic scale systems as they moved across Texas. Each produced rains in excess of 250 mm (9) and flooding across portions of Texas and/or southeastern Oklahoma. Monthly rainfall totals in excess of 300 percent of normal were recorded from the Texas Big Bend region into southeastern Oklahoma (9,10). But nearly half the monthly total fell during the three-day period from about 0900 GMT 11 October to about 0600 GMT 14 October. This was when the remnants of eastern Pacific Hurricane Norma (NORMA) affected the area.

Tropical moisture from NORMA combined with several other synoptic features to produce rainfall amounts of 125 to 250 mm across much of the area from the Edward's Plateau of Texas into southeastern Oklahoma. There were several 380 mm centers with maximum rainfall amounts in excess of 500 mm (Figure 1) (11, 12). These rains caused devastating floods with extensive damage, estimated in excess of 175 million dollars. Ten flood-related deaths were also recorded, eight in Texas and two in Oklahoma (13).

In October 1983, eastern Pacific Hurricane Tico followed a similar pattern to NORMA. This produced heavy rains and flooding from north central and west Texas into central Oklahoma. Maximum rainfall amounts across central Oklahoma were 356 to 432 mm.

This paper is a case study examining the various meteorological and hydrologic parameters which helped trigger the heavy rain event associated with tropical cyclone NORMA during mid October 1981.

2. SYNOPTIC SCALE

2.1 Upper Air

A high latitude blocking pattern became well established over the Davis Straits in eastern Canada during the first half of the month, but began to break down toward mid month (Figure 2) (9,10). Nevertheless, a strong eastern U.S. ridge coupled with a Great Basin trough allowed for southwesterly flow to persist from the Gulf of California into the central plains throughout the period under study. This flow acted as the steering mechanism for the entrainment of middle and upper level moisture from both eastern Pacific Hurricanes Lidia (LIDIA) (October 6-8) and NORMA (Figure 3) across northern Mexico into Texas.

In the lower troposphere, weak 850 mb and 700 mb warm air advection (Figure 4) was indicated on the analysis beginning at 1200 GMT on the 11th and continued through 0000 GMT on the 14th. A low level high pressure system in the central Gulf of Mexico maintained a strong moist south to southeast flow into Texas. Local studies have shown that warm air located to the west of the moist axis is an important criteria for heavy rains in the Texas/Oklahoma area.

In the mid-levels of the troposphere, several short-wave troughs (S/W) and positive vorticity advection (PVA) lobes rotated through the long-wave trough and aided the development of thunderstorm activity. The first weak PVA lobe moved across the Pecos Valley during the morning and afternoon hours of the 11th (per Kansas City Satellite Interpretation Message). This triggered thunderstorms across the Edward's Plateau during the day. Another S/W moved across central Texas on the evening of the 11th and aided thunderstorms in that area throughout the night. At 0900 GMT on the 12th, satellite imagery indicated the heaviest thunderstorms associated with this S/W were in north Texas, northwest of Fort Worth (Figure 5). On the evening of the 12th, a vorticity maximum associated with NORMA moved northeastward from Mexico into the Edward's Plateau and then turned eastward during the morning hours of the 13th. (Figures of the S/W and PVA lobes are not shown).

In the upper levels of the atmosphere, the subtropical jet (STJ) was a major factor in this heavy rain event. It was generally located from southwestern New Mexico/far west Texas into central Kansas then anticyclonically into Missouri. Several speed maxima rotated through this flow, one during the late nighttime hours of the 11th (Figure 5), and another during the day of the 13th. Central Texas and southeast Oklahoma were in the right rear quadrant of these wind maximas, which is a region of upward vertical velocity (UVV). A weak diffluent region was also apparent across this same area during the period. (Figures of the diffluent region are not shown). Both UVV and diffluence have been found to be favorable areas for thunderstorm development (14,15).

The winds were south and southeast in the lower atmosphere veering to a more westerly direction with height on the 11th and early on the 12th (16). This was indicative of the warm advection pattern mentioned earlier. During the afternoon and evening of the 12th, the winds became more southerly at all levels.

This was during the rain event itself. Southerly wind flow in the lower atmosphere, combined with veering winds in the mid and upper troposphere, has been observed with many significant rain events (3). The atmosphere over Texas became increasingly moist and unstable between 0000 GMT on the 11th and 0000 GMT on the 12th.

This was reflected by a doubling in both the mean relative humidity and the precipitable water values between 0000 GMT and 1200 GMT on the 11th at Stephenville, TX (about 50 miles southwest of Fort Worth), as illustrated in Figure 6a. The lifted index also destablized; the K-index increased rapidly during the same period (Figure 6b) and remained nearly constant throughout the heavy rain event.

2.2 Surface Pattern

A cold front had moved southward across west and north Texas on October 9th, becoming quasi-stationary along the upper Texas coast by 1200 GMT on the 11th. Behind the front, dew points remained in the upper 50s to mid 60s. The front moved slowly northward as a warm front on the 11th (Figure 7). The warm front continued to move northward into Oklahoma on the 12th before dissipating. South of the front, dew points were in the upper 60s to lower 70s through the 13th.

Warm, moist air from the Gulf of Mexico was lifted over the warm front as it moved northward and combined with an upper level S/W (discussed above) to produce rains across the Edward's Plateau during the day of the 11th. The rains moved northward and fell between Abilene and southeast Oklahoma during the nighttime hours of the 11th and early morning of the 12th. This was a classic example of a frontal flash flood pattern (17).

3. DISCUSSION OF MESOSCALE FEATURES

There were several mesoscale features, such as rain-cooled boundaries, mesohighs, and thunderstorm outflow boundaries, evident during the heavy rain episode. Since many of these features were subtle, only two of the predominant ones will be discussed.

