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Natural Disaster Survey Report

The Widespread November 21-23, 1992, Tornado Outbreak: Houston to Raleigh and Gulf Coast to Ohio Valley



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service, Silver Spring, Maryland

Cover: Mute tribute to four victims. American flags mark a homesite in Brandon, Mississippi where a tornado killed four people. National Weather Service photograph.

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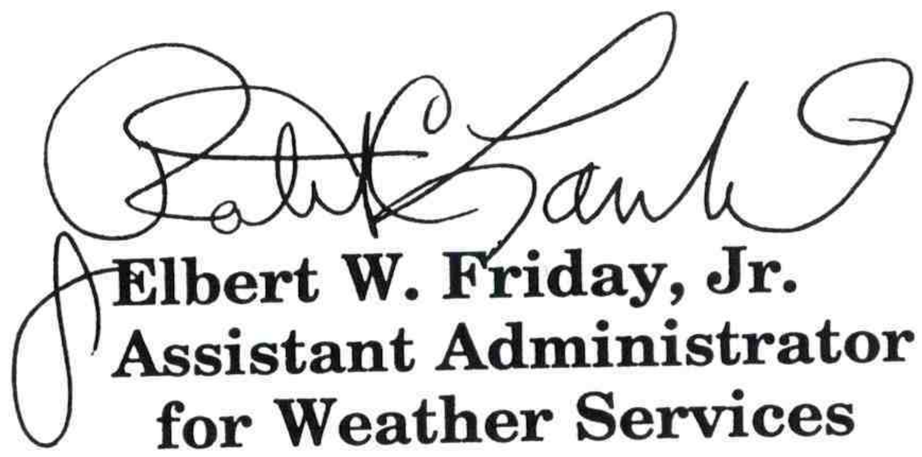
National Weather Service
Dr. Elbert W. Friday, Jr., Assistant Administrator

PREFACE

The tremendous destructive force of tornadoes was unfortunately demonstrated once again during the widespread outbreak of severe convective weather over the Southeastern United States in November 1992. To view the devastation after the fact is distressing and difficult; to experience such a tragedy must be the ultimate nightmare.

Painful as the experience may be, we at the National Weather Service and in the hazards community must examine these disasters to fully assess our warning procedures and capabilities. To learn nothing from the past is undeniably foolish. To learn from the past to improve the future is wise.

I thank the members of the Disaster Survey Team, and all those who assisted them in their work, for accepting this important assignment and for undertaking the extra effort it entailed.



Elbert W. Friday, Jr.
Assistant Administrator
for Weather Services

November 1993

FOREWORD

The principal mission of the National Weather Service (NWS) is to forecast, and warn the public of, impending meteorological and hydrological events that pose a threat to life and property. To perform this mission, a system has evolved over many years which spans the activities of all components of the Service and which extends into communities through ties with the media, public service groups, and emergency management agencies.

No form of natural disaster challenges the NWS watch and warning system more than a widespread tornadic event. Tragic as such events are, they do provide an opportunity for the NWS to see how well its units have performed their functions--to see what may have gone wrong, what went right, and what improvements are needed. The widespread outbreak of tornadoes that occurred over the Southeastern United States during the three-day period from November 21-23, 1992, provided an especially severe test of the NWS system.

At the request of the Assistant Administrator, National Weather Service, a Disaster Survey Team was formed and charged to examine the performance of the NWS during this outbreak. Many offices in the very large area extending from East Texas to Atlantic Coastal states and from the Gulf Coast to the Ohio River valley were involved. Because all affected sites and involved offices could not be covered, the attention of the Team members was directed to those areas where the most severe damage and fatalities had occurred.

The Team assembled at the National Severe Storms Forecast Center in Kansas City to receive an overview of the storm and also to review the performance of the Severe Local Storms unit, which had issued watches throughout the period of the storm events. The team then divided into two groups: one visited affected areas near Jackson, Mississippi, and Atlanta, Georgia; the other travelled to Houston, Texas, Raleigh-Durham, North Carolina, and areas near Cincinnati, Ohio. At each location, contacts were made with NWS personnel, civil emergency managers, public services units, the media and with members of the general public.

This document has been produced from information gathered by the Team members in the course of the survey. It provides an assessment of the performance and effectiveness of NWS units involved in this stressful and tragic series of events; it is not intended to be a comprehensive chronicle of those events. A number of findings and related recommendations based on the Team's work are presented with the expectation that, from this experience, more effective warning and forecasting procedures might result.

The Disaster Survey Team

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EXECUTIVE SUMMARY

By a very great margin, tornadoes occur more frequently in the United States than anywhere else on Earth. Tropical air unimpeded by significant geographical barriers, under appropriate conditions, sweeps up from the Gulf of Mexico and the western Atlantic to blanket much of the country east of the Rockies. When colder and drier air moves from the west against this warm moisture-laden air, enormous instabilities are produced along the boundary of the air masses. Widespread thunderstorms are triggered, some of which may spawn tornadoes.

Such an event occurred in November 1992 when moisture-rich tropical air covered the Southeastern states from Texas eastward to Georgia and northward to the Ohio River Valley. Tremendous energy was released in this unseasonably warm and unstable air mass as a low pressure center entered Texas from the west. Severe weather first developed over southeastern Texas early on Saturday afternoon, November 21. During the next 48 hours, the storms spread eastward and northward and spawned a destructive and deadly outbreak of tornadoes that affected 13 states before finally dissipating in the mid-Atlantic region. A total of 94 tornado tracks were identified during this widespread episode which was unusually intense for November. Twenty-six fatalities and 641 injuries are directly attributable to this episode, and damages to property have been estimated at more than $291 million.

Tornadoes first formed in eastern Texas in the early afternoon of Saturday, November 21, causing great damage in the area but no fatalities. Clusters of thunderstorms moved through Louisiana and spawned ten tornadoes that caused damage and injuries during that evening. The first deaths and the largest number attributable to this episode were in Rankin County, Mississippi. Shortly before midnight, an F4 tornado devastated a mobile home park in Brandon where six people were killed; it then moved on to level a two-story brick home in its path, claiming another four lives. Before exiting the state in the early morning hours of November 22, killer tornadoes caused 15 fatalities in Mississippi.

The storms continued to move eastward and northward into Georgia, Tennessee, Kentucky and the Carolinas where lives were lost in killer tornadoes in each of those states. The last of the fatalities was associated with an F3 tornado that touched down in Hillsborough, North Carolina, in the early morning of November 23. Tornadoes tracked as far north as Indiana and Ohio in the afternoon and evening of November 22, and four touched down in Virginia and Maryland during the early morning hours of November 23.

The advance of the low center through the Southwest and the kinematic and thermodynamic conditions within the contending air masses were well depicted in the model-based forecast guidance provided by the National Meteorological Center. Both synoptic and mesoscale weather patterns were suggestive of very severe weather and served to alert forecasters of the National Severe Storms Forecast Center (NSSFC) and in NWS field offices of the potential for severe thunderstorm and tornadoes over much of the Southeastern United States.

The NSSFC provided excellent support throughout the episode, correctly identifying the threat of tornadoes more than 24 hours in advance of the first event in southeast Texas. The NSSFC Severe Weather Outlooks and the 16 watches issued during the course of the episode were timely and accurate. NWS field forecasters have credited the NSSFC products as being vital to their ability to recognize the magnitude of the event and to the issuance of their own timely forecasts, statements and warnings.

The consensus among members of the Disaster Survey Team was that NWS personnel involved in this episode, both in the National Centers and in field offices the team visited, recognized the deadly seriousness of this situation and made effective use of the available guidance and tools at their disposal. Without exception, all behaved responsibly and with dedication. In particular, the performance at the Weather Service Office (WSO) Houston was exemplary and the value and capabilities of the recently installed WSR-88D radar there were clearly demonstrated. The Houston office issued warnings for 15 of the 17 tornado events that occurred in its area of responsibility, with an average lead time of 25 minutes.

Unfortunately, the big killer tornado in Mississippi set down without Rankin county having been warned. Two thunderstorm systems moved through central and southeastern Mississippi on essentially parallel tracks during late evening of November 21 and early morning of November 22. The Weather Service Forecast Office (WSFO) Jackson was well prepared as these systems approached their area of responsibility and had issued a timely Tornado Warning well before a tornado associated with the westernmost cell touched down just before midnight in Copiah County. The storm seemed to be weakening as it moved northward and, in the total absence of ground-truth reports, the warning was not continued in Rankin County; attention instead was focused on the growing supercell to the southeast. The decision not to warn was a professionally responsible one given the observations available at the time.

The offices at Atlanta, Cincinnati and Raleigh-Durham were also well prepared for the unseasonable incursion of tornadic activity into their areas of responsibility where the severe weather developed rapidly but not unexpectedly. Appropriate warning service was provided in almost all instances from these offices.

The members of the Disaster Survey Team were gratified to note that other facets of the NWS watch and warning systems also worked well. Although not perfect, rapport with emergency managers was excellent and indicative of long and hard work on both sides. The media in the areas visited were very supportive and well aware of their own commitment to the public for disseminating watches and warnings prepared by the NWS. The importance of spotter networks and cooperation with amateur radio operators cannot be over-emphasized. It was clear that much effort had gone into preparing and presenting programs designed to educate the public regarding severe weather events. It was also clear that much more must be done to prepare the public to assume more responsibility for their own protection when in harm's way from such events.

The levels of accuracy and timeliness of severe weather alerts, watches and warnings during this episode were high. This, coupled with the responsiveness of the emergency and civil managers, the media and a generally aware public, without doubt saved lives. Overall, the public was well served.

DISASTER SURVEY TEAM MEMBERS

The Natural Disaster Survey Team for the November 21-23, 1992 tornado outbreak is listed below. To more effectively investigate the outbreak, the group was split in two. One group, Team 1, consisting of Howcroft, Bocchieri, Andra, White, and Littin visited Mississippi and Georgia. The other group, Team 2, consisting of Dean (Group Leader), Schurr, Cooper, and Heidelberger visited Texas, North Carolina, and Kentucky. Additional information on damage in the other states affected by the outbreak was provided by local offices and Southern and Eastern Region Headquarters of the NWS.

Special recognition is due to Paul Polger, Barry Goldsmith, Bill Lerner, and Bob Krebs, all of the Services Evaluation Branch, Office of Meteorology/NWS, for their significant contribution to this report, especially Chapter 3 and Appendices B and C.

Team Members

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ACRONYMS AND ABBREVIATIONS

ADAP	AFOS Data Analysis Program
AWIPS	Advanced Weather Interactive Processing System
BWER	Bounded Weak Echo Region
C	Degrees Celsius
CAPE	Convectively Available Potential Energy
cm	Centimeter
CWA	County Warning Area
DST	Disaster Survey Team
EBS	Emergency Broadcast System
EMA	Emergency Management Agency
EOC	Emergency Operations Center
F	Degrees Fahrenheit
GEMA	Georgia Emergency Management Agency
gpm	Geopotential meters
HAM	Licensed amateur radio operator
J/kg	Joules/Kilogram
km	Kilometer
kts	Knots
LETS	Law Enforcement Teletype System
M	Million dollars
mb	Millibar
MEMA	Mississippi Emergency Management Agency
m/s	Meters per second
MSL	Mean Sea Level
NAWAS	National Warning System
NCDC	National Climatic Data Center
NEXRAD	Next Generation Radar
NGM	Nested Grid Model
nm	Nautical Mile
NMC	National Meteorological Center
NSSFC	National Severe Storms Forecast Center
NWR	NOAA Weather Radio
NWSO	NEXRAD Weather Service Office
NWWS	NOAA Weather Wire Service
PPI	Plan Position Indicator
PUP	Principle User Processor
PWO	Public Severe Weather Outlook
RAOB	Rawinsonde observation
SDM	Station Duty Manual
SHARP	Skew T/Hodograph Analysis and Research Program
SOO	Science and Operations Officer
SPS	Special Weather Statement
SRM	WSR-88D Storm Relative Map product
UTC	Coordinated Universal Time
VAD	Velocity Azimuth Display
WCM	Warning Coordination Meteorologist
WPM	Warning Preparedness Meteorologist
WRSAME	Weather Radio Specific-Area Message Encoder
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR-57	Weather Surveillance Radar-1957
WSR-74C	Weather Surveillance Radar-1974 C-band
WSR-88D	Weather Surveillance Radar-1988 Doppler

FINDINGS AND RECOMMENDATIONS

DESCRIPTION AND IMPACT OF THE EVENT (CHAPTER 1)

Finding 1.1: The deadly and destructive tornado outbreak which struck the United States November 21-23, 1992, was unusually intense and one of the most widespread for November (94 tornadoes). The 26 fatalities associated with the storms were the most since the Plainfield, IL, tornadoes in 1990 in which 29 people died.

Finding 1.2: Fourteen of the tornado deaths, or 54 percent, occurred in mobile homes.

Recommendation 1.2: Continued emphasis is needed to stress the importance of the availability of shelters in mobile home parks and the actions to be taken by those in harms way.

METEOROLOGICAL ANALYSIS (CHAPTER 2)

Finding 2.1: Storm relative helicity proved especially useful for identifying the potential for mesocyclones and tornadoes. Strong vertically veering wind fields in the warm sector resulted in large values of storm relative helicity (at times exceeding 500 m^2/s^2 in the lowest 3 km). Parameters such as Lifted Index and CAPE indicated convection was possible, but values for these quantities were modest and not sufficient to discriminate between severe and non-severe convection.

Finding 2.2: National Weather Service Offices effectively utilized excellent, available guidance and tools, including SHARP and ADAP, to anticipate and monitor mesoscale meteorological developments. Forecasters in Houston also used VAD wind data from the WSR-88D radar to modify early morning helicity calculations and identify the increased tornado threat.

Recommendation 2.2a: Continue education, training and research in the area of mesoscale meteorology.

Recommendation 2.2b: Ensure the NWS Advanced Weather Interactive Processing System (AWIPS) provides a complete set of mesoscale analysis tools. These tools must be interactive, allowing modification of data and effective assessment of critical quantities like CAPE and helicity quickly.

WARNINGS, FORECASTS, AND GUIDANCE (CHAPTER 3)

Finding 3.1: The NSSFC provided excellent guidance and watch products to WSFOs, WSOs and the public throughout the outbreak. NSSFC correctly identified the threat of tornadoes and severe storms more than 24 hours in advance of the episode. NSSFC also accurately forecast relatively rare late season tornadoes in the Ohio Valley. Field forecasters interviewed by the DST believed NSSFC's watches and guidance products were vital to their ability to anticipate the magnitude of the event and to issue timely forecasts, statements, and warnings.

Finding 3.2: The performance of WSO Houston was exemplary. Several tornadoes struck in the Houston metropolitan area, producing the vast majority of the damage in Texas. Despite the numbers and strength of the storms there were no fatalities.

Finding 3.3: The single greatest number of deaths associated with one tornado was 12 in Mississippi. Ten of these deaths were in Rankin County, which is in WSFO Jackson's CWA. When the tornado that killed 10 in Rankin County first touched down in Copiah County a Tornado Warning for Copiah County had been in effect. However, no Tornado Warning was in effect in Simpson County or Rankin County as the storm moved from Copiah County through those counties.

Finding 3.4: One of the factors in the decision not to issue a warning for Rankin County, Mississippi, where 10 people were killed, was that no ground truth reports were received from spotters, the public, police, or HAMs. Ground truth severe weather reports are often critical in the NWS warning process.

Recommendation 3.4: The NWS should continue to help establish and train new spotter groups plus provide refresher training to the existing spotter networks. The emphasis for continued feedback of severe weather information from spotter networks, Emergency Management Agency officials, and law enforcement personnel must be continued and strengthened.

RADAR EVALUATION (CHAPTER 4)

Finding 4.1: WSR-88D radar at WSO Houston provided useful information. Velocity data (particularly the storm relative data) proved extremely valuable in evaluating tornadic potential. WSR-88D products were clearly superior to conventional WSR-57 and WSR-74C products available at other locations.

