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Technical Attachment

THE PRODUCTION OF SEVERE WEATHER AND HEAVY RAINFALL ACROSS MISSISSIPPI ASSOCIATED WITH DISSIPATING TROPICAL CYCLONE ANDREW

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1. Introduction

After landfall along the central Louisiana coast early on 26 August 1992, dissipating Hurricane Andrew turned northeast and cut a diagonal path across Mississippi. During a 24-hour period, Andrew was responsible for 29 reported incidents of wind damage, many of which may have been caused by tornadoes. A 100-mile-mile wide band of rainfall between four and eight inches fell along the storm's track, with isolated totals of over nine inches recorded.

This paper provides a review of the wind damage and heavy rainfall associated with Andrew. The severe weather warnings issued by the Jackson Weather Service Forecast Office (WSFO) and the Meridian and Tupelo Weather Service Offices (WSO) are highlighted along with locations and times of all damage reports.

Upper air sounding data from Jackson and derived Energy-Helicity Indices (EHI) are used to show the amount of low-level shear present, providing the potential for tornadic development. Several comparisons are made between Andrew's wind field (and subsequent damage locations) and composite data from previous tornado- and non-tornado-producing tropical cyclones.

2. Tornado Warnings and Wind Damage Reports

An important aspect of hurricane landfall is the production of tornadoes (Anthes, 1982). The addition of friction from the earth's surface after landfall provides a vertical wind shear profile in the lowest levels of the atmosphere which is conducive to the formation of tornadoes, particularly within the right front quadrant of the storm.

Hurricane Andrew proved to be a prolific producer of damaging thunderstorm winds and possible tornadoes. Determination of whether wind damage was actually produced by tornadoes or convective straight-line wind gusts during a hurricane event is a difficult task. The majority of tornadoes associated with hurricanes are weak (F0-F1) and short-lived (Anthes, 1982), making damage assessment complex. In addition, with such a large number of events, on-site storm surveys are often impractical. Therefore, the damage reports cited in this paper are termed "possible tornado" events.

As the center of Hurricane Andrew was located over Louisiana, approximately 100 miles south of the southwest comer of Mississippi, the first strong convective band rotated northward across South Mississippi. A High Wind Warning was issued for the southwest portion of the state in anticipation of the center's approach (Fig. 1).

Shortly after 1200 UTC 26 August, a severe thunderstorm warning was issued by the Jackson office for three counties in the southern portion of the state. During the next five hours, an additional eight tornado warnings were required as the spiral rainband rotated northwestward.

Andrew continued to move slowly north, entering extreme southwest Mississippi as a rapidly weakening tropical storm. Fig. 2 illustrates the track of Andrew across Mississippi as determined from surface data. By 0300 UTC 27 August, Andrew was downgraded to a tropical depression, and the system began to turn toward the northeast. The center of circulation was located slightly west of Jackson by 0900 UTC. During this time period, 21 tornado warnings were issued by the Jackson and Meridian offices.

Once the center of the depression moved north of Jackson, no further tornado warnings were required within Mississippi. This was not the end of Andrew's tornado production however, as the adjacent states of Alabama and Tennessee reported several areas of tornado-producing wind damage during the next 24 hours.

A post-storm review indicated that of the 33 tornado/severe thunderstorm warnings issued within Mississippi, all except five verified. Additionally, only two missed events were recorded. Although most of the damage was associated with downed trees and power lines, some minor structural failures did occur. Only three reports of minor injuries were received.

3. Vertical Shear Profile and Tornado Locations: A Comparison With Past Events

To determine the vertical environment associated with Andrew, sounding data from Jackson are examined. Data from 00 UTC 27 August (Fig. 3), as Depression Andrew is located 80 miles southwest of Jackson, indicate a very moist and marginally unstable environment. The amount of Convective Available Potential Energy (CAPE, or positive buoyancy B+) is 1040 J/kg.

The hodograph in Fig. 4 shows a speed shear of 17 m/s between the surface and the 1.5 km level (roughly 850 mb) and a veering of 50 degrees above Jackson. Using radar determined cell motion of north at 20 knots, Storm Relative Helicity (SR Helicity) values of 527 and 635 are determined for the 0-2 km and 0-3 Ian layers, respectively. The resulting EHI value (table 1), indicates a combination of low level wind shear (SR Helicity) and CAPE sufficient for possible tornado production (LaPenta, 1992).