3.1 Outflow Boundary Features

Scattered thunderstorms which occurred over southern Oklahoma and the extreme northern portion of north Texas during the early part of October 12th had dissipated but produced an outflow boundary. A classic "arc cloud" associated with this boundary was easily recognized in satellite imagery (Figure 8). Scattered thunderstorms redeveloped about 1700 GMT along the intersection of the western flank of this outflow boundary and a low level convergence line southwest of Abilene. By 2100 GMT, the thunderstorms were intensifying rapidly along the western flank of the arc cloud. This is often a favored location for heavy rainfall (18). Figure 9 illustrates the intersection of the arc cloud, as depicted by satellite imagery and also defined in the surface analysis and by the surface moist axis.

3.2 Meso-High Feature

A cluster of thunderstorms associated with the center of NORMA'S circulation redeveloped in the western portion of the Edward's Plateau during the evening hours of the 12th. During the early nighttime hours, thunderstorms increased in areal coverage and intensity. By 0800 GMT on the 13th, a small meso-high became discernible at the surface in the vicinity of San Angelo, TX (Figure 10). During the early morning hours of the 13th, the thunderstorm cluster evolved into the "core rain" regime (19). The meso-high acted as the focusing mechanism for flood- producing rains during the late nighttime and early morning hours (16). This high persisted as it drifted eastward during the morning of the 13th under the influence of NORMA. This was another classic "nocturnal" flash flood event (20).

4. HURRICANE NORMA

NORMA was the third of four eastern Pacific hurricanes (LIDIA, Oct. 2-8; MAX, Oct. 8-10; NORMA; and OTIS, Oct. 25-30) to develop during the month of October 1981. Of these, only MAX did not strike the Mexican coast; however, mid and upper level moisture from all the storms was transported into Texas. Tropical Depression NORMA developed near 14.5N 104.4W around 1800 GMT October 8th and by 1800 GMT on the 9th NORMA was classified as a hurricane. NORMA moved northwestward to near 18.6N 108.5W at 0600 GMT on the 11th before curving northeastward and striking the Mexican coast near Mezatlan around 1100 GMT on the 12th (Figure 11). The upper circulation from NORMA remained well defined on satellite imagery through much of the 12th. By 0000 GMT on the 13th, the center was located about 160 Km south of the Texas Big Bend. By 1200 GMT, NORMA had moved northeastward to near San Angelo.

Mid and upper level moisture from the remnants of MAX became entrained in the southwesterly flow and spread across Arizona and New Mexico into west Texas around 1200 GMT on the 10th. By 0600 GMT on the 11th, the moisture from MAX and the outflow from NORMA merged and spread into western and northern Texas (Figure 12). Satellite photos showed this entrainment of moisture continued across the highlands of Mexico into Texas until the remnants of NORMA's upper level circulation moved across Texas on the night of the 12th and the day of the 13th. NORMA demonstrated oscillations between daytime "pheripheral showers" and nighttime "core rains" on both the 12th and the 13th (Figure 13) (19). This system produced the third significant rainfall event within a three-day period.

5. HYDROLOGICAL CONSIDERATIONS

Flash flooding and river flooding of record or near record magnitude occurred over portions of north central Texas and south central Oklahoma, generally bounded by an Abilene-Wichita Falls-Sulphur OK-Clayton OK (about 40 miles southeast of McAlster)-Dallas-Abilene line (Figure 1). County, state and federal roads and bridges were blocked, washed out or destroyed at hundreds of locations. Extensive damage to homes, businesses and agricultural interests also occurred during the episode. Record stages were reported at numerous locations across this area. These included: the mainstream of the Red River from Thackerville, OK to near De Kalb; Clear Boggy Creek near Caney, OK; the Trinity River at Boyd, TX; and the Brazos River near Dennis, TX. The Deep Creek in Shackleford County of Texas reached its highest crest in 100 years.

The heavy rains and flash flood waters across the region filled many reservoirs and lakes. Several of the dams were breached during the event. Texoma, Atoka and Coalgate Reservoirs in Oklahoma were filled during the event.

Heavy rains across the Edward's Plateau of Texas also produced flash flooding/flooding along the Devil's River on the 11th and along many other streams and rivers on the 12th and 13th.

The nocturnal nature of the heavy rains made rescue and evacuation operations more difficult and hazardous. As an example, a nursing home in Breckenridge, TX had to be evacuated on three consecutive nights, while in Oklahoma, one nursing home had to be evacuated for two days due to high water.

6. SUMMARY OF SEQUENCE OF EVENTS

a. The heavy rains across portions of Texas and Oklahoma on 11-14 October 1981 were the combined effects of several synoptic and mesoscale features. As observed in other heavy rain events (21), this event was preceded by heavy rains associated with LIDIA the previous week, saturating the ground and swelling many rivers and streams. Thus, the additional 250 to 500 mm rains (second event) of 11-14 October were reflected mainly as runoff and increased the seriousness of the flood situation.

b. Early on the 11th, heavy rains developed over the Edward's Plateau in association with a warm front drifting northward through central Texas and an upper level S/W. Total rains from this episode ranged from 250 to 380 mm.

c. During the evening hours of the 11th, heavy rains developed from the Abilene area of north central Texas into southeastern Oklahoma. These thunderstorms developed along the warm front as it moved across the same area. The heavy rainfall was enhanced by the entrainment of moisture from NORMA which was located near the west coast of Mexico (Figure 5). This resembled Maddox's (16) frontal flash flood pattern and was nocturnal in nature (20). Rains of 50 to 175 mm were received across north central Texas during the night. This pattern continued across south central Oklahoma on the 12th, with rainfall amounts in excess of 450 mm reported.