Finding 4.2: Multiple elevation angle displays (four-panels) of reflectivity and velocity data proved extremely valuable to the Houston Office during this episode. The data, and other products provided by the WSR-88D, required intense analysis

by a highly skilled radar interpreter to accurately determine the likelihood that a tornado would develop. Proper interpretation of WSR-88D data during active events requires dedication of at least one staff member to that task.

Recommendation 4.2: At least one skilled radar interpreter should be dedicated to the radar, whether it is a WSR-88D, WSR-74 or WSR-57 any time severe weather threatens (including times when severe weather watches are in effect) and thunderstorms are present.

Finding 4.3: Meteorologists who interpreted the Houston WSR-88D felt training they received at the Norman, Oklahoma WSR-88D OSF Training Branch provided a strong base upon which to build their skills. The value of that training was measured in the effective warnings issued November 21, 1992.

Finding 4.4: No warnings were in effect for the fatality-producing tornadoes in Rankin, Choctaw, and Webster counties in Mississippi. The no-warning decision was, in part, due to radar indications the storm was decreasing in intensity. The decreased reflectivity of the storm as it tracked into Rankin then Attala counties suggests the storm updraft weakened briefly as the mesocyclone occluded in each case. Such an evolution is consistent with tornadic supercell thunderstorms.

Recommendation 4.4a: The NWS should continue to improve instruction on severe storm evolution and radar structure. Although such instruction may be performed on-site by the SOO, the instruction should be in addition to the resident WSR-88D course, with content formulated by subject matter experts.

Recommendation 4.4b: The NWS should ensure that future radar display systems (e.g. WSR-88D PUP, AWIPS) provide the tools necessary to quickly and easily assess three-dimensional storm structure and evolution.

Finding 4.5: Despite using conventional radar that did not always identify characteristics normally associated with tornadoes, the Cincinnati WSO issued effective warnings. They used an intensive mesoanalysis effort that helped to identify the area where the tornado developed. The mesoanalysis directly contributed to the effectiveness of the Tornado Warning they issued.

Recommendation 4.5: All radar-related training should emphasize mesoscale analysis as an important aspect of radar data interpretation.

PREPAREDNESS (CHAPTER 5)

Finding 5.1: Overall, a vigorous Warning and Preparedness program existed in the areas visited. However, in Rankin County, Mississippi, (WSFO Jackson's responsibility) the Emergency Management Agency was just getting organized. The County's storm spotter network needed to be reorganized and trained. Also, spotter training in WSFO Raleigh's area of responsibility was limited due to minimum staffing, and the spotter network for WSO Houston's CWA was sporadic in some locations.

Recommendation 5.1: To allow the WPM/WCM more time to perform his/her preparedness duties, efforts should be increased to limit shift work by the WPM/WCM to no more than 25 percent of the time. Spotter training and organization is an indispensable part of each NWS Office's program and must be given a high priority, even in times of limited staffing. Staffing should be brought up to full complement where insufficient staffing has a negative effect on WPM/WCM duties.

Finding 5.2: WSFO Raleigh placed a low priority on logging information during the event. Many telephone calls and conversations were recorded after the event from the memory of individuals working the event. WSFO Raleigh has since instituted procedures to enhance their real-time logging of events during severe weather episodes including the addition of a voice-activated recording device.

Recommendation 5.2: A greater importance should be placed on logging events, particularly severe weather information.

Finding 5.3: The preparedness effort was, in general, well rewarded during this outbreak. Interviews and individual accounts indicated people were generally aware of the threat, the warnings, and of the proper safety measures to take.

Recommendation 5.3: The NWS, along with the entire hazards community, needs to continue and enhance preparedness and educational activities to minimize loss of life.

Finding 5.4: NWS offices often have a HAM base station in the operations area. HAM radio operators provide some of the most timely and accurate storm information. WSFO's Jackson and Atlanta were in temporary quarters with limited space, and no HAM base station was in service. Both offices plan space for a HAM station at their new facilities.

Recommendation 5.4: NWS offices should make every effort to provide space for HAM radio, even while occupying temporary quarters.

DISSEMINATION AND COMMUNICATIONS (CHAPTER 6)

Finding 6.1: GTE/Contel performed 20 minutes of maintenance on the weather wire system at 3:00 a.m., November 21. Advance notice of this 20 minutes of down time was supplied to users, but no procedure was established to assure there was no weather threat before taking the system down. This shut-down occurred before the start of the outbreak and did not affect dissemination of critical NWS products, but it could have been dangerous if the maintenance had occurred on November 22.

Recommendation 6.1: Routine NWWS maintenance must not be performed when severe weather threatens. NWS must establish a procedure with GTE/Contel to avoid routine outage during critical weather situations.

Finding 6.2: Only manual or semi-automated systems for relay of NWS data to law enforcement officials were in operation in Texas, Mississippi, Georgia, and North Carolina. In North Carolina distribution was accomplished by manually typing products received from NWWS.

Recommendation 6.2: The NWS should encourage state agencies to incorporate automatic relay of NWWS information on LETS so that minutes and possibly lives may be saved.

Finding 6.3: Many people were aware of NWR, but the majority of citizens do not own an NWR receiver.

Recommendation 6.3: The NWS, emergency management officials, the media, etc., should cooperate in promoting NWR. The NWS should increase public education about the NWR system.

Finding 6.4: The North Carolina Division of Emergency Management in Raleigh noted the coverage of NWR in western North Carolina is poor and additional transmitters are needed.

Recommendation 6.4: Investigate NWR coverage in western North Carolina and determine the need and feasibility of installing additional transmitters. Also, investigate coverage nationwide to determine unserviced areas with significant need.

Finding 6.5: WSO Cincinnati received positive feedback with their NWR "Quick Warn" program. Many users stated they believed issuing the warnings with the quick format saved lives.

Recommendation 6.5: Continue using the "Quick Warn" format. Other offices with adequate NWR coverage should consider using this type of broadcast.

Finding 6.6: None of the media in the areas visited utilize WR-SAME (Weather Radio Specific Area Message Encoder) for the automatic "override" of their audio to transmit warnings from NWR.

Recommendation 6.6: Increase efforts to make the media (especially automated radio stations), emergency management agencies, schools, law enforcement officials, etc., aware of WR-SAME and the benefits it provides.

Finding 6.7: The EBS serving the Texas, Mississippi, Georgia, and North Carolina areas appears to have performed well.

Finding 6.8: Television stations commonly used either text crawls or "live" broadcasts to alert the public to impending severe weather. In many instances, the crawls were produced manually resulting in delayed dissemination to the public.

Recommendation 6.8: The NWS should encourage TV stations to increase the use of the automatic production of text crawls.

Finding 6.9: Leading radio news people in two states stated that because of a budget squeeze many radio stations forego NWWS and rely on the Associated Press (AP) for weather and other news. They observed that AP gives priority to hard news stories and scheduled daily summaries, and weather alerts are apt to be held up.

Recommendation 6.9: At national, regional and state capitol levels, NWS should discuss this assertion with AP leaders.

Finding 6.10: The media often does not break into certain programming even for urgent weather messages. Television stations may limit the time a crawl can be broadcast. Automation of radio stations leave limited personnel available to broadcast critical weather information.

Recommendation 6.10: The NWS should point out the importance of the media's role in delivering warnings and stress the need to avoid limiting times that information can be broadcast. The NWS should also promote use of new techniques like WR-SAME and electronic switching systems that help deliver critical messages in seconds.

USER RESPONSE (CHAPTER 7)

Finding 7.1: In general, people were aware of and responded properly to the threat of inclement weather in their area. Most first utilized the media to obtain weather information. Then, personal, visual confirmation verified the absence or presence of actual danger before safety measures were taken. These factors worked less effectively where there were no warnings, people were asleep, or were primarily in mobile homes. In those areas where an actual warning may not have been in effect, forecasts, watches, and warnings for nearby areas usually indicated the threat of severe weather.

Finding 7.2: In Houston, the users felt that the short format (several lines) severe weather and special weather statements were extremely helpful to update the situation.

Recommendation 7.2: Continue using these types of statements to update the event and encourage other NWS offices to act similarly.

Finding 7.3: Some users felt that more emphasis should be given to warning messages for situations that are particularly certain and dangerous (e.g. confirmed tornado in highly populated area).

Recommendation 7.3: The NWS should explore ways to more effectively convey the urgency and serious nature of the warning message during especially high threat situations.

CHAPTER 1

DESCRIPTION AND IMPACT OF THE EVENT

The outbreak of 94 tornadoes from Texas to the Central Atlantic Seaboard November 21-23, 1992, was unusually widespread and intense for so late in the season. These storms were responsible for the most fatalities (26) since the Plainfield, Illinois, tornado in August 1990 in which 29 died. This was one of the largest November tornado outbreaks on record. Records show, however, that tornadoes occur with good frequency across the southern states in November, and widespread outbreaks are not unprecedented.

National Severe Storms Forecast Center (NSSFC) and National Climatic Data Center (NCDC) records show November as the month with the greatest number of tornado fatalities (83) for the 6 years from 1987 through 1992. Nearly all those fatalities have occurred in the southern and eastern states.

Beginning in the early afternoon of Saturday, November 21, severe weather developed over southeastern Texas. For the next 48 hours, the storms moved northeast before finally dissipating in the northeast United States Monday morning, November 23. Left behind were paths of destruction resulting in 26 deaths, 641 injuries, and damages estimated at over $291 million covering 13 states. Table 1 shows the details of the fatalities. Table 2 presents a summary of the deaths, injuries and damage estimates in each state.

Tornado watches were in effect where 91 of the 94 tornadoes were reported. Twenty-five of the 26 fatalities occurred in valid tornado watches. Fourteen of the 26 deaths (or 54 percent) occurred in mobile homes. Severe storm warnings were in effect for 12 of the 26 deaths.

The focus of this report will be on the states that were visited by the Disaster Survey Team (DST), that is, Texas, Mississippi, Georgia, Kentucky, and North Carolina. Highlights of the storm activity and impact in other states affected by this outbreak are also summarized in this Chapter.

Summary of Events in States Visited by the DST

Texas

Widespread tornadoes devastated portions of southeast Texas during Saturday afternoon, November 21. Several tornadoes struck the Houston metropolitan area, producing the vast majority of the damage. Amazingly, all who endured these storms survived, even though the storms were some of the strongest in recent memory.

TABLE 1

Summary of Deaths Including Age, Gender, and Location

	Age	Sex	Dwelling	Location
1.	4	Female	mobile home	Rankin Co., MS
2.	7	Male	house	Rankin Co., MS
3.	7	Male	house	Rankin Co., MS
4.	10	Male	house	Rankin Co., MS
5.	30	Female	mobile home	Rankin Co., MS
6.	31	Female	mobile home	Rankin Co., MS
7.	39	Female	mobile home	Rankin Co., MS
8.	42	Male	house	Rankin Co., MS
9.	50	Male	mobile home	Rankin Co., MS
10.	68	Female	mobile home	Rankin Co., MS
11.	58	Female	mobile home	Leake Co., MS
12.	5	Male	mobile home	Choctaw Co., MS
13.	67	Male	house	Webster Co., MS
14.	75	Female	house	Webster Co., MS
15.	91	Female	house	Kemper Co., MS
16.	11	Male	mobile home	Hardeman Co., TN
17.	43	Female	office bldg	Lumpkin Co., GA
18.	31	Male	mobile home	Putnam Co., GA
19.	52	Male	mobile home	Putnam Co., GA
20.	59	Female	house	Putnam Co., GA
21.	63	Male	house	Putnam Co., GA
22.	61	Female	mobile home	Greene Co., GA
23.	62	Female	mobile home	Carroll, Co., KY
24.	81	Male	house	Saluda Co., SC
25.	2	Male	house	Orange Co., NC
26.	53	Male	mobile home	Orange Co., NC

Summary of Totals:

Gender:	*Males*	*14*
	Females	*12*
Locations:	*Mobile homes*	*14*
	Houses	*11*
	Office Building	*1*

641 people injured

TABLE 2

Summary of Death / Damage by State

State	**Dead**	**Injuries**	**Damage** (**$ Millions**)
Texas	0	34	105
Louisiana	0	28	3
Mississippi	15	269	60
Tennessee	1	4	0.03
Alabama	0	43	18
Georgia	6	144	70
South Carolina	1	9	5
North Carolina	2	74	9.3
Kentucky	1	9	2.5
Ohio	0	21	5
Indiana	0	6	12
Virginia	0	0	0.5
Maryland	0	0	1.5
TOTAL	**26**	**641**	**291+**

In all, 14 tornadoes occurred statewide injuring 34 persons and damaging nearly 3000 residences, businesses, and aircraft. Between 1:30 and 4:30 p.m.[1] on Saturday, November 21, 12 tornadoes struck six counties in the Weather Service Office (WSO) Houston County Warning Area (CWA). The counties affected were Wharton, Fort Bend, Brazoria, Harris, Polk, and Liberty. At one time in Harris County, four tornadoes were likely producing damage. The tornado in eastern Harris County was rated an F4 (see Appendix A for definition of Fujita Tornado Intensity Scale).

Miraculously, even though some of the tornadoes moved through the highly populated Houston area, there were no deaths (see Fig. 1 for tornado tracks). Damage, however, was extensive, especially in the Channelview area in the eastern suburbs of Houston. Overall in the Houston CWA, more than 2000 homes were destroyed or damaged, and insured losses were estimated at $105 million.

The onset of the outbreak was marked by three separate tornadoes, two F1s and one F2, that occurred in Wharton County between 1:30 p.m. and 2:45 p.m. Three tornadoes also touched down in Fort Bend County. The strongest was an F2 tornado, which touched down near Fulshear around 2:20 p.m. This tornado then moved into Harris County near Katy at 2:28 p.m. The tornado caused considerable damage to West Side Airport, a major general aviation facility. Two other F1 tornadoes touched down in Fort Bend County.

The most devastating tornadoes struck central and eastern Harris County, including the Houston metropolitan area, between 3:12 and 4:15 p.m. The most violent of the tornadoes touched down at 3:27 p.m. in the Channelview area. In this vicinity, 15 persons were injured and more than 1200 homes and businesses sustained damage. About a mile north of the touchdown, the tornado intensity increased to F4. After about a mile, the tornado diminished to an F2 and stayed that way into Liberty County.

At approximately the same time, an F2 tornado touched down 2 miles southwest of downtown Houston, on the southeast edge of Hermann Park, and moved northeast across heavily travelled highways. There were six minor injuries and over 500 residences and 100 commercial buildings were damaged.

A total of three tornadoes also struck Liberty County. The longest tornado, an F3 with a 32-mile track, started about 3:20 p.m., moving from Harris County to Liberty County. The tornado injured one person in Liberty County and damaged residential property in Tarkington before completing its track just east of Romayor.

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[1]All times in this report are Local Standard Time unless otherwise noted.