Novlan and Gray (1974) estimate from composite data that tornado-producing hurricanes have a mean speed shear of 23 m/s between the surface and 850 mb, compared to about 12 m/s in storms without tornadoes. Directional components show a slight veering of approximately 10 degrees. An inferred CAPE value from their composite sounding was determined to be only 114 J/kg (McCaul, 1987).

Although Andrew's low level shear and buoyancy profiles differ from the Novlan and Gray composite, they closely resemble Tropical Cyclone Danny (1985), another significant tornado producer. Danny was responsible for at least 22 tornadic storms across Mississippi, Alabama, and Tennessee. Several of these reached F2-F3 'in-tensity, while others yielded long tracks. McCaul (1987) determined a surface to 850 mb speed shear of 15 m/s, 50 degrees of veering, and a positive buoyancy value of 1044 J/kg for a location within Danny's tornadic environment. All of these values are remarkably similar to data obtained from the Jackson sounding during Andrew.

Fig. 5 depicts the Jackson sounding at 1200 UTC shortly after passage of Andrew's center. An increase in moisture can be seen from the previous sounding, with a nearly saturated environment through 700 mb. The atmosphere has become more stable with a significant decrease in the CAPE (Table 2). Low level winds veer 140 degrees, and the speeds lessen by over 40 percent within the lowest layers above the surface (Fig. 6). Using the 0-6 Ian mean wind for the storm motion, SR helicity values for the 0-3 Ian layer drop markedly, resulting in an EHI near zero. In agreement with these predictors, the region of damaging convective winds have shifted into Alabama by this time.

Tornadoes are normally heavily concentrated in the right front quadrant of the storm (relative to the track) in regions where the air has had a relatively short trajectory over land (Elsberry, et al., 1987). All of the Mississippi wind damage events occur between azimuths of 330 and 55 degrees at a distance of at least 60 miles from the center (Fig. 7). This is similar to the Novlan and Gray finding shown in Fig. 8; however, their centroid location occurred at a slightly larger radius and a more eastward position.

It is interesting to note that tornadoes are rare within about 40 miles of a tropical cyclone center where the strongest winds are usually found (Atkinson, 1971). Within this region, the low level wind shear is apparently too weak to develop the streamwise vorticity necessary for tornado evolution.

4. Heavy Rainfall

Recent studies have shown tremendous variability in measured rainfall associated with tropical cyclones (Frank, 1977). The amount of rainfall can be affected by the speed of storm motion, amount of upper/lower level forcing, moisture supply, topography, and the outer wind strength of the cyclone (Elsberry, et al., 1987). Frank (1977), however, estimated an average rainfall rate of nearly four inches per 24 hours within a 120-mile radius of the center.

Rainfall totals across Mississippi varied considerably, depending on the distance from the storm's center (Fig. 9). Totals of less than two inches fell over the southeast coastal region and the northwest portion of the state, while isolated values exceeded nine inches across south-central Mississippi. Most of the rain fell during a six-hour period centered on Andrew's closest point of approach. Totals of more than five inches were generally confined to within 40 miles of the center's track. Precipitation totals tended to decrease along the northeastward path of the depression.

The excessive rainfall during such a short duration prompted numerous flood warnings. TIM Jackson and Meridian offices combined to issue 19 flood warnings, with the Tupelo office issuing one flash flood warning (Fig. 10). Reports indicated that flooding - of creeks, county roads, and low lying area occurred across all but one of the warned counties.

5. Conclusion

During a 24-hour period, dissipating Tropical Cyclone Andrew bisected Mississippi. During Andrew's impact, nearly 30 damaging wind events occurred across the state, many of which may have been associated with tornadoes. Rainfall totals over four inches fell across a huge portion of the state, with isolated totals exceeding nine inches. Flooding of creeks and low lying area occurred across several counties. A total of 53 severe weather warnings were issued by Mississippi weather offices during Andrew's impact.

Upper air data obtained from the Jackson sounding prior to the passage of Andrew's center exhibited a vertical wind profile conducive to tornadic thunderstorm production. Given the degree of low-level shear, coupled with moderate instability and a nearly saturated environment, the number of ensuing wind events were not surprising. With passage of the depression's center, thermodynamic data and hodographs revealed the rapid decrease of severe weather potential

Andrew's wind shear and buoyancy profiles differed somewhat from composite data of past tornado-producing tropical cyclones. However, they were remarkably similar to values obtained during the remnants of Danny (1985). The distribution of damaging convective winds were concentrated within the northeast quadrant relative to cyclone motion. This compared well with past events.