d. Heavy thunderstorms developed on the afternoon of the 12th over the western portion of north central Texas. This thunderstorm activity was associated with an outflow boundary, as discussed in the section on mesoscale features.

e. Finally, the upper level circulation of NORMA moved northeastward from Mexico into Texas. By midnight on the 13th, the remnants of NORMA were just to the southwest of Del Rio. Convection redeveloped from the western portions of the Edward's Plateau into north central Texas during the nighttime hours. Thunderstorms intensified during the late nighttime hours as NORMA neared the Edward's Plateau. Heavy thunderstorms gradually moved eastward into north central Texas and southeastern Oklahoma during the daytime hours of the 13th. Heavy rains continued into the evening hours and ended around midnight on the 14th (Figure 14). Twenty-four hour rainfall amounts ending at 1200 GMT on the 14th ranged from 50 to 250 mm.

f. These combined systems produced widespread rainfall totals of 125 to 250 mm. There were several 8 to 10 square km areas with rainfall totals in excess of 500 mm (Figure 1).

7. CONCLUSIONS

Several synoptic and mesoscale features interacted to produce this excessive rainfall event from the Edward's Plateau of Texas into southeastern Oklahoma. One of the primary factors was the prolonged entrainment of mid and upper level tropical moisture from the eastern Pacific (NORMA) across the Mexican highlands into Texas and Oklahoma. The intrusion of low level moisture from the Gulf of Mexico combined with mid and upper level moisture to produce precipitable water values in excess of 200 percent of normal. K-indices of 36 to 41 and lifted indices of minus 4 to minus 6 reflected the highly unstable air mass in the area.

Both the frontal and meso-high flash flood pattern of Maddox were evident during the event. Several other mesoscale features helped to focus the excessive rains. These included rain-cooled boundaries and thunderstorm outflow boundaries. Detailed mesoscale analyses and satellite imagery were a tremendous aid to forecasters in identifying these potentially dangerous areas for severe flooding. The first heavy rain spell saturated the ground in early October and set the stage for the second event of 11-14 October 1981. Thus, the additional 250 to 500 mm rains were reflected as mainly runoff and intensified the flood situation.

The heaviest rains and much of the flash flooding were "nocturnal" during the event, occurring mainly after midnight. In some cases, radar and satellite showed that thunderstorms repeatedly moved across the same area.

8. ACKNOWLEDGMENTS

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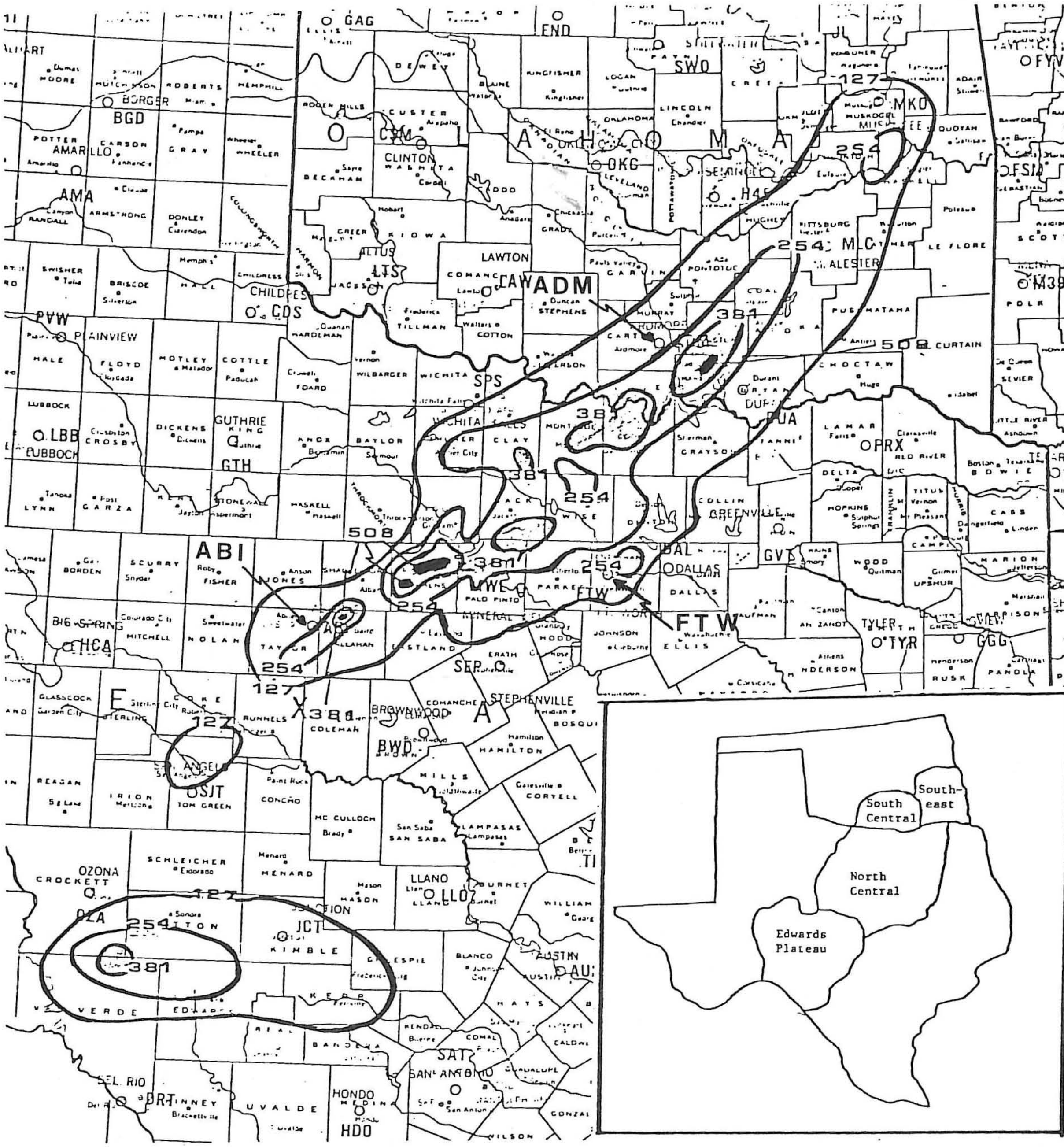