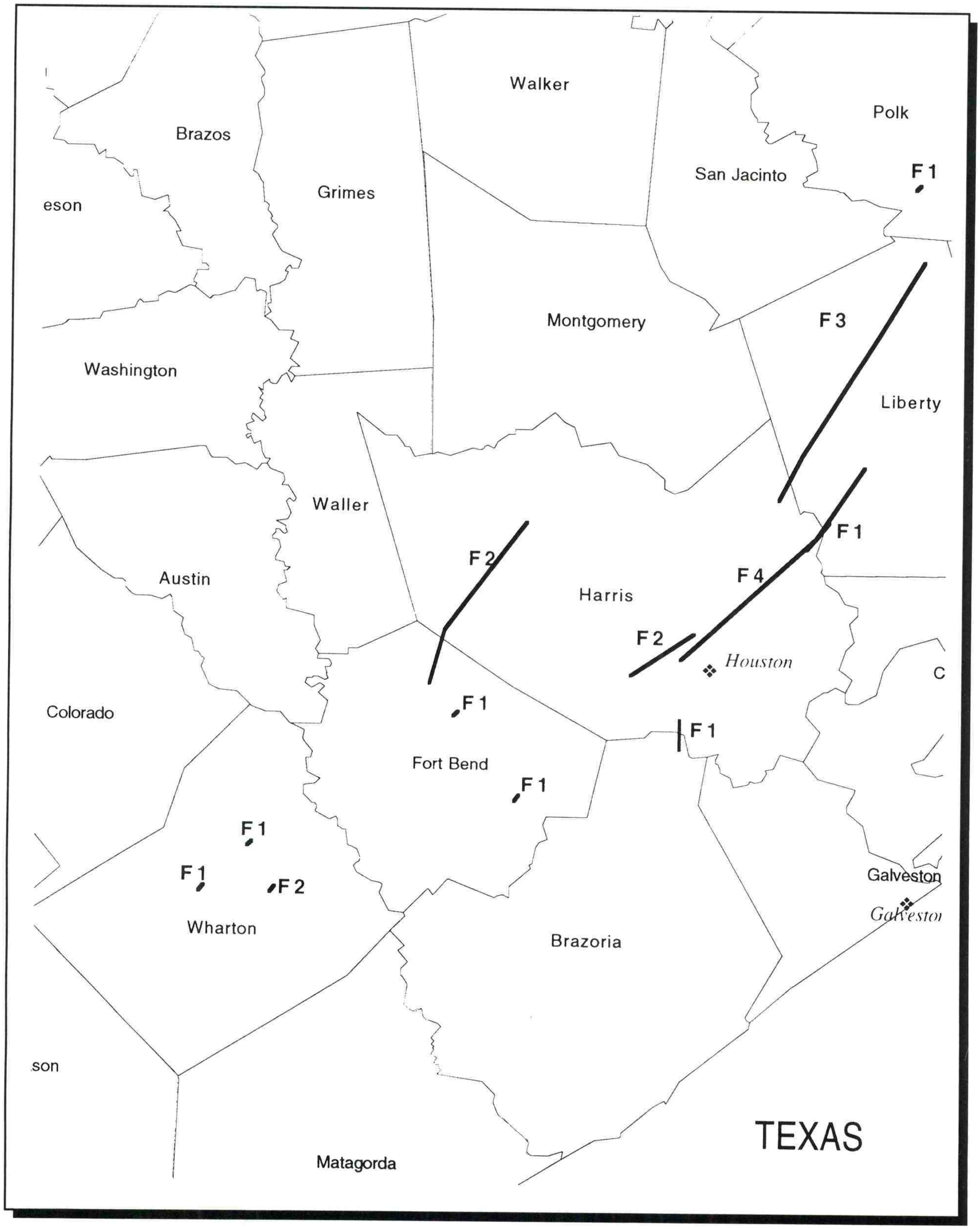


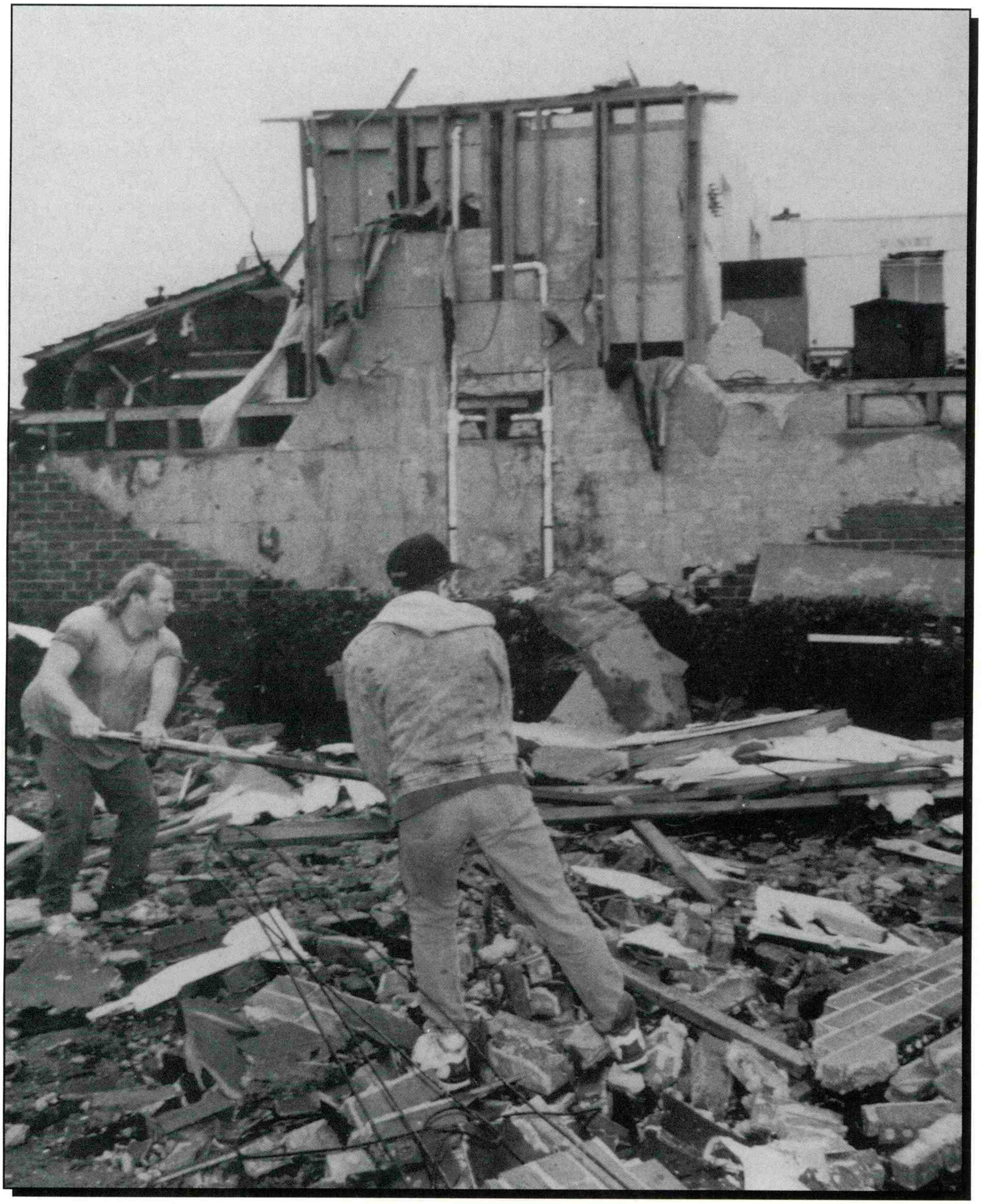
Figure 1. Tornado tracks in Texas, November 21, 1992.



Photograph of damage inflicted on a home near Katy, Texas, on the border of Harris and Fort Bend Counties. Photograph courtesy of the Houston Chronicle.



A tornado which struck the Houston, Texas, area left this scene at a street intersection of Channelview, a community east of the city. Photograph courtesy of the Houston Chronicle.



Photograph of damage inflicted on a home in the Kelliwood subdivision in Western Harris County, Texas. Photograph courtesy of the Houston Chronicle.

Mississippi

Mississippi, which leads the nation in tornado fatalities, was dealt the hardest blow during this tornadic outbreak. There were 15 fatalities (10 in Rankin County, 1 in Leake, 1 in Choctaw, 2 in Webster, and 1 in Kemper County). There were 269 injuries. Damages were estimated at $60 million. Nearly 300 homes were destroyed and over 700 damaged. Twenty-one counties were declared disaster areas.

At least 60 mobile homes were destroyed. Six of the 10 people who died in the Brandon, Mississippi area (Rankin County) and two who died elsewhere in Mississippi were in mobile homes. Few states, including Mississippi, have mobile home tie-down laws. Even where they may exist, enforcement is very difficult. There is no Mississippi law that requires mobile homes parks to have shelters.

Nearly all of the damage in the state occurred with two storm cells. Fifteen tornadoes, associated with the two storm cells, touched down in Mississippi late Saturday and early Sunday, November 21 and 22. The tornado tracks are shown in Fig. 2. At 9:30 p.m. Saturday, Mississippi's first tornado (F1) began in Wilkinson County in the southwest corner of the state. The last tornado struck 9 miles east of Meridian at 3:20 a.m. Sunday. The more significant tornadoes are summarized below.

At 11:27 p.m. a tornado touched down in northeast Copiah County, 1 mile north of Hopewell, beginning a path that was to extend for 128 miles through Simpson, Rankin, Scott, Leake, and Attala Counties, and finally dissipating 4 miles southwest of Mathiston at 2:01 a.m. in Choctaw County. The tornado left 12 people dead and 122 injured. At 11:37 p.m. this tornado moved into Rankin County, where most of the fatalities occurred, passing 1 mile southeast of Florence. It then moved through the southwest city limits of Brandon at 11:53 p.m. and continued northeast exiting the county 7 miles east of Sandhill at 12:19 a.m. The tornado killed two people in a mobile home park in the south side of Florence. The tornado then moved toward Brandon. It struck another mobile home park where it destroyed 30 mobile homes, killed four people and injured many more. As the tornado moved through the south and east sides of Brandon it damaged or destroyed many more houses and mobile homes. It completely leveled a large, well built, brick home in the East Haven subdivision and killed four people. In Rankin County, a total of 60 homes were destroyed, over 500 homes were damaged, 10 people were killed, and 98 were injured. One death occurred in Leake County in a mobile home in the Pine Tree Community, west of Carthage. In Attala County 36 homes were destroyed or severely damaged. Twelve people were injured. In Choctaw County, 101 homes were damaged or destroyed. One person was killed in a mobile home in Weir and twelve others were injured. The tornado appeared to reach its maximum strength in Brandon where it was rated F4, but it had much F3 damage all along the path.

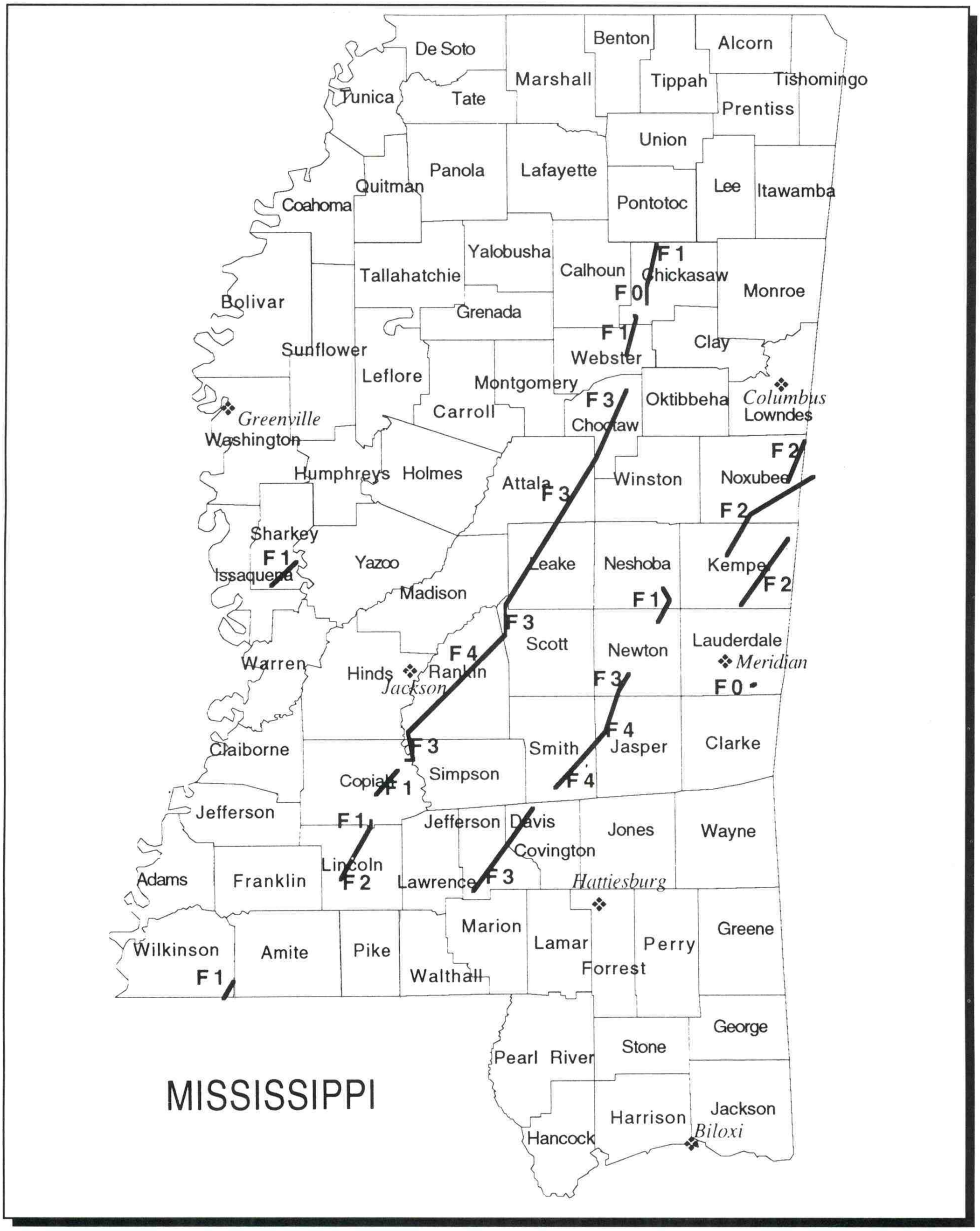


Figure 2. Tornado tracks in Mississippi, November 21-22, 1992.



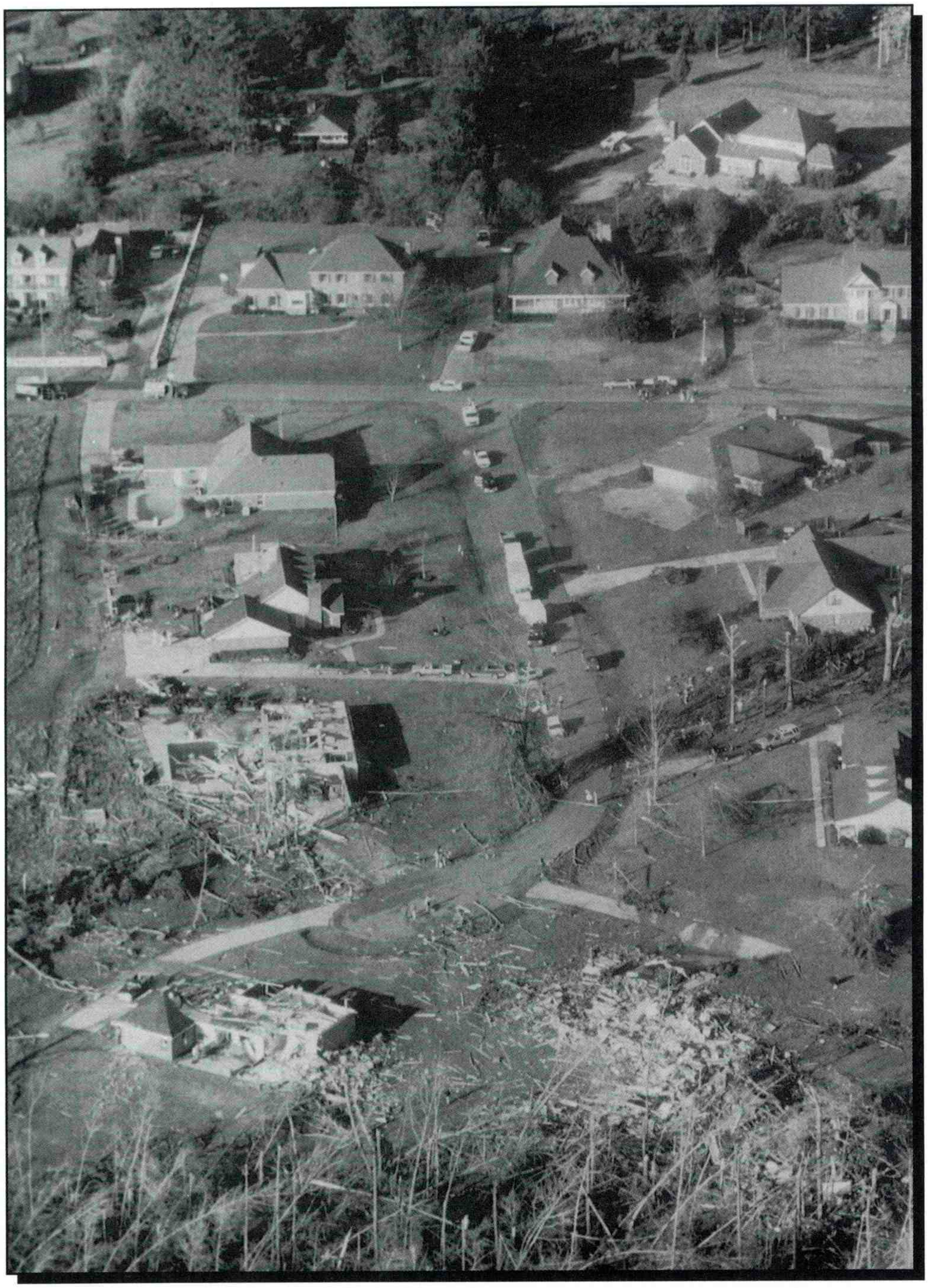
Tree damage helps gauge force of storm in Rankin County, Mississippi. Photograph courtesy of the National Weather Service.