Although Tropical Cyclone Andrew had a major impact on Mississippi's weather, overall damage and casualties were minimal. The majority of wind damage was related to downed trees/power lines and minor structural failure, with only a few isolated reports of substantial mobile home and roof damage. In addition, only three persons sustained minor injuries during the storm.

Acknowledgements

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Novlan, D.J., and W.M. Gray, 1974: Hurricane spawned tornadoes. *Mon. Wea. Rev.*, **102**, 476-488.

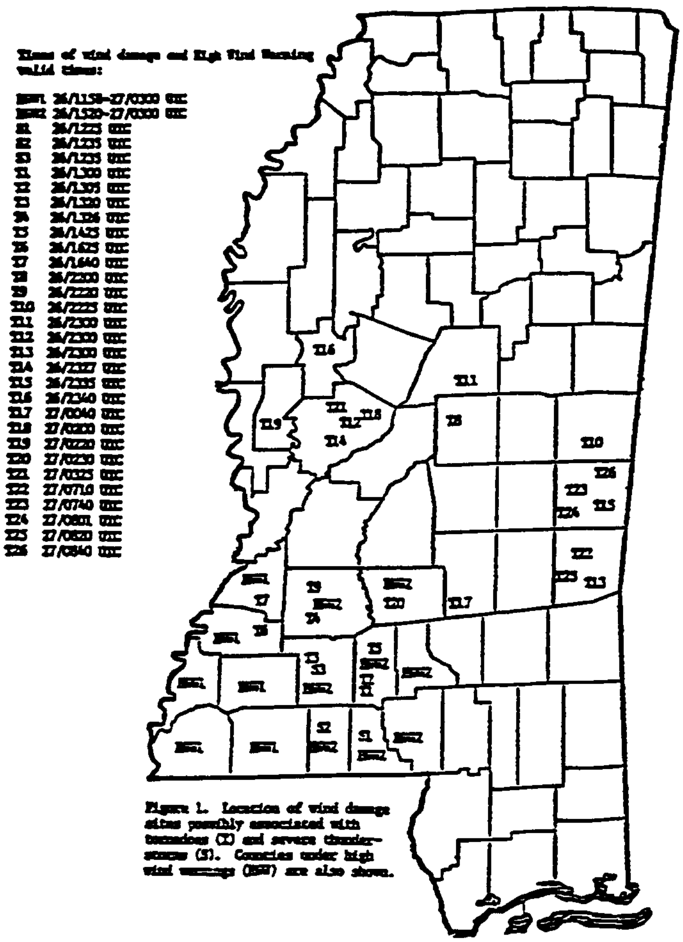

Figure 1. Location of wind damage sites possibly associated with tornadoes (T) and severe thunderstorms (S). Counties under high wind warnings (HWW) are also shown.