Figure 1 Isohyets of storm totals 11-14 October 1981. Dark areas indicated storm totals in excess of 508 mm. Greatest storm totals were 665.5 mm at Linn, Ok (southeast of Ardmore) and 584.2 mm at Clyde 5n, Tx. (east of Abilene). The insert map shows the geographical regions discussed in the paper. (Note: ADM - Ardmore, ABI - Abilene, FTW - Fort Worth)

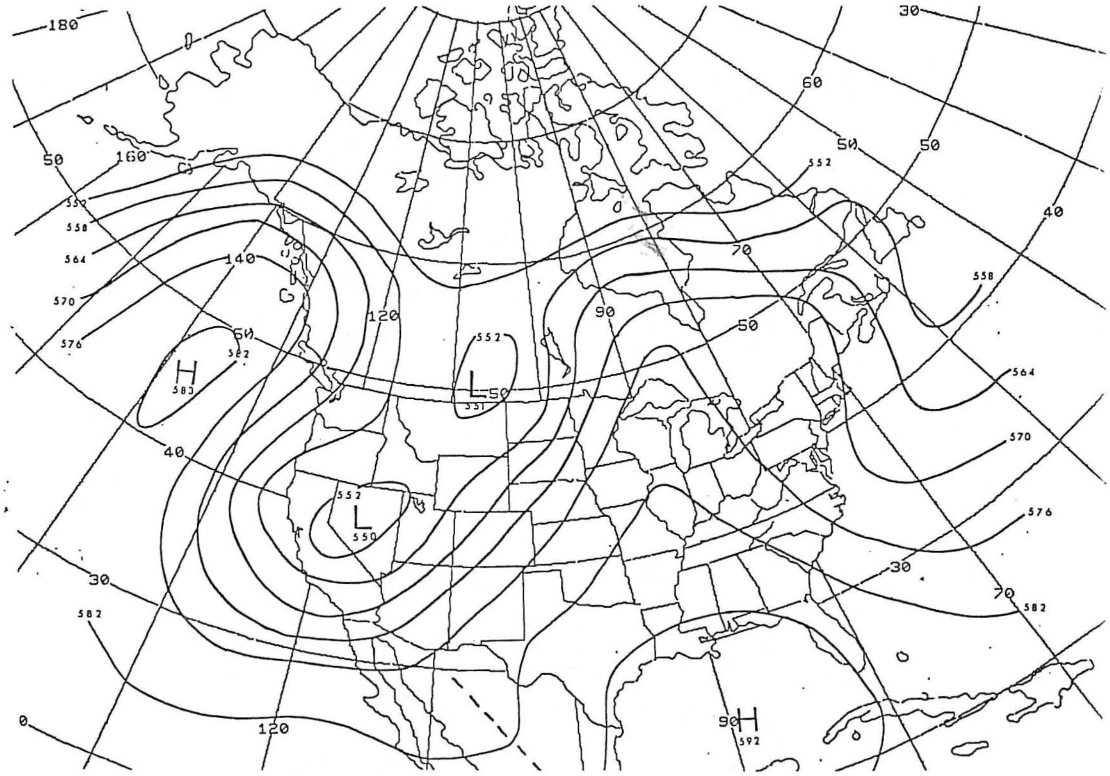


Figure 2 500 MB analysis 0000 GMT 13 October 1981.