Brandon, Mississippi, resident catches a double view of the wreckage at the mobile home park as he retrieves from the wreckage a large mirror, surprisingly unbroken. Photograph courtesy of Jackson Clarion Ledger.



Young victim of tornado wipes away tears as she removes belongings from a trash pile that once was her home at a Brandon Mississippi, mobile home park. Photograph courtesy of Clarion-Ledger.



Aerial view of Easthaven, a suburban development of homes near Jackson, Mississippi, show the storm's force. Lower three homes were demolished. On bottom right, only a driveway remained from a home where four people were killed (see cover photo). Photograph courtesy of Clarion Ledger.

Later, the weakening supercell which produced the above-described tornado spawned an F1 tornado in extreme northeast Webster County at 2:14 a.m. Two elderly people were killed when the tornado destroyed the small wood-frame home in which they lived.

The second major storm/tornado (F3) system to affect the state began at 11:23 p.m. in Jefferson Davis County and ended in Kemper County along the Alabama border at 3:20 a.m. The initial tornado started its 27-mile long path 8 miles southwest of Carson in Jefferson Davis County. The tornado then moved into Covington County and began to turn more northeasterly. It continued through the town of Mount Olive and lifted 2 miles northwest of town at 12:05 a.m. Within Jefferson Davis County, 14 homes were destroyed and numerous trees downed. Five people were injured. In the Mount Olive community 32 homes were destroyed and 55 others were damaged with over 100 people injured.

The supercell spawned another intense tornado (F4) about 10 minutes later. The storm, which lasted 1 hour, cut a 40-mile path through Smith, Jasper, and Newton Counties. The storm initially touched down at 12:14 a.m., 2 miles southeast of Mize in Smith County, and lifted on the southern city limits of Newton in Newton County at 1:14 a.m. This was an extremely large and intense tornado that fortunately moved through mainly uninhabited areas. In Smith County, 15 people were injured in Sylvarena. Over 90 homes were destroyed and one large church was demolished. Within Jasper County, three houses and four mobile homes were destroyed, and 21 houses and two mobile homes were damaged. In Newton County, six homes were damaged, and one mobile home and one commercial building were destroyed.

At 2:15 a.m. an F2 tornado with a path length of 27 miles associated with the supercell began in central Kemper County and moved into Noxubee County. One house and several mobile homes were damaged. One person was killed and one injured in a wood frame home just west of Wahalak in Kemper County.

Georgia

Severe storms moved across mainly the northern half of Georgia between 7:00 a.m. and 7:00 p.m. on Sunday, November 22. Six people were killed and 144 injured. Damage was estimated at $70 million. Five counties were declared federal disaster areas and 20 were declared disaster areas by the State. In addition to the storms that produced microbursts, there were 11 tornado tracks, as shown in Fig. 3.

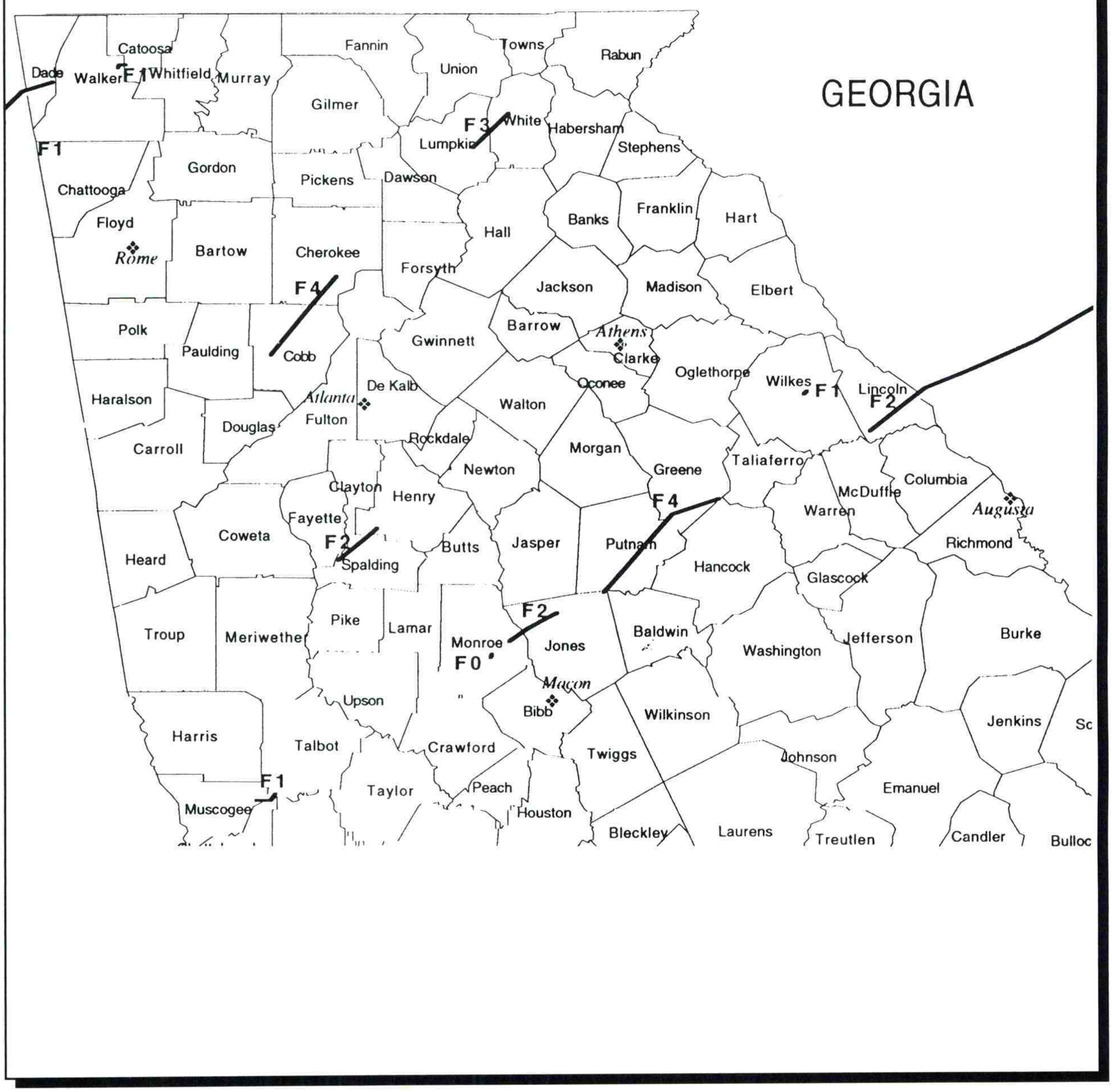


Figure 3. Tornado tracks in Georgia, November 22, 1992.



Homes on a peninsula of Georgia's Lake Oconee were leveled and surrounding wooded area was shredded as a tornado whipped through the neighborhood. Photograph courtesy of Macon Telegraph.



Residents search wreckage of a home on the shore of Lake Oconee, near Macon, Georgia, destroyed by the November 1992 tornado outbreak. Photograph courtesy of Macon Telegraph.



The Hill Dairy farm 10 miles northeast of Eatonton, Georgia, was churned by the November 1992 tornado outbreak. Photograph courtesy of Macon Telegraph.

One of the most destructive tornadoes (F4) of the day developed in western Cobb County at 11:44 a.m. starting a path that would last for 20 miles and leave 46 people injured. The tornado began north of Powder Springs, then travelled northeast to Kennesaw before entering Cherokee County just south of Woodstock, and then dissipated at Hickory Flats around 12:35 p.m. The tornado damaged or destroyed over 325 residences and businesses in Kennesaw (Cobb County). Tractor-trailers were overturned on Interstate 75. Several subdivisions suffered major damage when the tornado moved into the Woodstock area in southern Cherokee County. At least 200 homes in Cherokee County had varying degrees of damage. About 800 buildings were damaged to some extent. Of the injuries, 34 occurred in Cobb County and 12 in Cherokee County.

The first killer tornado (F3) struck in Lumpkin County at 1:10 p.m. Its 10-mile path began north of Dahlonega. The storm moved northeast through Yahoola Valley and then struck a resort ranch before dissipating at Cedar Mountain. The majority of the damage occurred at the ranch where 40 structures were damaged or destroyed. Two employees in a two-story building were carried about 65 yards by the tornado (one person died), while another employee in another building was carried 300 yards.

Georgia's deadliest tornado (F4) left a 32-mile path from 10 miles south-southwest of Eatonton in Putnam County, through Meda, ending at White Plains in Greene County between 4:45 p.m. and 5:20 p.m. Five people died and 86 were injured. The violent tornado developed near the Putnam-Jones County line and travelled northeast for 20 miles before going another 12 miles through Greene County. Power outages were widespread. In Putnam County, several residential areas were struck leaving extensive damage. Putnam County's dairy industry, the state's leader, suffered $18 million in damages (four dairies were lost, five heavily damaged, and about 300 cattle were lost). Around 68 homes were destroyed with another 109 damaged. Three deaths occurred at Lake Oconee when a house and a trailer were swept into the lake. The other death occurred in a mobile home near U.S. Highway 441. In Greene County, the tornado demolished most of the town of White Plains, population 800. At least 66 homes and five businesses were destroyed. One woman died in a mobile home.

Kentucky

Four tornadoes touched down in extreme northern Kentucky (see Fig. 4) during the late afternoon of November 22 resulting in one death and nine injuries. Dollar damage was estimated at $2.5 million.

The killer tornado touched down at about 4:52 p.m. in southern Carroll County west of Worthville and then moved northeast crossing the Ohio River east of Ghent into Switzerland County, Indiana. It then crossed the winding Ohio River

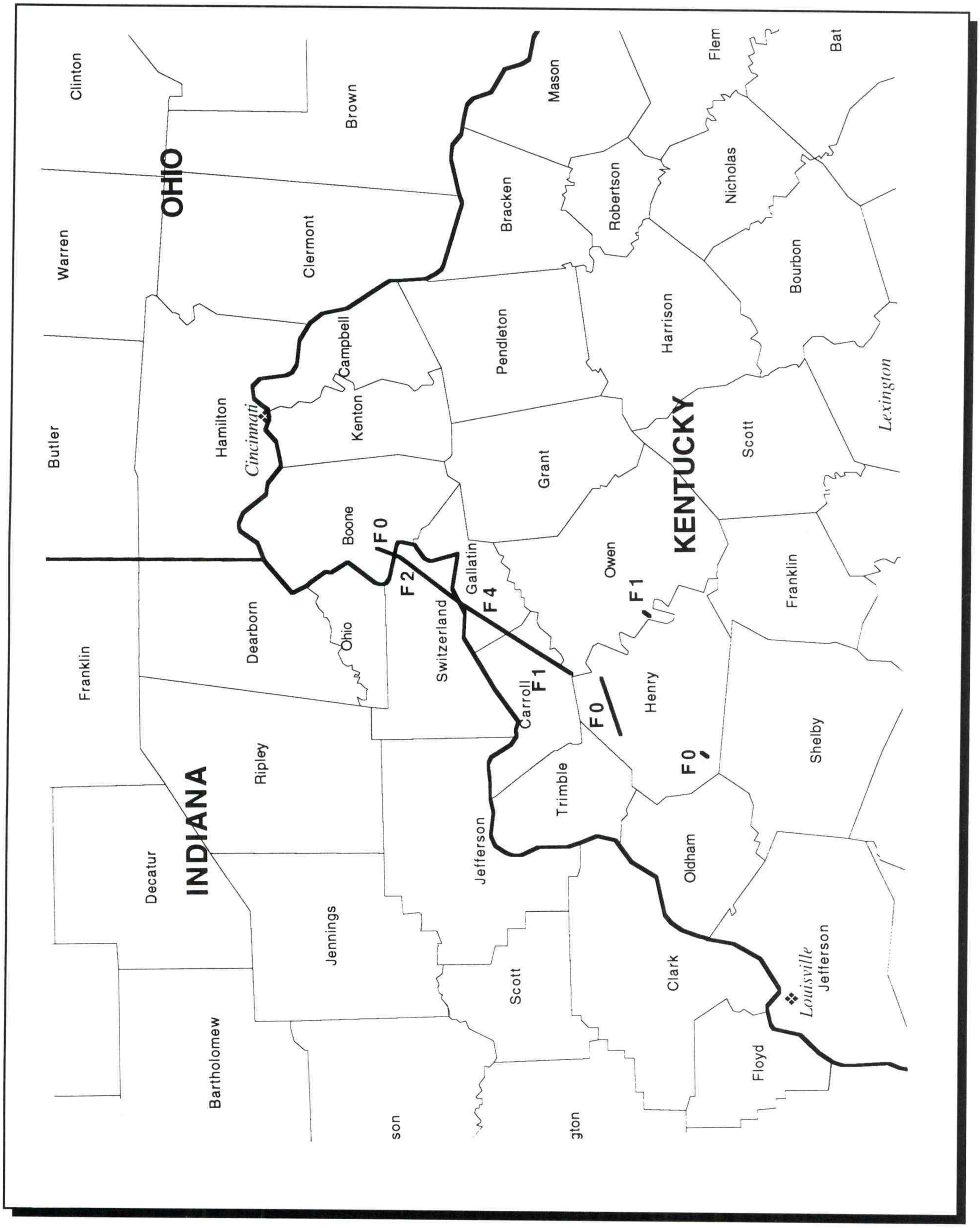


Figure 4. Tornado tracks in Kentucky, November 22, 1992.

a second time into Boone County, Kentucky, finally lifting and dissipating around 5:27 p.m. about 10 miles southwest of the Cincinnati Airport. It was on the ground for 22 miles. The tornado strength was generally F1-F2 except when it was briefly F4 in Carroll County. A 62-year-old woman died in her mobile home in Carroll County after she refused to leave and join others in a shelter. Her mobile home was destroyed by the F4 tornado. Ten others were injured along the tornado's path and numerous residences were destroyed.

North Carolina

Five tornadoes crossed North Carolina Sunday night, November 22 and early Monday morning, November 23 (see Fig. 5). Two persons were killed and 74 injured. One-hundred-ten homes and seven businesses were destroyed. In addition, nearly 600 homes and two businesses were damaged resulting in an estimated loss of $9.3 million.

At 2:20 a.m. Monday, November 23, an isolated F3 tornado touched down in Orange County. This tornado resulted in the two reported deaths and 10 injuries in a subdivision near Hillsborough.

A supercell formed over Harnett County at 4:10 a.m. and produced an F3 tornado which remained on the ground for 3 hours and 15 minutes, travelling 160 miles to the northeast. The tornado injured 49 people. It passed through Johnston, Wilson, Edgecombe, Martin, Bertie, Chowan, Perquimans, and Pasquotank Counties. Nearly half (22) of the injuries occurred at the onset, in Harnett and Johnston Counties. Twenty-one were hurt when a school bus was damaged near Elizabeth City (Pasquotank County), North Carolina at 7:24 a.m. Monday morning.