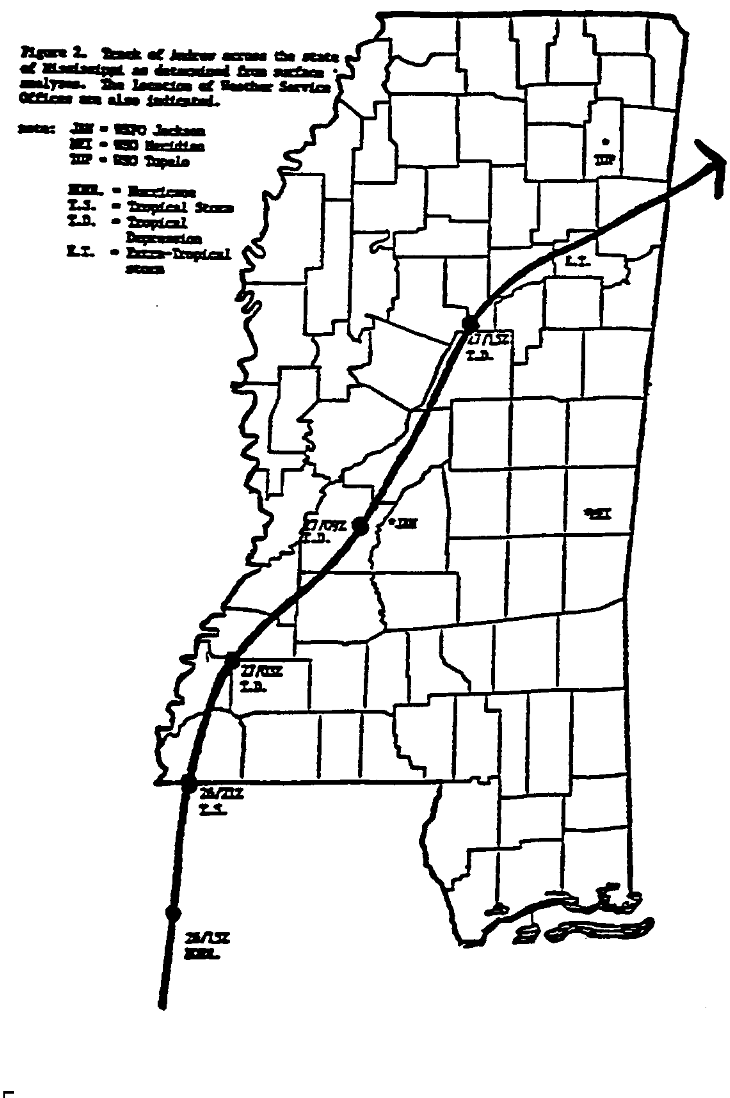

Figure 2. Track of Andrew across the state of Mississippi as determined from surface analyses. The location of Weather Service Offices are also indicated.

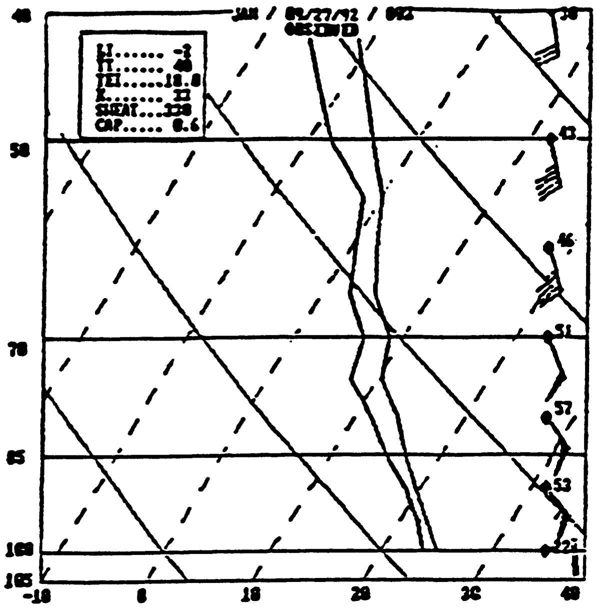

Figure 3. 00 UTC 27 August 1992 sounding for Jackson, Mississippi (JAN) as Tropical Storm Andrew was located 80 nautical miles southwest of Jackson.

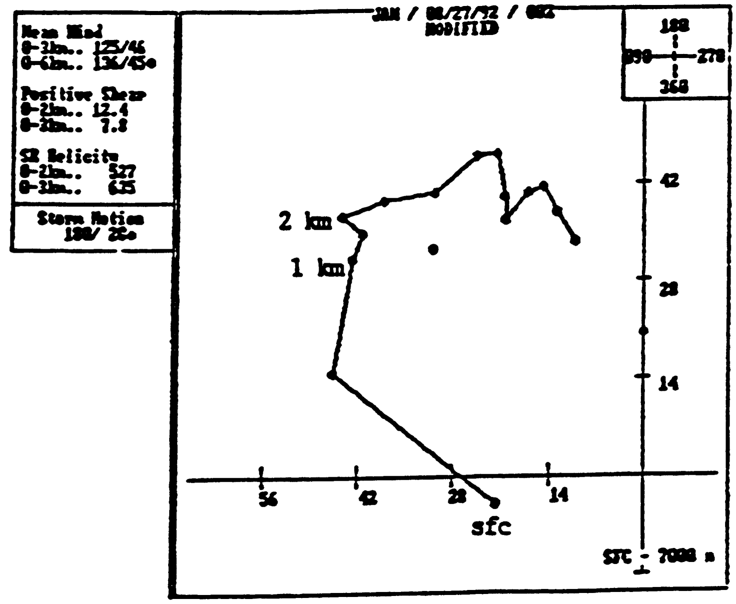

Figure 4. 00 UTC 27 August 1992 hodograph for Jackson, Mississippi.