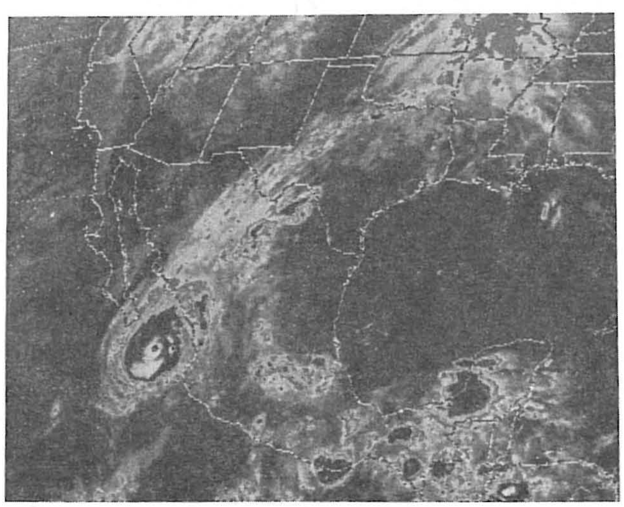
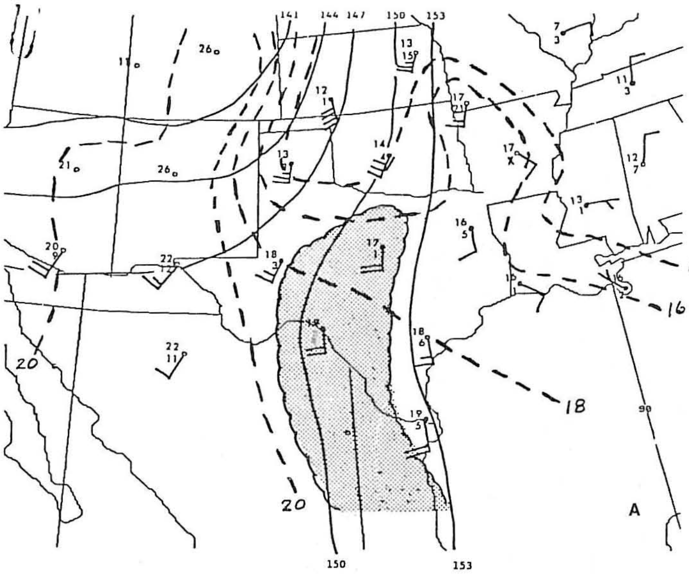
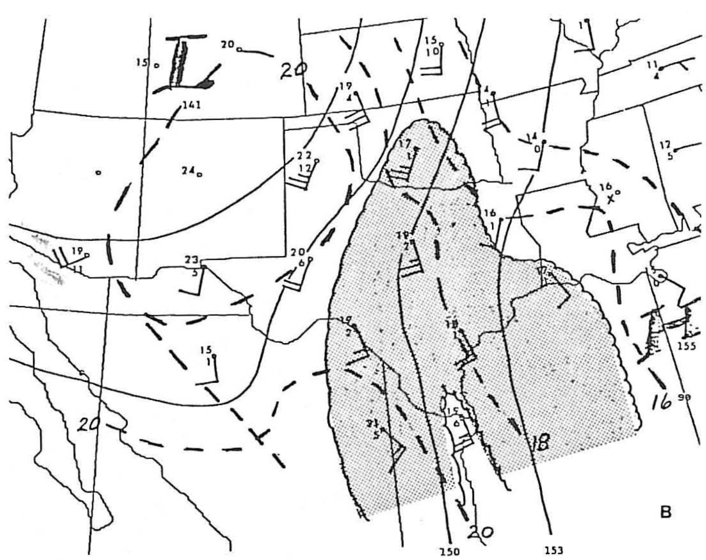


Figure 3 Infrared satellite imagery 0200 GMT 12 October 1981 showing entrainment of tropical moisture from NORMA northward into Texas.

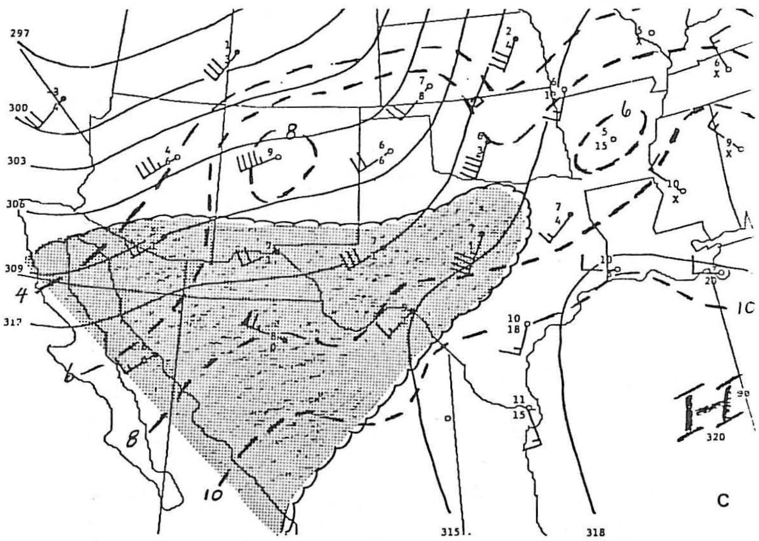




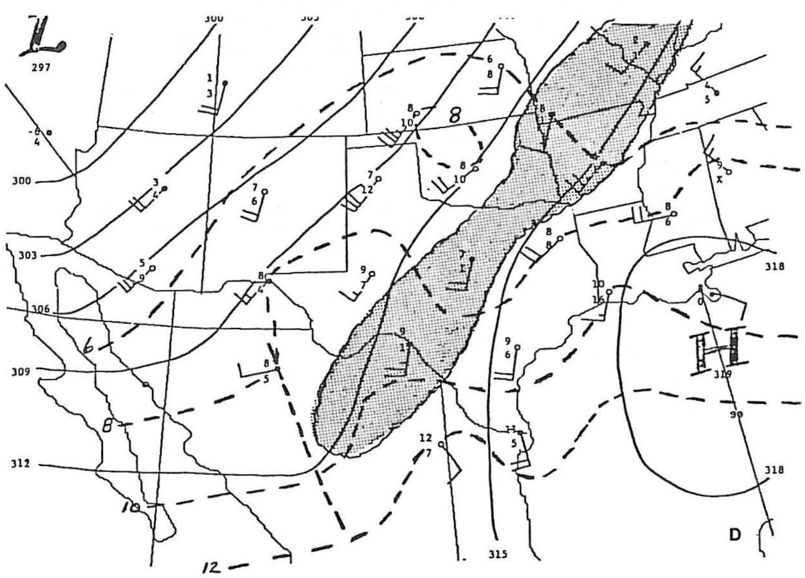
A) 850 MB analysis 0000 GMT 12 October 1981; B) 850 MB analysis 0000 GMT 13 October 1981;

Figure 4

Stipled area indiates low and mid- level moisture.



C) 700 MB analysis 0000 GMT 12 October 1981;



D) 700 MB analysis 0000 GMT 13 October 1981.