Summary of Events in Other States

Louisiana

Several clusters of severe thunderstorms developed rapidly over western and east-central parts of Louisiana Saturday evening, November 21, and produced 10 tornadoes. Twenty eight people were injured, and nearly $3 million damage was caused by these storms.

The tornado with the longest track (38 miles) in Louisiana began at 9:55 p.m. in extreme northeast Catahoula Parish and tracked across the northern part of Tensas Parish before dissipating in eastern Madison Parish. Eleven, or about one-third of the 28 injuries in Louisiana, occurred with this storm. It also destroyed 15 mobile homes, a church, three barns, and damaged 10 homes.

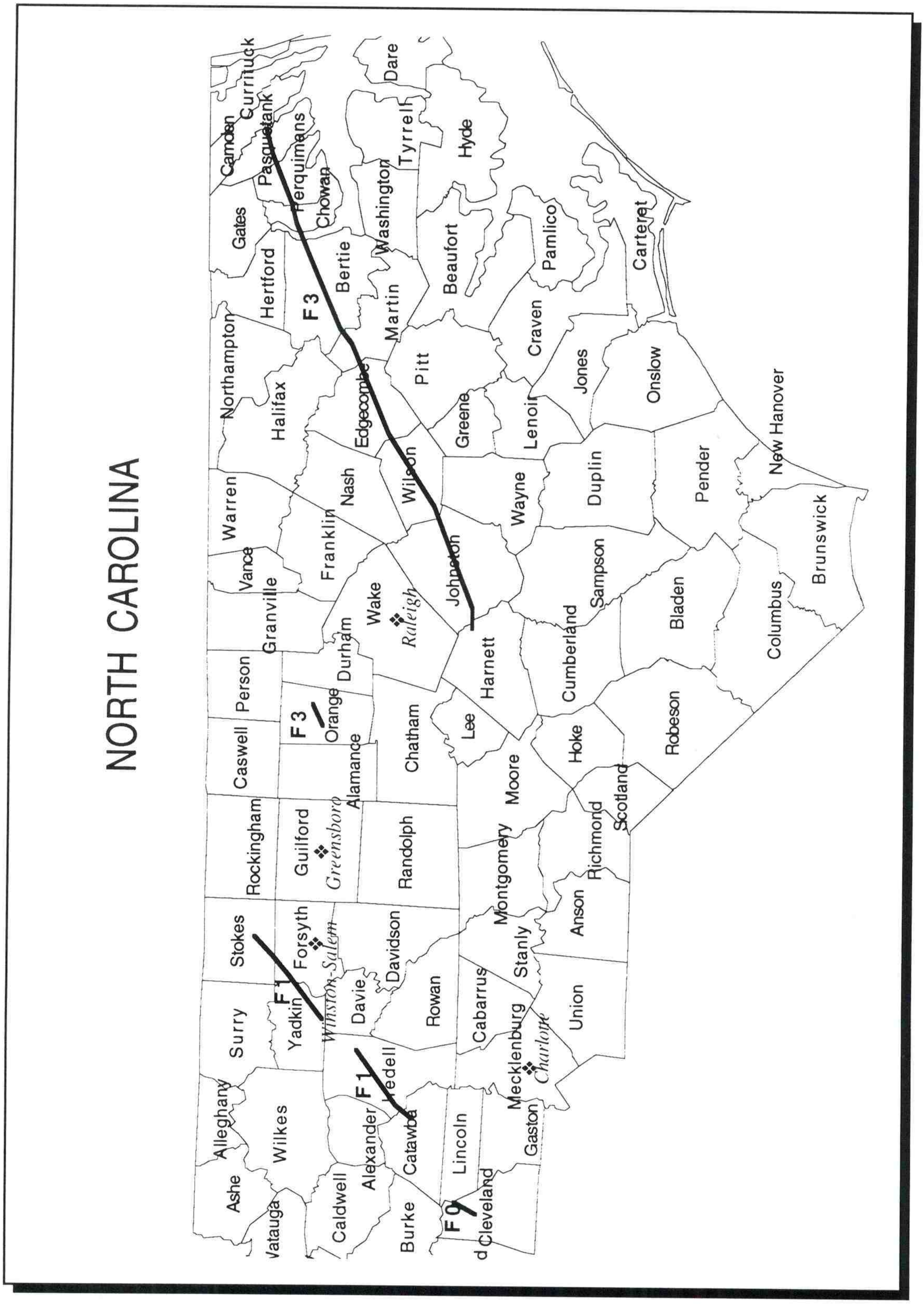


Figure 5. Tornado tracks in North Carolina, November 22-23, 1992.

At 9:45 p.m., an F3 tornado with a 3-mile-long path in Concordia Parish caused six injuries.

Alabama

Much of the state experienced severe weather between 3:30 a.m. and 1:00 p.m. on Sunday, November 22. There were nine confirmed tornadoes, 43 injuries, and several hundred buildings destroyed or damaged.

The first tornado (F2) hit around 3:30 a.m. in Sumter County leaving a 6-mile path from 2 miles north of Geigor to Panola. Also, about 3:30 a.m., an F2 tornado with only a 2-mile path south of Ethelsville in Pickens County destroyed six mobile homes injuring seven people.

Five separate tornadoes affected De Kalb County between 8:00 a.m. and 8:50 a.m. Three of the storms were strong (F2). One of the strong tornadoes touched down near Sardis City in northern Etowah County at 8:15 a.m. and tracked northeast into De Kalb County. Combined, the storms produced 25 injuries, destroyed 17 homes, and damaged 133 others.

An F1 tornado swept across northeast Tallapoosa County into extreme southwest Randolph County. The narrow track extended 17 miles from the Horseshoe Bend National Military Park to the Wadley vicinity. Most of the damage occurred in Wadley in Randolph County where mobile home damage left five injuries. Three homes were destroyed and 40 damaged. Also, 29 businesses were destroyed or damaged.

Tennessee

An F1 scale tornado (path 15 miles long) first touched down north of Van Buren in Hardeman County around 3:50 a.m. Sunday, November 22. It lifted but touched down two more times (just northwest of Bolivar around 4:00 a.m. and near Toone at 4:15 a.m.). Near Toone, the storm overturned a mobile home, pinning and smothering an 11-year-old boy under a waterbed. Some 30 homes were damaged or destroyed. There were four injuries.

Indiana

Fifteen tornadoes made a path through Indiana on November 22, the largest November tornado outbreak on record. Six injuries and about $12 million damage occurred.

The largest tornado started in Putnam County at 2:50 p.m. and moved north-northeast into Montgomery County before lifting about 3:20 p.m. The tornado was

close to 1/2 mile wide in northern Putnam County and was on the ground for about 12 miles. Numerous homes were damaged and two mobile homes were destroyed. There was one injury and $2 million in damage. The greatest damage occurred in eastern Indianapolis (Marion County) between 3:45 p.m. and 4:04 p.m. An F3 tornado destroyed 20 homes and damaged several hundred more inside the beltway. Property damage was estimated at $4 million. The tornado was on the ground for 9 miles.

The killer tornado from Kentucky briefly crossed into Switzerland County, Indiana, at 5:05 p.m., injuring one person and damaging more than 40 residences before moving back into Kentucky.

The longest tornado in Indiana started in Union County about 5:35 p.m. before moving into Wayne County and then into the state of Ohio at 6:00 p.m. This F2 tornado destroyed several barns and blew the roofs off numerous houses. This tornado tracked for 12 miles in Indiana, and then 21 miles in Ohio.

Ohio

Two tornadoes occurred in Ohio. There were no deaths; however, 21 were injured when a strong tornado struck western Ohio.

In Preble and Darke Counties, a tornado with a 20-mile path touched down about 6:00 p.m.; this tornado started in Wayne County, Indiana. The strong (F2/F3) storm, which lasted 28 minutes, destroyed a house and caused 21 injuries and $5 million in property damage. More than 150 homes and businesses suffered varying degrees of damage.

South Carolina

Four tornadoes crossed South Carolina during the early night hours of Sunday Nov. 22. One person was killed and nine injured. Damage estimates totalled $5 million.

Two of the tornadoes moved across Saluda County resulting in the one death and eight injuries. Nine mobile homes, 14 residences and five businesses were destroyed.

Virginia/Maryland

Four tornadoes touched down during the early morning hours of November 23 in Virginia and Maryland, producing an estimated $2 million in damage.

Three Virginia counties suffered tornado damage during the early hours of Monday, November 23. There were no deaths or injuries.

In Maryland, at 3:00 a.m. November 23, a brief F1 tornado did $1.5 million damage to the Smithsonian's Garber facility for the Air and Space Museum

located in Silver Hill, 5 miles east of the District of Columbia, in Prince Georges County.

FINDINGS AND RECOMMENDATIONS

Finding 1.1: The deadly and destructive tornado outbreak which struck the United States November 21-23, 1992, was unusually intense and one of the most widespread for November (94 tornadoes). The 26 fatalities associated with the storms were the most since the Plainfield, IL, tornadoes in 1990 in which 29 people died.

Finding 1.2: Fourteen of the tornado deaths, or 54 percent, occurred in mobile homes.

Recommendation 1.2: Continued emphasis is needed to stress the importance of the availability of shelters in mobile home parks and the actions to be taken by those in harms way.

CHAPTER 2

METEOROLOGICAL ANALYSIS

Synoptic Scale Meteorological Analysis

The synoptic (large-scale) meteorological environment across much of the southern and eastern United States during November 21-23, 1992, was characterized by thermodynamic and wind profiles suggestive of severe thunderstorms and tornadoes. Strong, southerly, low-level flow transported unseasonably warm and moist air northward in advance of a strong upper-air low center that tracked from the southern Great Plains on the 21st into the Ohio Valley on the 23rd. The warm moist air served to lower stability and increase Convectively Available Potential Energy (CAPE) values throughout the warm sector of the associated surface system. A strong veering wind profile was also prevalent throughout the warm sector resulting in high values of storm relative helicity and an environment favorable for supercell thunderstorms.

Initial Conditions

Examination of the 500 mb (millibar) analysis at 1200 UTC November 21, 1992 (Fig. 6) found a strong closed low centered over southeast New Mexico. Temperatures were extremely cold, with -31C (degrees Celsius) observed at El Paso (ELP). A jet (wind maximum) greater than 80 knots was present to the southwest of the low, curving from western Arizona across northern Mexico into southern Texas. The 300 mb jet (not shown) associated with the low was nearly 100 kts.

In the lower levels of the atmosphere, the 850 mb analysis (Fig. 7) indicated a developing low center over west Texas. Southerly flow east of the 850 mb low was advecting warm, moist air from the Gulf of Mexico northward into the southern and eastern United States. The moisture was initially deepest east of the Mississippi River, but a low level jet (50 kts at Brownsville, Texas) was acting to increase moisture values along the Texas Gulf Coast as well.

The 1200 UTC surface analysis (Fig. 8) depicted a complex pattern of low pressure over west Texas. A weak, developing cold front from San Angelo south into Mexico separated moist air in central and east Texas from much drier air across southwest Texas and New Mexico. Warm, moist air with dewpoint temperatures in the upper 60sF (degrees Fahrenheit) was spreading north along the Gulf Coast.

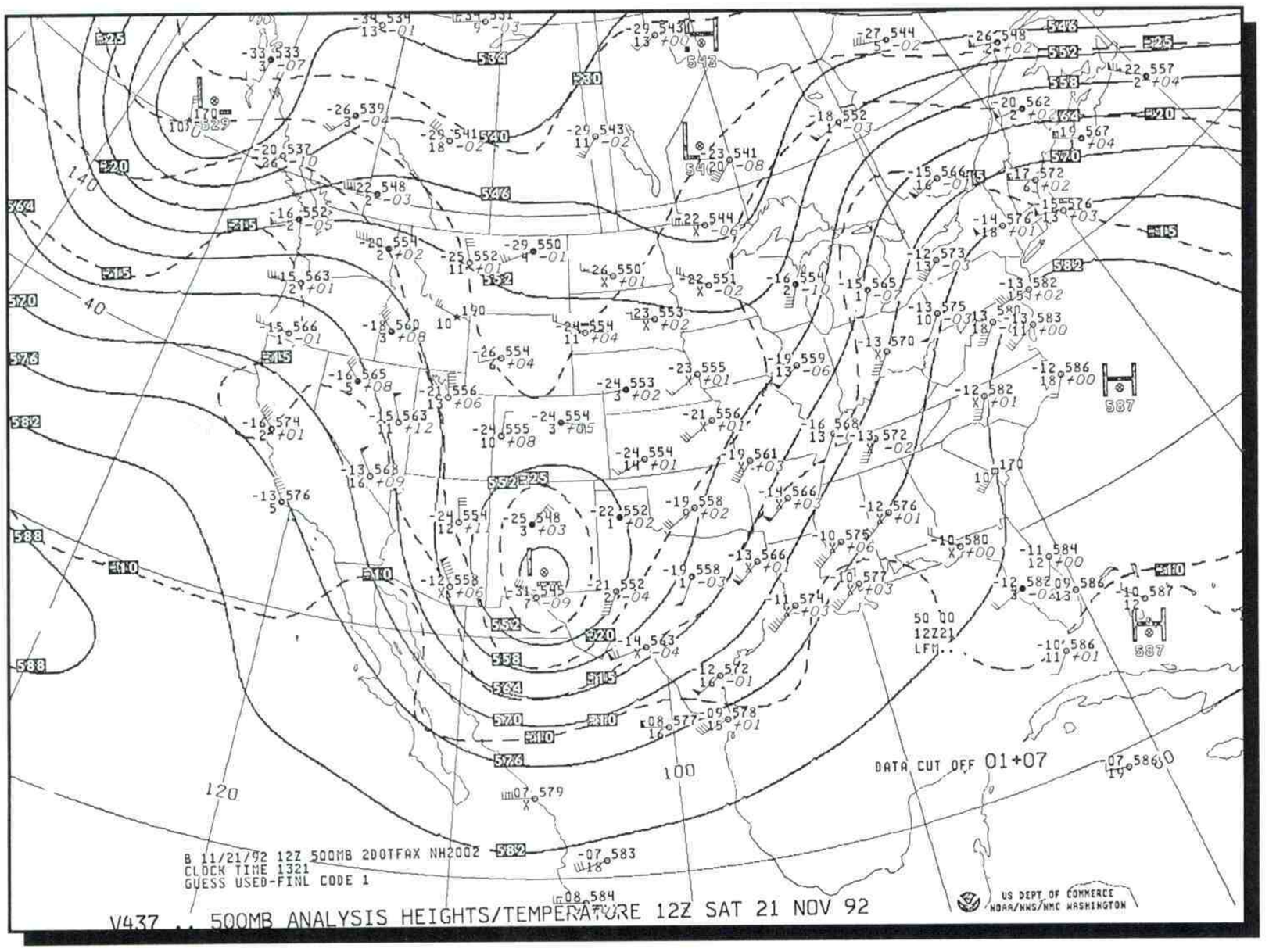


Figure 6. 500 mb analysis valid 1200 UTC, November 21, 1992.