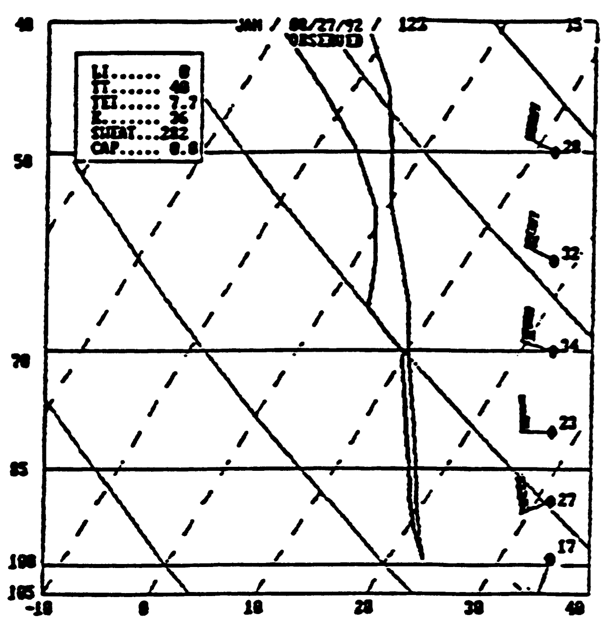

Figure 5. 12 UTC 27 August 1992 sounding for Jackson, Mississippi (JAN) as Tropical Depression Andrew was located 60 nautical miles northeast of Jackson.

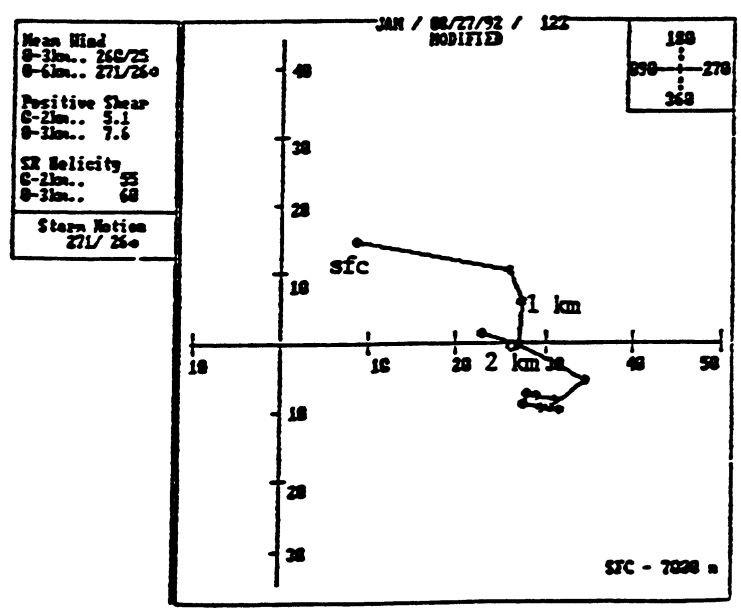

Figure 6. 12 UTC 27 August 1992 hodograph for Jackson, Mississippi.

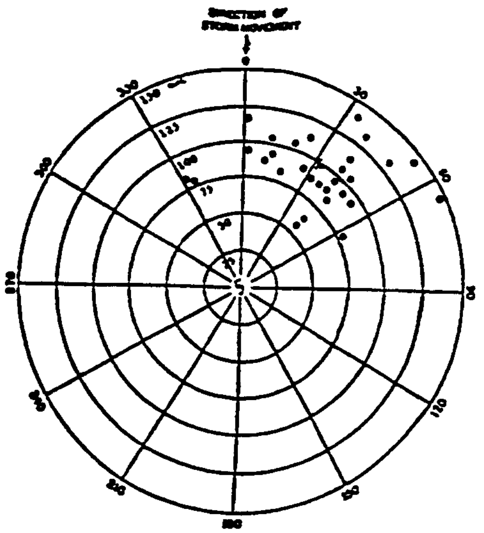

Figure 7. Plan view of 29 Mississippi wind damage locations (possible tornadoes) associated with Tropical Cyclone Andrew (1992) with respect to its direction of motion. The symbol X is the centroid of all damage sites.