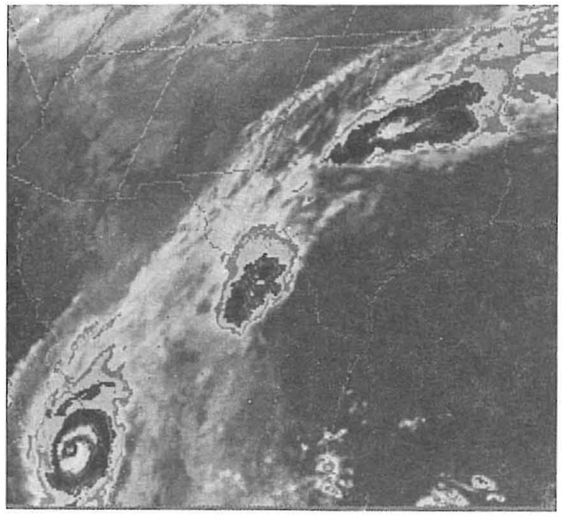


Figure 5 Infrared satellite imagery 0800 GMT 12 October 1981. Note: Bulge in cirrus clouds over southeast New Mexico suggests a speed maximum in the general jet-stream pattern. NORMA was approaching the western Mexican coast. Heavy thunderstorms can be seen south of the Big Bend National Park and over north Texas.

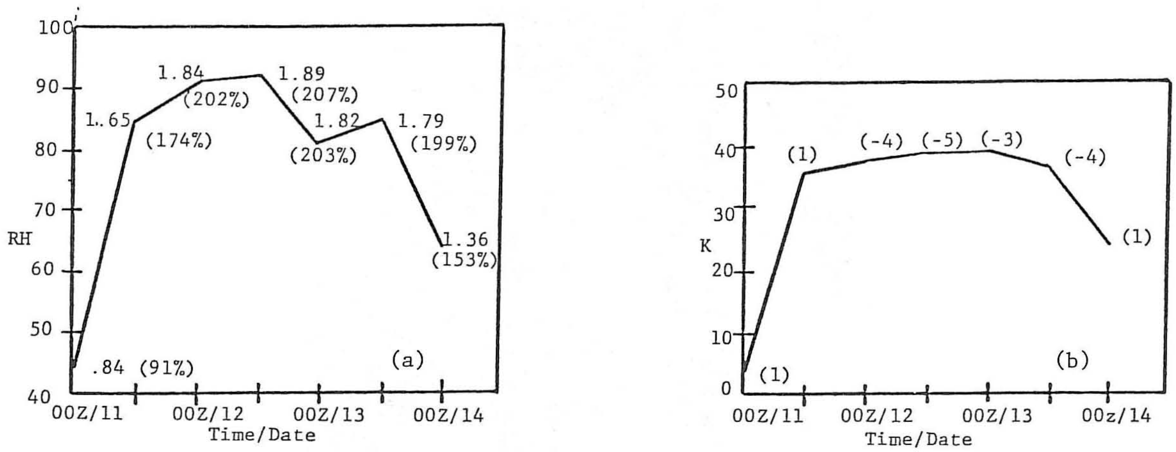


Figure 6 a) Mean relative humidity and precipitable water amounts with percent of normal in parentheses for Stephenville, TX during the heavy rain episode.

b) K-index with lifted index in parenthesis for Stephenville, TX for the same period.

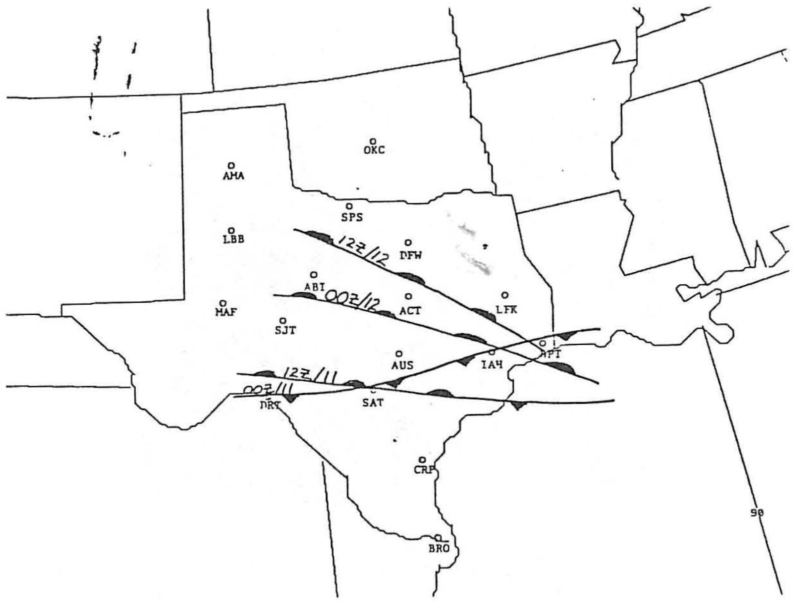


Figure 7 Sequence of frontal positions.

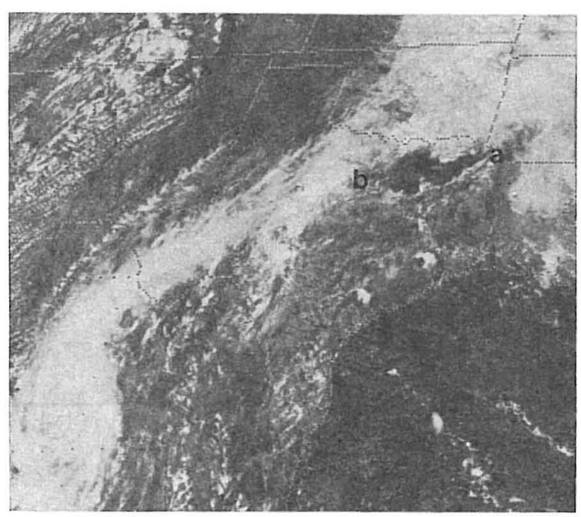


Figure 8 Visible satellite imagery 1900 GMT 12 October 1981.
NOTE: Arc cloud (a-b) in north central Texas.