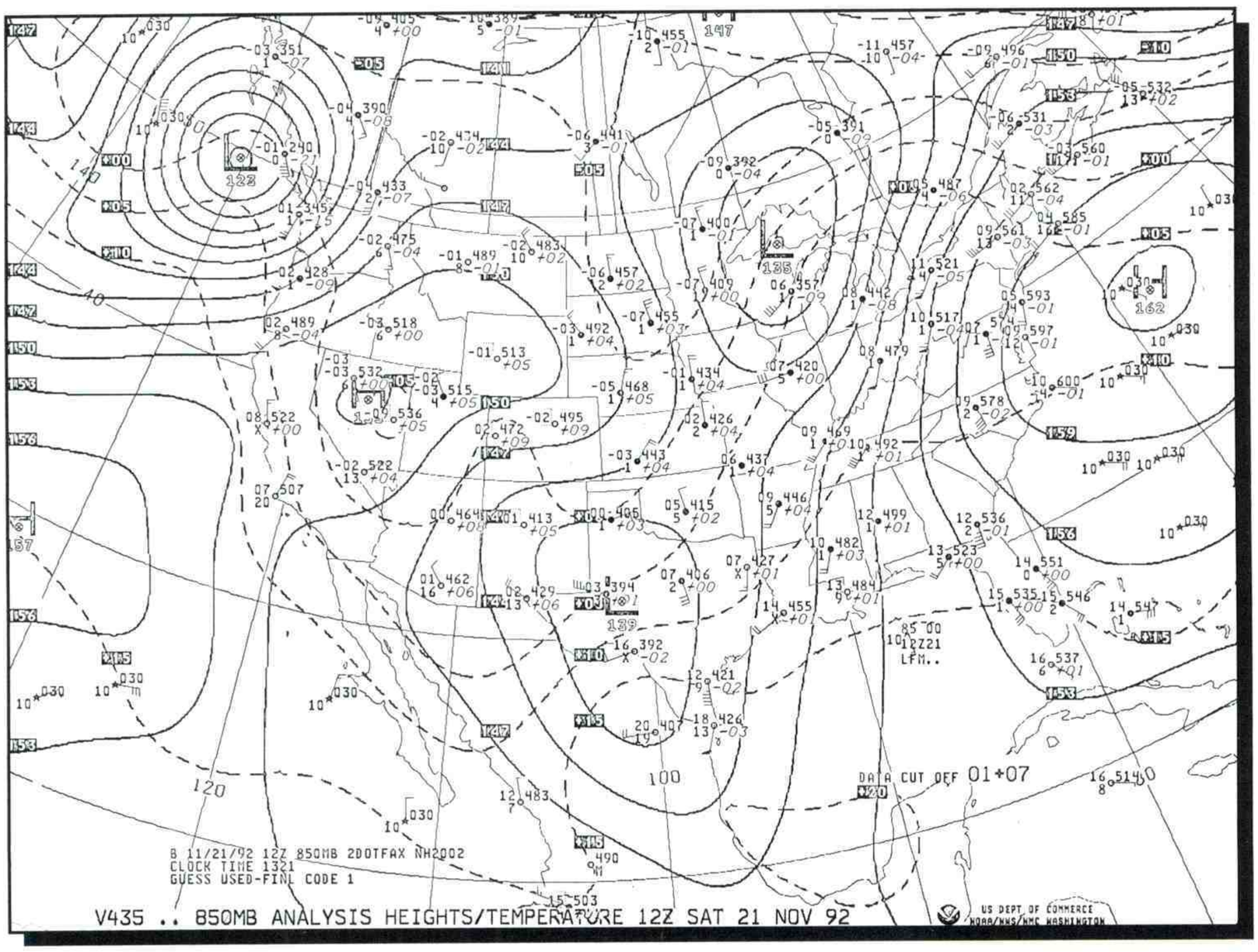


Figure 7. 850 mb analysis valid 1200 UTC, November 21, 1992.

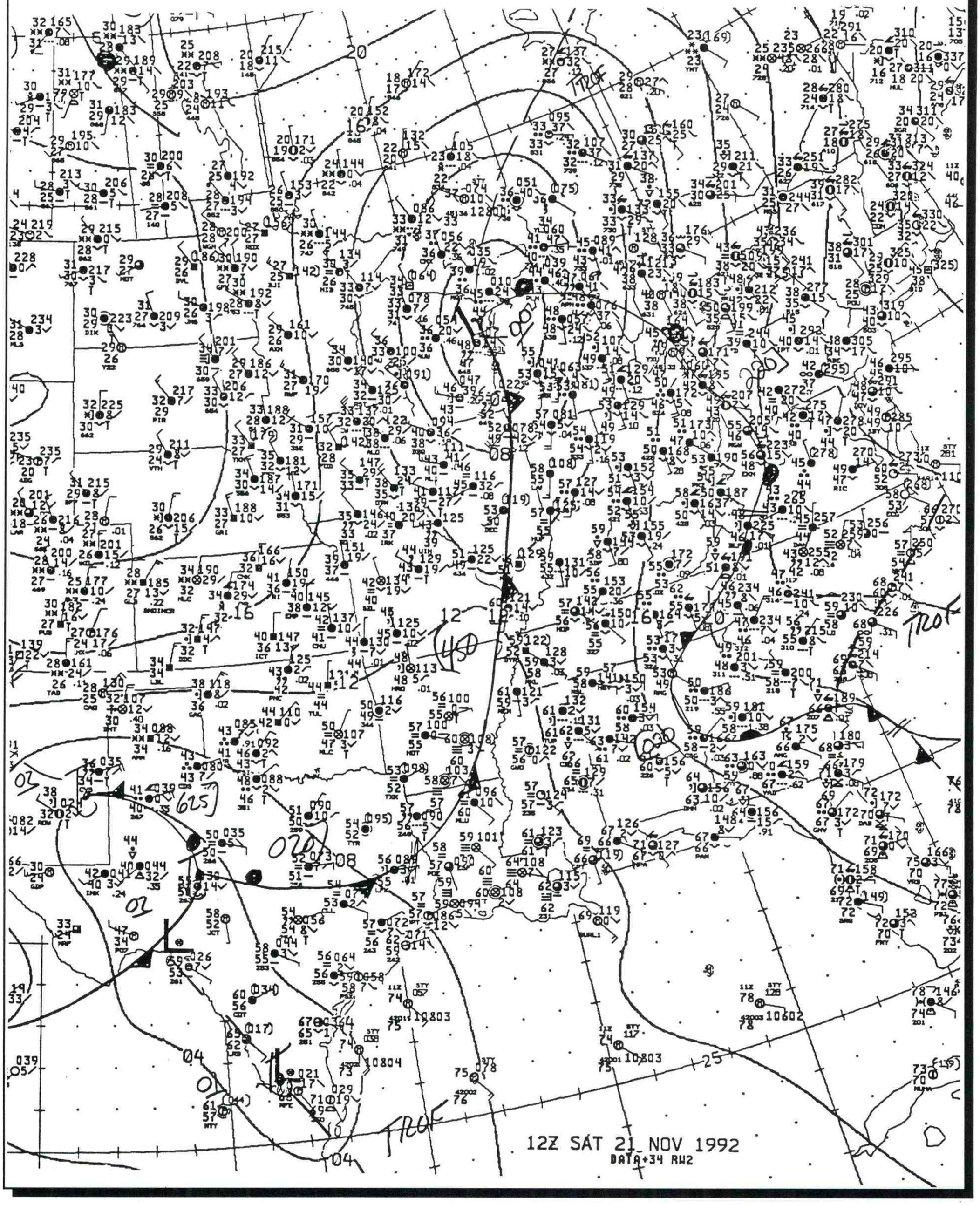


Figure 8. Surface analysis valid 1200 UTC, November 21, 1992.

Synoptic Evolution of the Event

The system lifted northeastward over the following 48 hours producing a large area favorable for the formation of severe thunderstorms and tornadoes. The primary factors contributing to the widespread and intense nature of the outbreak included:

1. Strong vertically veering wind fields in the warm sector resulting in large values of storm relative helicity (at times exceeding 500 m^2/s^2 in the lowest 3 km). Values of 150 m^2/s^2 or more are considered sufficient for mesocyclone formation.

2. Advection of temperature and moisture in association with the synoptic-scale system increased CAPE and created a thermodynamic profile capable of supporting convection.

3. The presence of mesoscale boundaries (e.g. cold front, warm front, outflow boundaries) which aided in convective initiation.

The closed 500 mb low tracked northeast from west Texas at 0000 UTC on the 22nd (Fig. 9) to the eastern Great Lakes at 1200 UTC on the 23rd (Fig. 10). The low remained closed with a minimum height of 5450 gpm (geopotential meters) until it opened into a trough by 1200 UTC on the 23rd.

The corresponding 850 mb low followed a similar track (Figs. 11, 12). The majority of the severe weather occurred near the 850 mb jet which shifted from the Texas Gulf Coast into Louisiana and Mississippi by 0000 UTC on the 22nd. Maximum wind speeds of 50 kts or more were associated with the jet. The jet continued its eastward progression to extend from Georgia to Ohio at 0000 UTC on the 23rd, then along the Atlantic Coast from South Carolina to Massachusetts at 1200 UTC on the 23rd.

The surface system (Figs. 13, 14, 15) increased in strength as it too tracked northeast. Surface dew points greater than 65F were advected by southeast winds from the Gulf into the warm sector east of the surface low and cold front. A weaker system that passed through the Great Lakes Region on the 21st left a weak frontal boundary in its wake. This front extended from north Texas into Michigan at 0000 UTC on the 22nd, then shifted northward as a warm front after 1200 UTC. The majority of the severe weather occurred with thunderstorms that developed in the warm sector of the surface system. Numerous tornadoes were associated with isolated supercell thunderstorms which formed in advance of the rapidly moving frontal squall line.

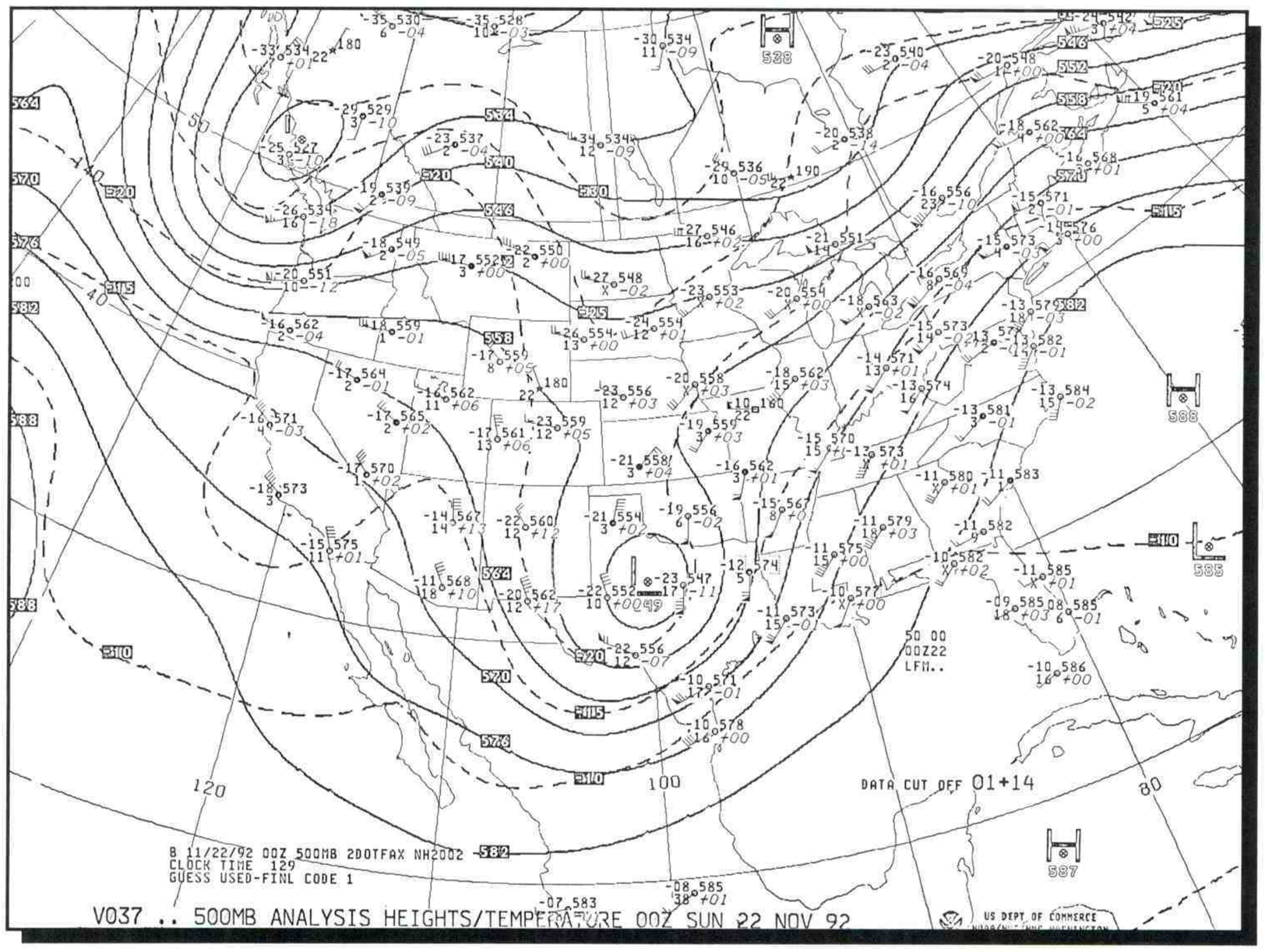


Figure 9. 500 mb analysis valid at 0000 UTC, November 22.

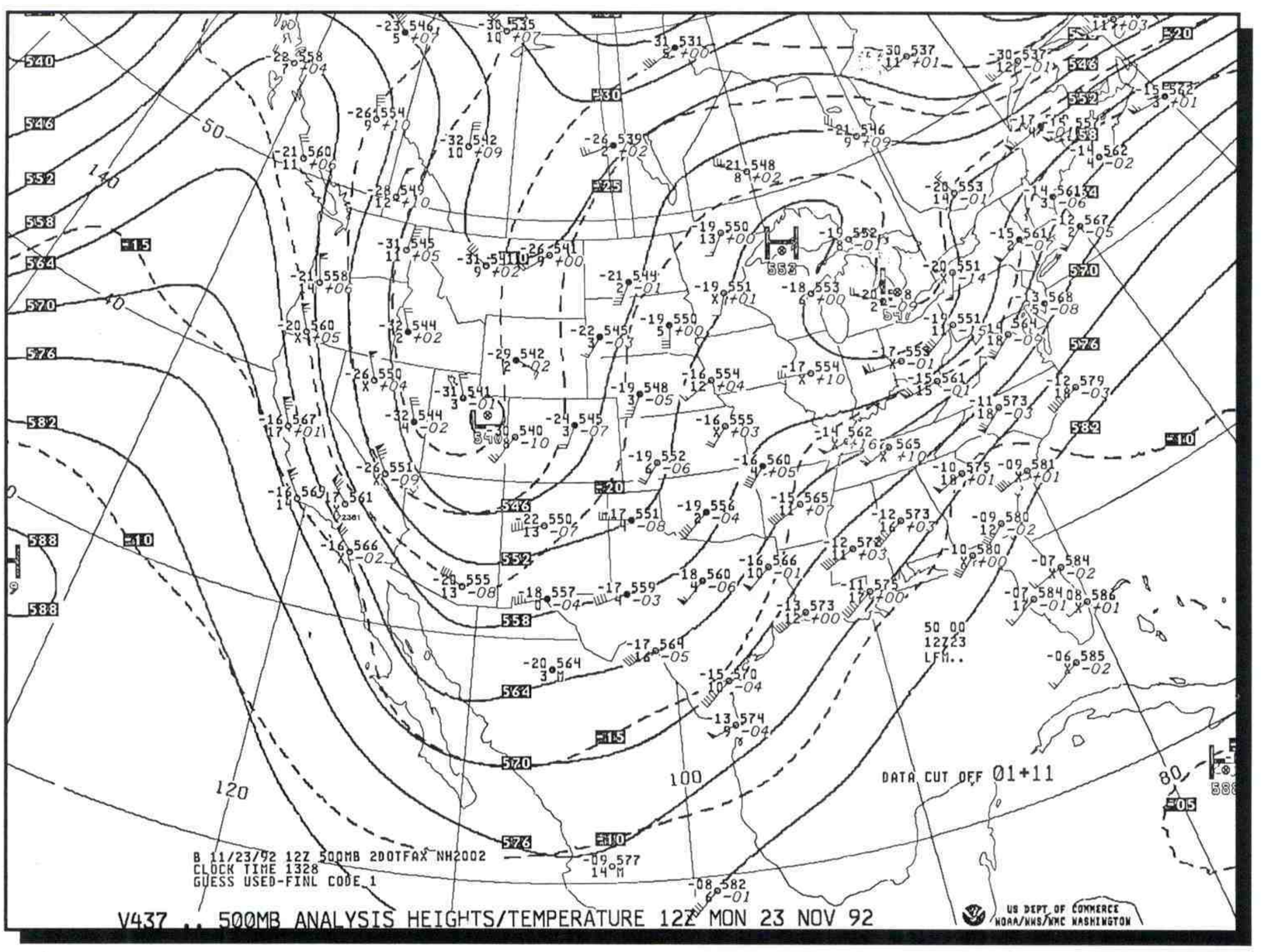


Figure 10. 500 mb analysis valid at 1200 UTC, November 23.