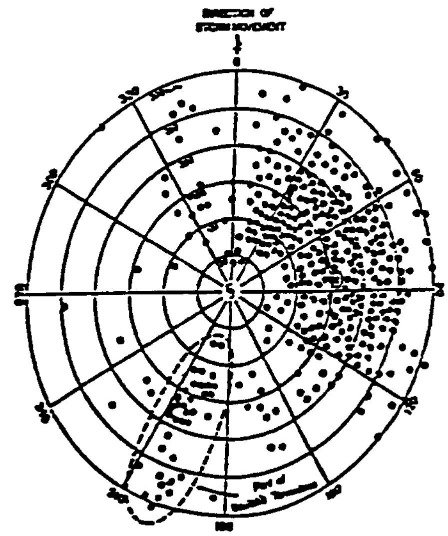

Figure 8. Plan view of 373 U.S. tornadoes associated with hurricanes (1948-72) with respect to its direction of motion. The symbol x is the centroid of all tornadoes. (Novlan and Gray, 1974).

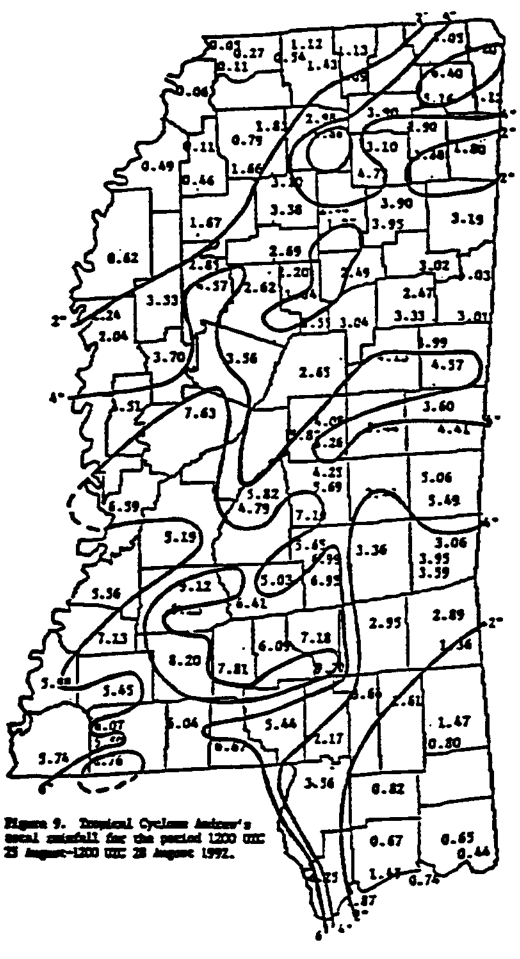

Figure 9. Tropical Cyclone Andrew's total rainfall for the period 1200 UTC 25 August-1200 UTC 28 August 1992.

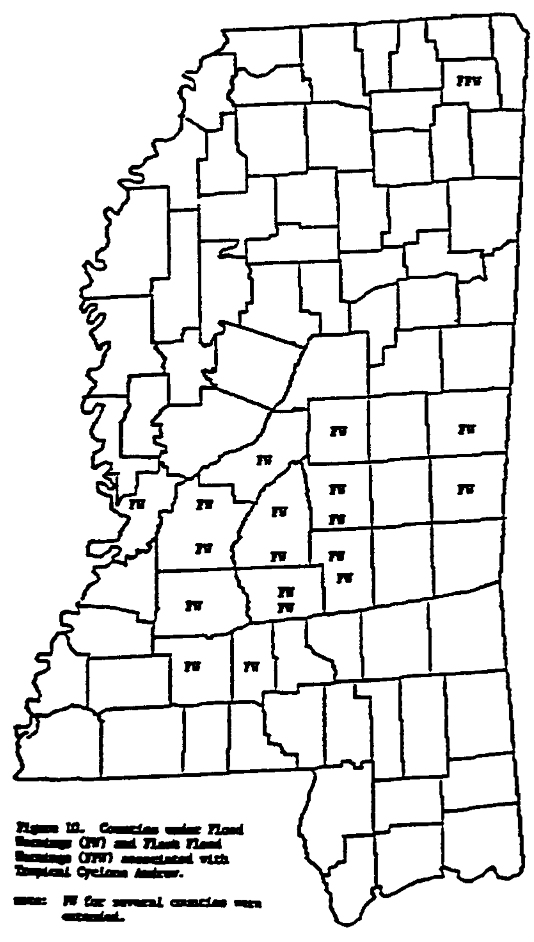

Figure 10. Counties under Flood Warnings (FW) and Flash Flood Warnings (FFW) associated with Tropical Cyclone Andrew.