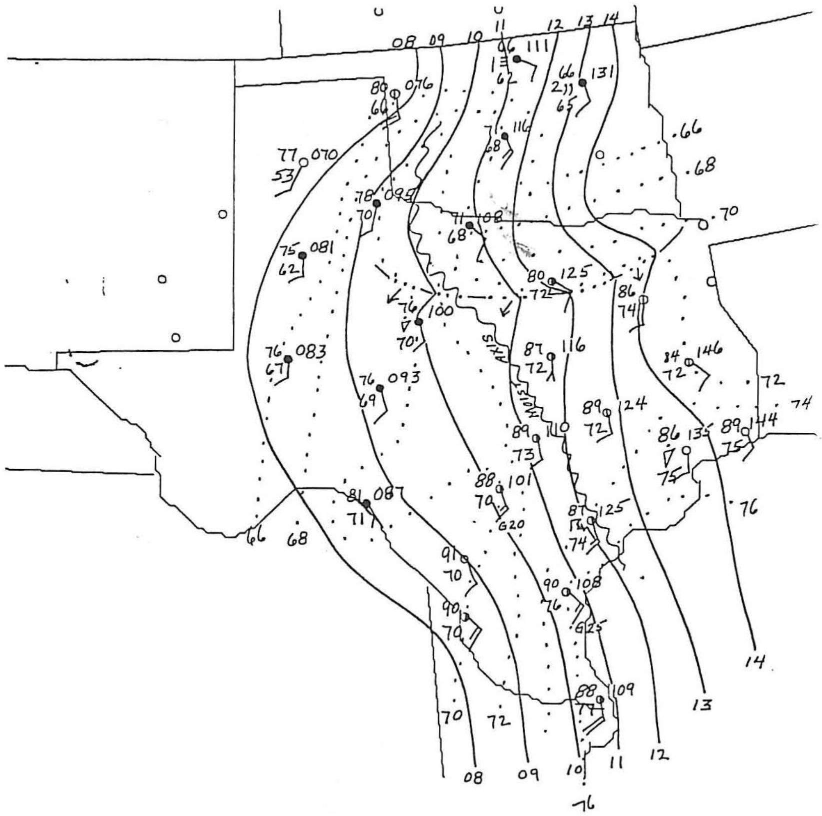


Figure 9 Mesoscale surface analysis 1900 GMT 12 October 1981. Dots are isodrosotherms.

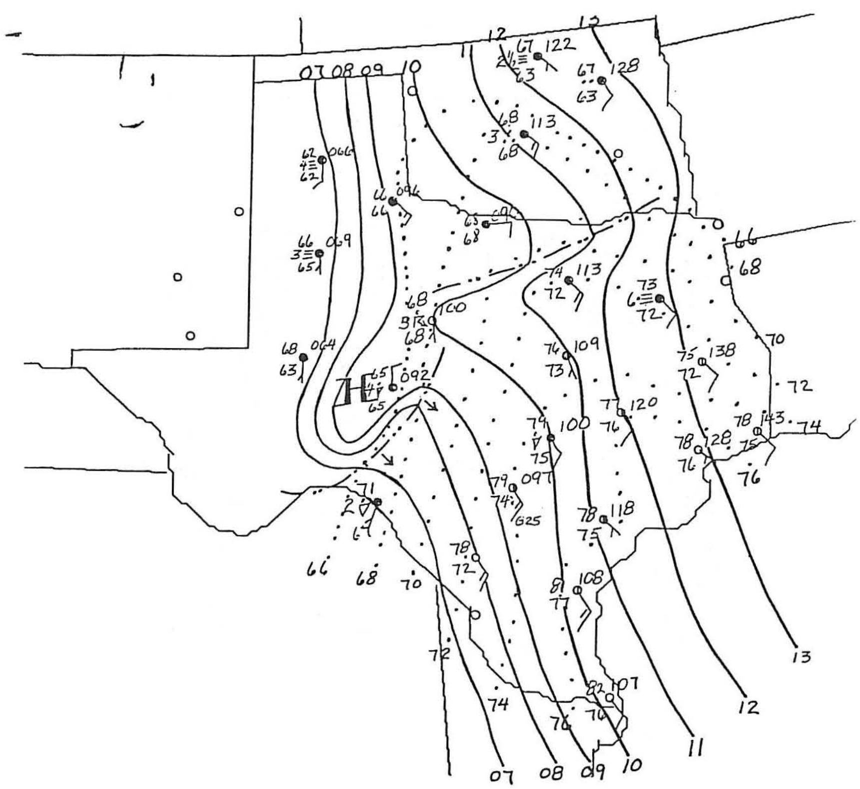


Figure 10 Mesoscale surface analysis 0800 GMT 13 October 1981.