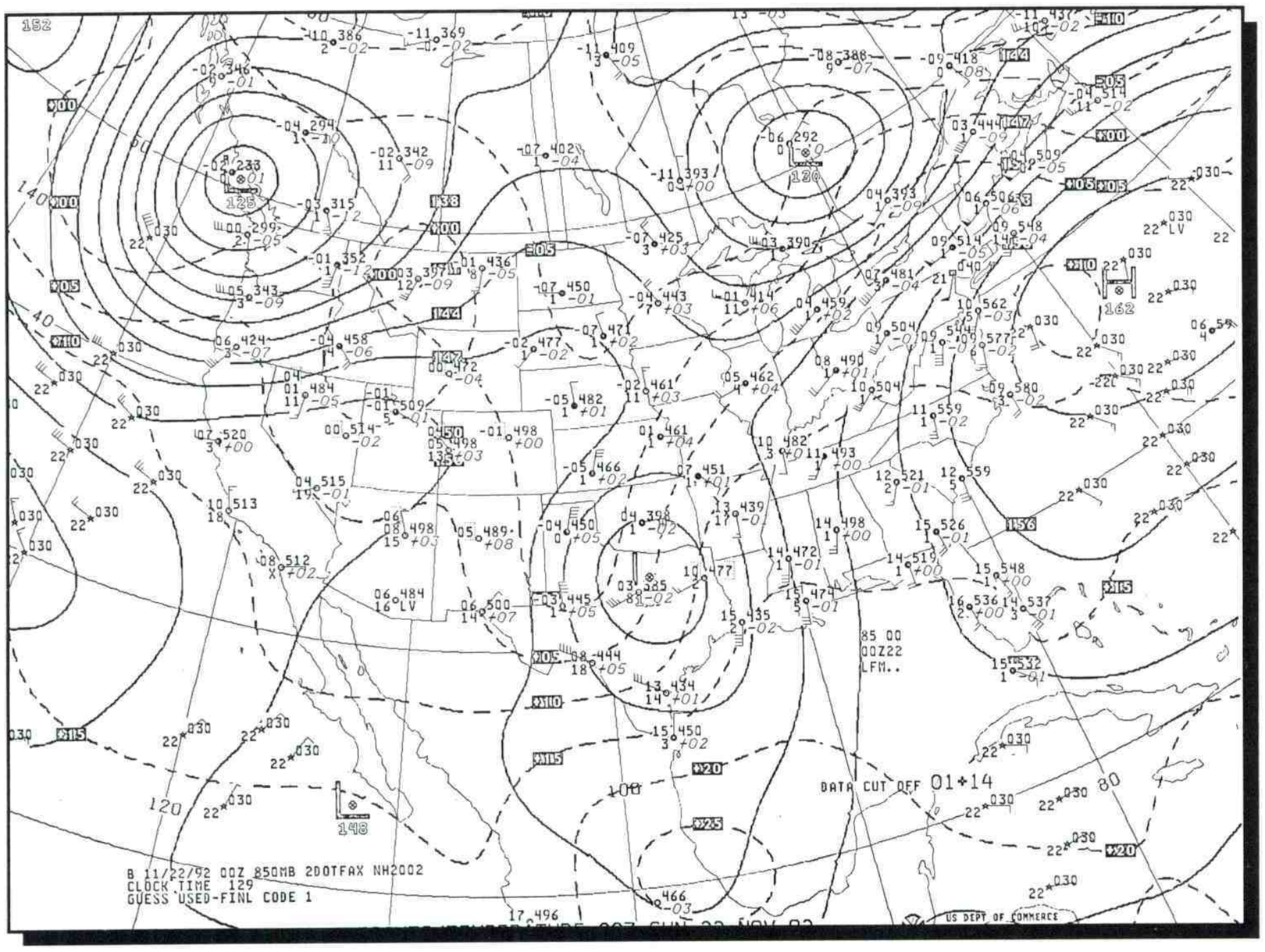


Figure 11. 850 mb analysis valid at 0000 UTC, November 22.

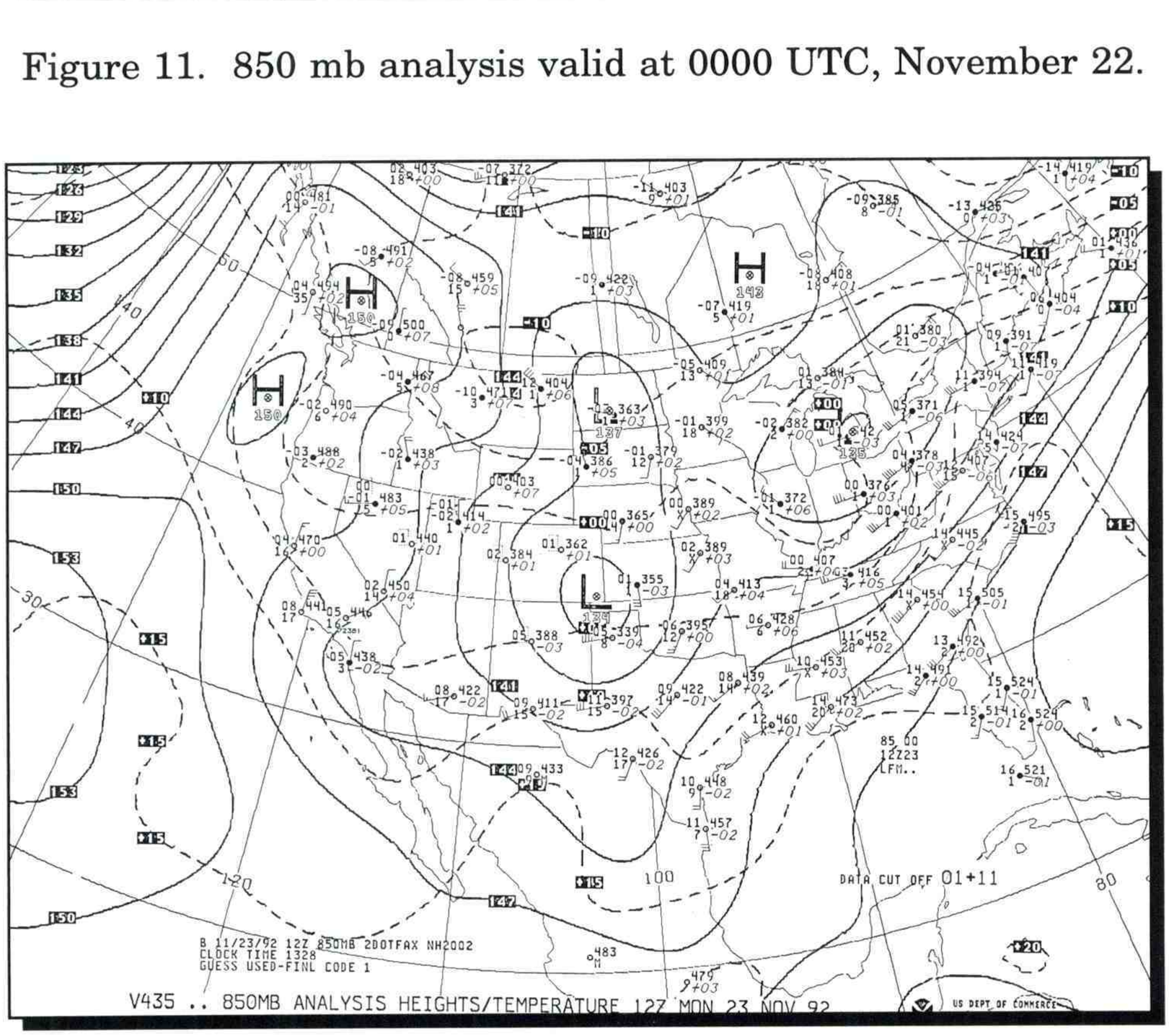


Figure 12. 850 mb analysis valid at 1200 UTC, November 23.

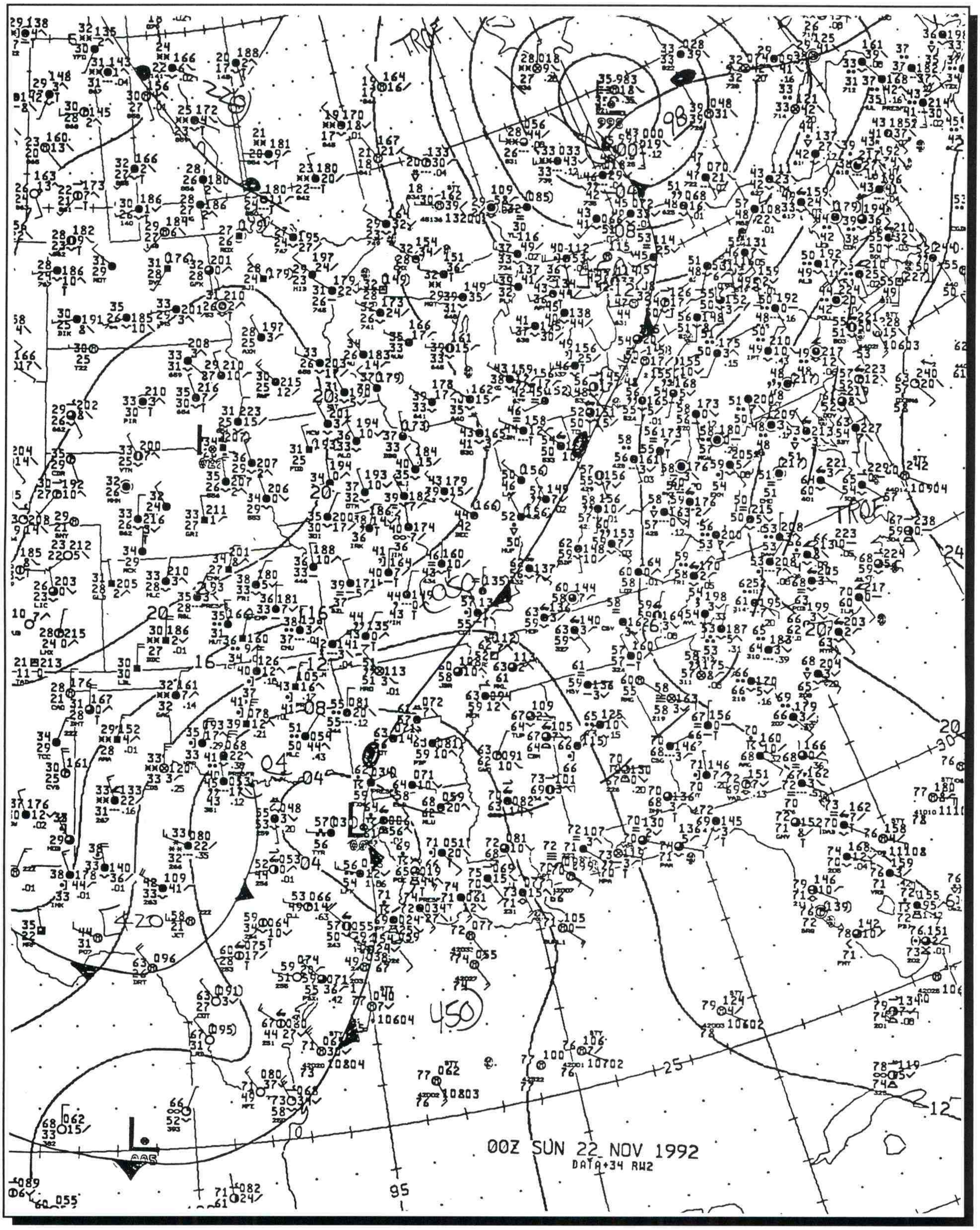
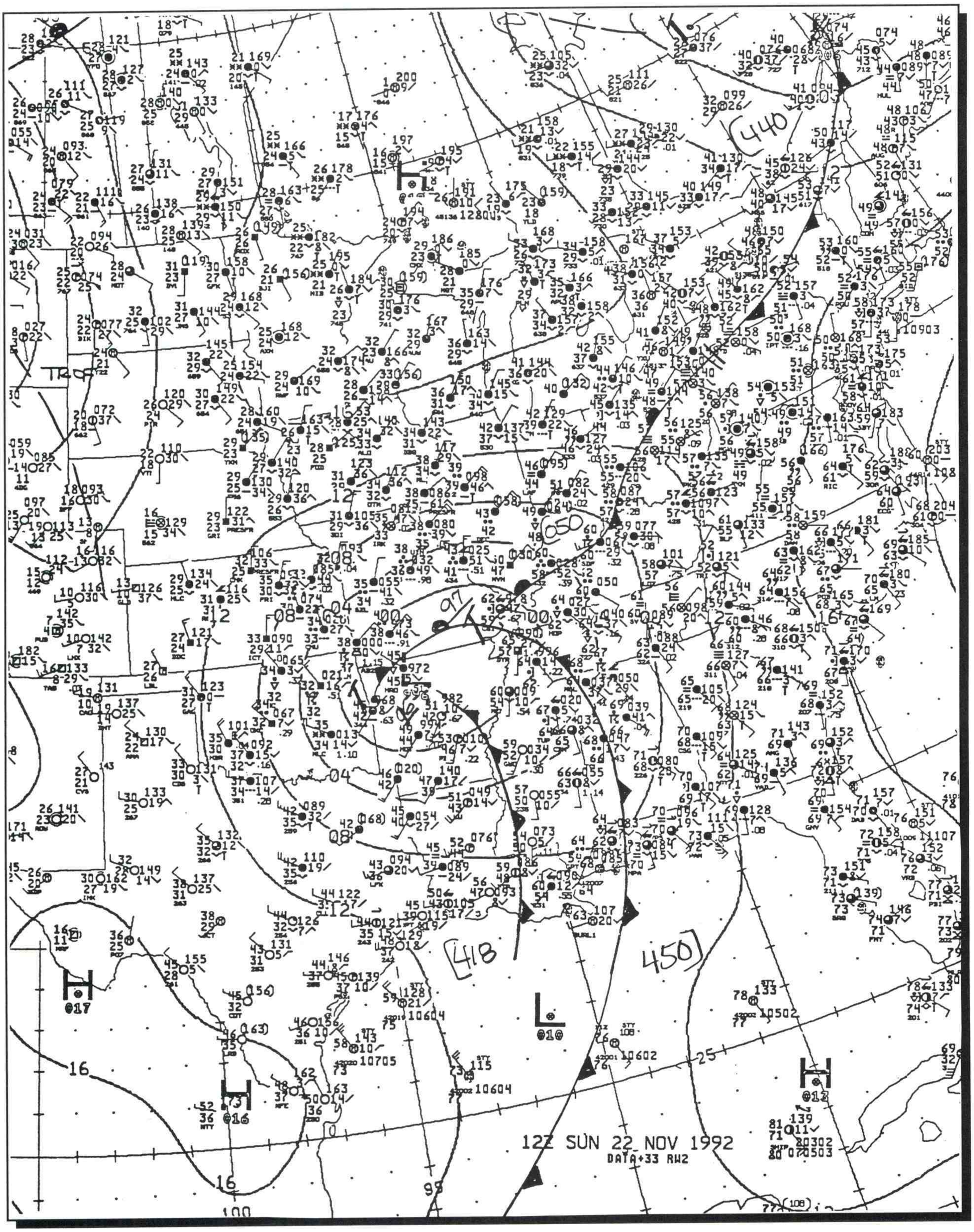


Figure 13. Surface analysis valid at 0000 UTC, November 22.