Note: FW for several counties were extended.

Single-Station RAOB data for: JAN

Date: 08/27/92 Time: 00 UTC

**********CONVECTIVE INDICES**********

Lifted Index @ 500mb...	-2	Cross Totals (CT).......	19
@ 300mb...	-1	Vertical Totals (VT)....	21
		Total Totals............	40
Showalter Index........	2		
Sweat Index............	330	B+....................	1040 J/kg
TEI....................	18.0	B-....................	1 J/kg
		Max UVV...............	46 m/s
K Index................	33		
Precipitable Water.....	2.29 in		
		BRN....................	11
700-500mb Lapse Rate...	4.7 C/km	Energy/Helicity Index..	3.43

********** STORM ENVIRONMENT **********

STORM MOTION: 180/ 20

DEPTH AGL m	SHEAR Pos (10-3 s-1)	SHEAR Neg (10-3 s-1)	SHEAR Tot (10-3 s-1)	HELICITY Pos (m/s)^2	HELICITY Neg (m/s)^2	HELICITY Tot (m/s)^2	HELICITY Ave (m s-2)	HELICITY Rel	MEAN WIND Vector (Dir/kt)	MEAN STORM Inflow (Dir/kt)	VORTICITY Horiz (10-3 s-1)	VORTICITY Stream (10-3 s-1)
1000	25.8	0.0	25.8	463	0	463	463.0	0.97	111/39	80/37	49.03	47.51
2000	12.4	0.0	12.4	527	0	527	263.5	0.84	120/45	92/39	16.74	14.02
3000	7.8	0.0	7.8	635	0	635	211.7	0.80	125/46	99/38	18.12	14.51
4000	6.3	0.4	6.7	717	-5	712	178.0	0.81	131/46	106/36	12.01	9.74
5000	4.8	1.0	5.8	724	-45	679	135.8	0.57	134/45	108/35	10.49	5.96
6000	4.7	0.8	5.5	767	-46	721	120.2	0.75	136/45	111/33	9.39	7.01

Table 1. Derived parameters from 00 UTC 27 August 1992 sounding for Jackson, Mississippi (JAN), nine hours prior to passage of Tropical Depression Andrew's center.

Single-Station RAOB data for: JAN

Date: 08/27/92 Time: 12 UTC

**********CONVECTIVE INDICES**********

Lifted Index @ 500mb...	0	Cross Totals (CT).......	20
@ 300mb...	-1	Vertical Totals (VT)....	20
		Total Totals............	40
Showalter Index........	1		
Sweat Index............	282	B+....................	143 J/kg
TEI....................	7.7	B-....................	31 J/kg
		Max UVV...............	17 m/s
K Index................	36		
Precipitable Water.....	2.46 in		
		BRN....................	4
700-500mb Lapse Rate...	4.7 C/km	Energy/Helicity Index..	0.05

********** STORM ENVIRONMENT **********

STORM MOTION: 271/ 26

DEPTH AGL m	SHEAR Pos (10-3 s-1)	SHEAR Neg (10-3 s-1)	SHEAR Tot (10-3 s-1)	HELICITY Pos (m/s)^2	HELICITY Neg (m/s)^2	HELICITY Tot (m/s)^2	HELICITY Ave (m s-2)	HELICITY Rel	MEAN WIND Vector (Dir/kt)	MEAN STORM Inflow (Dir/kt)	VORTICITY Horiz (10-3 s-1)	VORTICITY Stream (10-3 s-1)
1000	11.7	0.0	11.7	54	0	54	54.0	0.49	243/23	152/12	20.16	9.88
2000	5.1	1.0	6.1	55	-1	54	27.0	-0.03	253/23	150/ 8	12.91	-0.36
3000	7.6	0.7	8.3	58	-1	57	19.0	0.39	260/25	157/ 5	15.15	5.97
4000	4.7	0.4	5.1	70	-3	67	16.8	0.41	266/26	160/ 2	7.73	3.16
5000	3.4	0.5	3.9	73	-3	70	14.0	0.53	269/26	168/ 1	7.30	3.35
6000	3.1	0.3	3.5	76	-4	72	12.0	0.47	271/26	354/ 0	6.13	2.86

Table 2. Derived parameters from 00 UTC 27 August 1992 sounding for Jackson, Mississippi (JAN), three hours prior to passage of Tropical Depression Andrew's center.