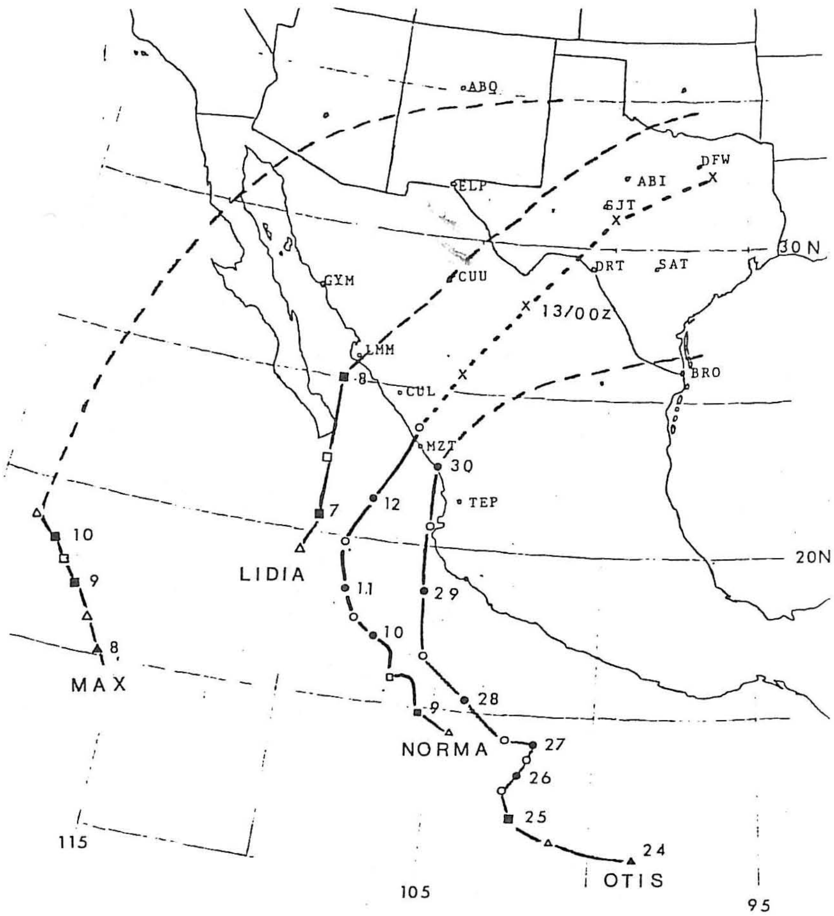


Figure 11 Track of eastern Pacific Tropical Cyclones affecting the U. S. during October 1981.

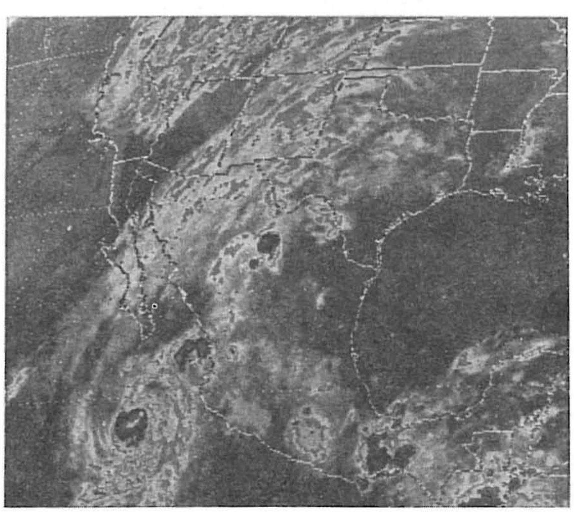


Figure 12 Infrared satellite imagery 0630 GMT 11 October 1981. Cloudiness over southeast Arizona and New Mexico is remnants of MAX.

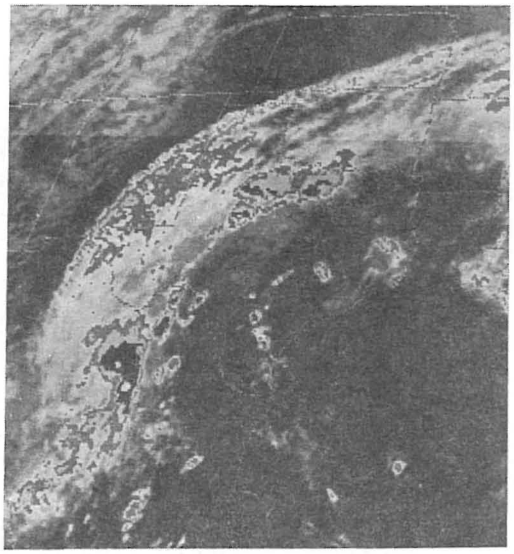


Figure 13a Infrared satellite imagery 2300 GMT 12 October 1981.
Peripheral showers associated with NORMA.

Figure 13b Infrared satellite imagery 0800 GMT 13 October 1981.
Nighttime core rains associated with NORMA.

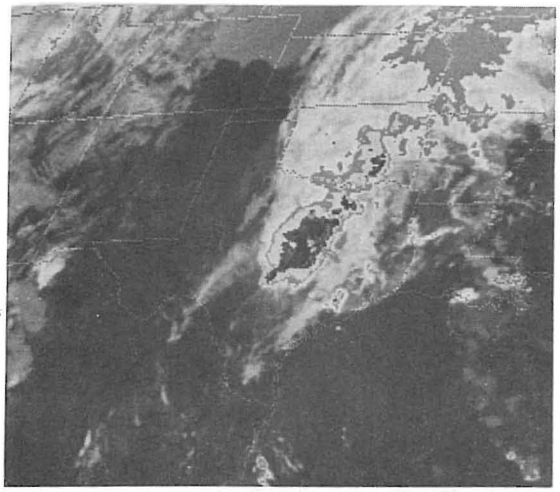


Figure 14 Infrared satellite imagery 1700 GMT 13 October 1981.

FOOTNOTES AND REFERENCES

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