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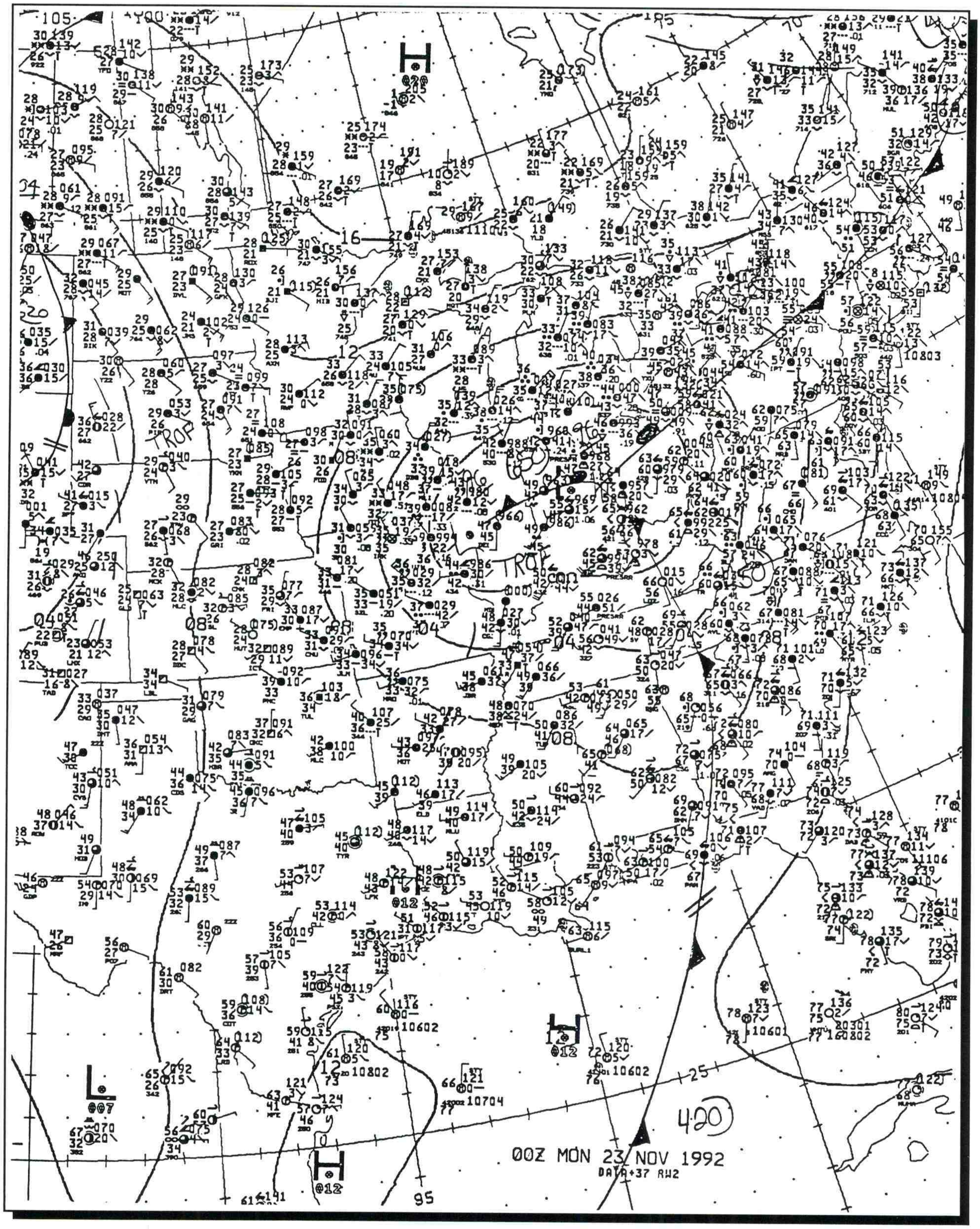


Figure 15. Surface analysis valid at 0000 UTC, November 23.

Mesoscale Analysis by Surveyed Location

Texas

Initially, low-level moisture appeared to be a possible limiting factor for severe convection with 1200 UTC rawinsonde observations (RAOB) at Corpus Christi, Texas (CRP) and Lake Charles, Louisiana (LCH) indicating relatively dry air at 850 mb and surface dew points in the upper 50sF. The CRP RAOB (Fig. 16a) showed moisture present just below 850 mb, and the 50 kt 850 mb wind at Brownsville, Texas, indicated substantial moisture advection was occurring.

An examination of the CRP RAOB using the SHARP (Skew-T/Hodograph Analysis and Research Program) found a highly sheared environment (east winds at the surface turned toward the southwest and increased in speed). Storm relative helicity (Fig. 16b), a measure of low-level wind shear and mesocyclone potential, was 455 m^2/s^2 below 3 km. Storm relative helicity values greater than 450 m^2/s^2 are often associated with strong or violent tornadoes.

Other measures of severe weather potential were less favorable. The CRP CAPE of 1058 J/kg (Joules per kilogram) and Lifted Index of -3C were modest, and both were below values commonly associated with severe weather.

WSO Houston forecasters correctly anticipated that sufficient moisture would be available by the time the surface front over central Texas arrived during the early afternoon. They also expected the strong shear over Corpus Christi at 1200 UTC would also be present at Houston. Because of the effective anticipation of the threat, the staff at Houston was increased well ahead of the event. Identification of the potential threat also allowed the issuance of statements highlighting the danger hours before it occurred.

Houston forecasters continued to monitor the evolving mesoscale environment into the afternoon. Moisture increased rapidly with the surface dew point at Palacios (PSX), Texas, rising to 70F at 1800 UTC. ADAP (AFOS Data Analysis and Programs) products were examined and indicated rapidly increasing moisture convergence along the frontal boundary. The 1200 UTC CRP RAOB was modified with SHARP using surface data at Houston and low-level winds from the Houston WSR-88D (Weather Surveillance Radar-1988 Doppler) VAD (Velocity Azimuth Display) wind profile (note that the location of the WSR-88D associated with the Houston office is referred to with call letters HGX). By 2200 UTC (toward the end of the event) the modified storm relative helicity analysis (Fig. 17b) indicated a value of 446 m^2/s^2.

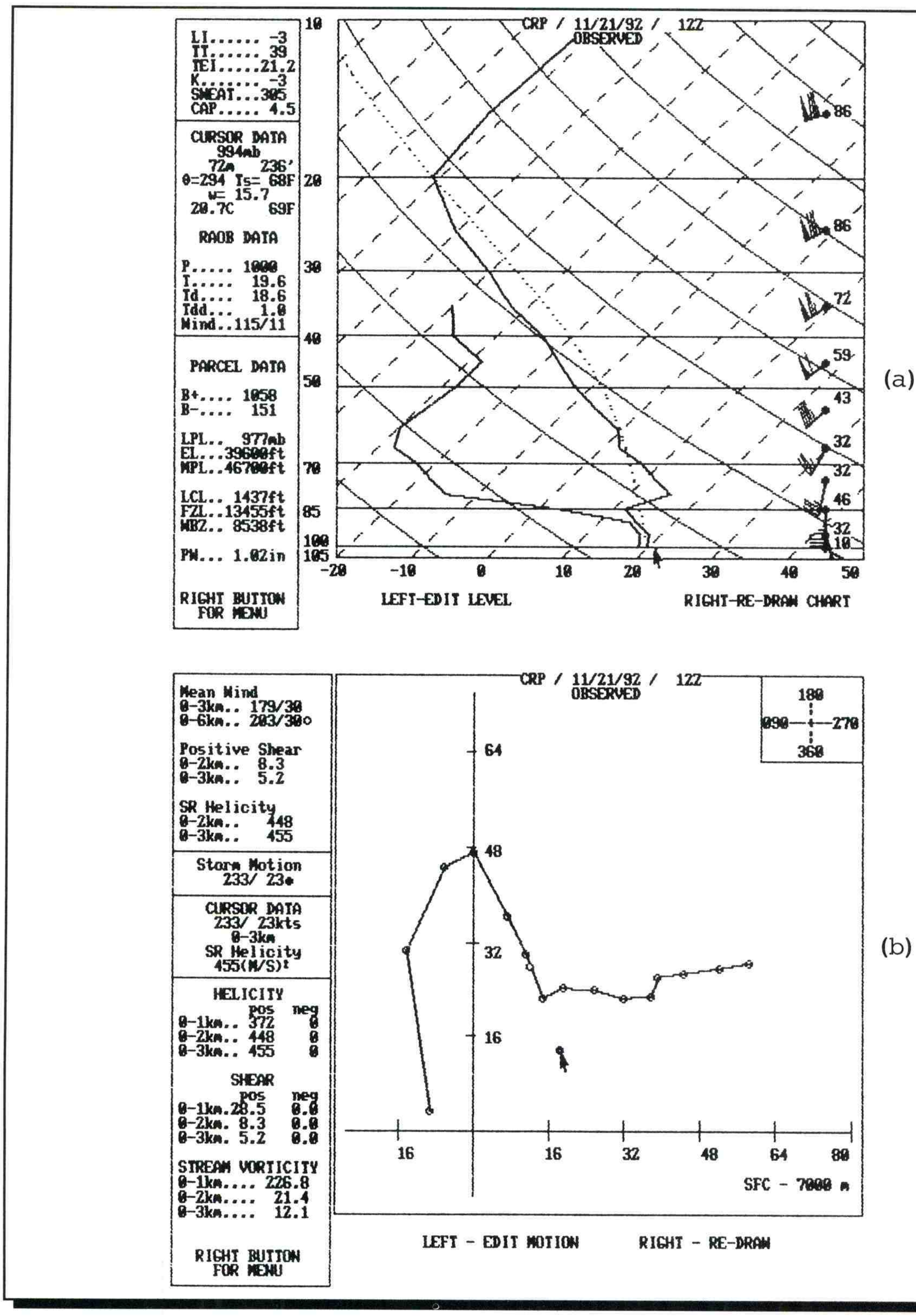


Figure 16. The Corpus Christi (CRP), Texas, RAOB (a) and storm relative helicity (b) produced by the SHARP program and valid at 1200 UTC, November 21, 1992.

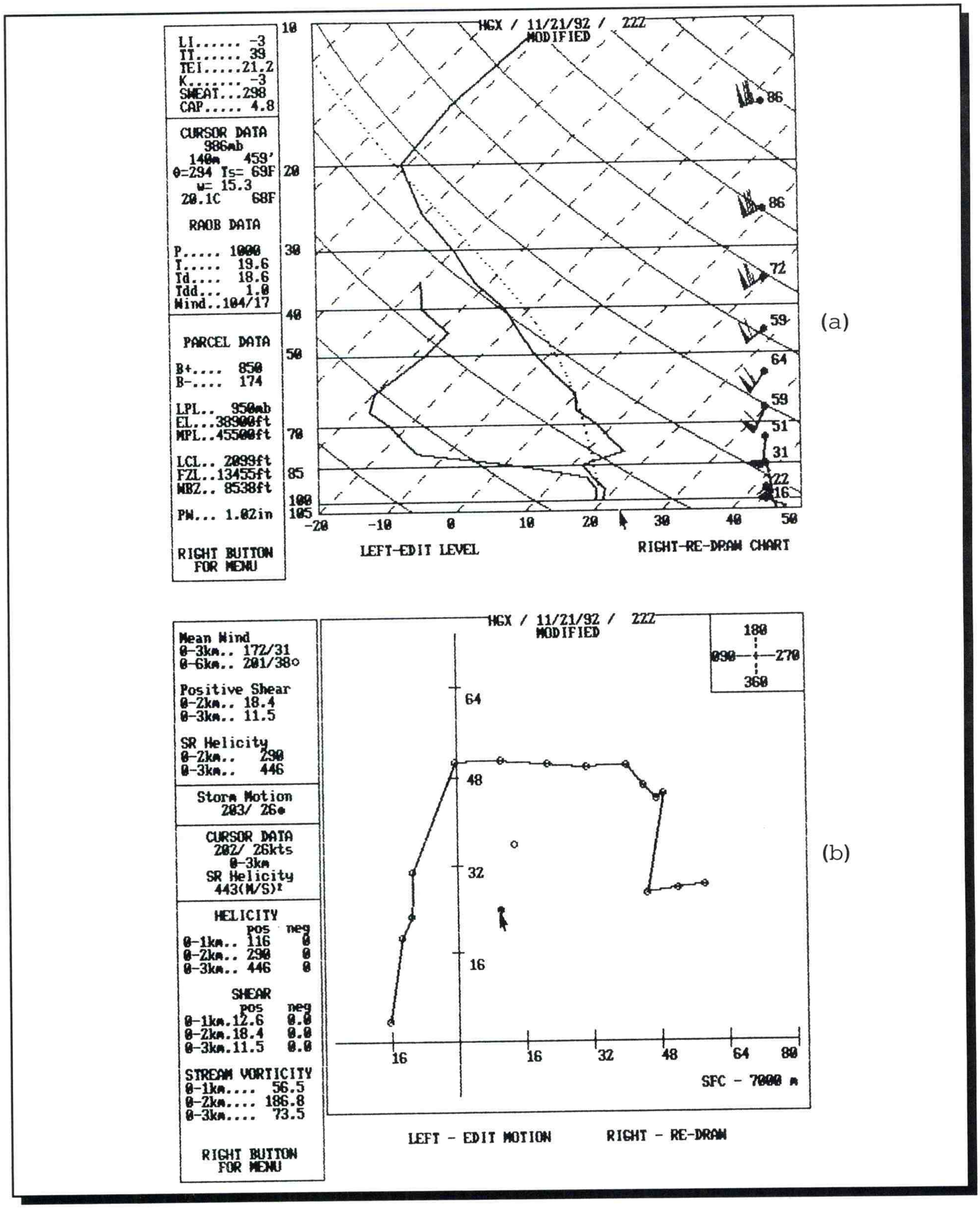


Figure 17. The same as Fig. 16 except for Houston (HGX), Texas, valid at 2200 UTC, November 21.

When the storms affected the Houston metropolitan area, the surface wind remained from the east and enhanced storm relative helicity values and the potential for mesocyclones in the Houston area.

Active mesoanalysis prior to the tornado episode contributed greatly to the overall readiness of the Houston staff. It also primed the staff for expected developments confirmed by the WSR-88D radar.

Mississippi

By 0000 UTC on November 22nd, an intense squall line had become well-established in the warm sector across the lower Mississippi Valley. Supercell thunderstorms were present in advance of the squall line with several reports of tornadoes in Louisiana during the evening. Reports of tornadoes and other severe weather continued as the squall line advanced to Mississippi during the late evening.

Forecasters at WSFO Jackson (JAN) examined a variety of meteorological data throughout the day and evening shifts on the 21st. In addition to hand analyses of upper-air and hourly surface analyses, ADAP, SHARP, numerical model guidance, and satellite imagery were utilized to support forecast and warning operations. Forecasters correctly interpreted the available data to conclude that severe thunderstorms, including tornadoes, were likely during the late night and early morning hours of the 21st and 22nd.

Analysis of the Jackson, Mississippi, November 22, 0000 UTC RAOB (Fig. 18) using SHARP revealed a storm relative helicity value of 160 m^2/s^2 and a CAPE of 602 J/kg. Although CAPE values were not impressive, storm relative helicity values were sufficient to support mesocyclone formation.

However, CAPE values increased dramatically by late evening as strong, southeast, low-level winds advected increasingly moist air into Mississippi. Post-event analysis of the JAN sounding, modified to reflect an increase in surface dewpoints to better represent the storm environment near the time of the strongest tornadoes, indicated an increase in CAPE to nearly 1900 J/kg by 0600 UTC. Although no profiler or RAOB data were available at 0600 UTC across central or southern Mississippi, it is likely that helicity values increased also as the low-level jet intensified east of the approaching squall line.

Georgia

Supercell thunderstorms persisted in advance of the frontal squall line as it tracked rapidly eastward during the morning hours on November 23rd.

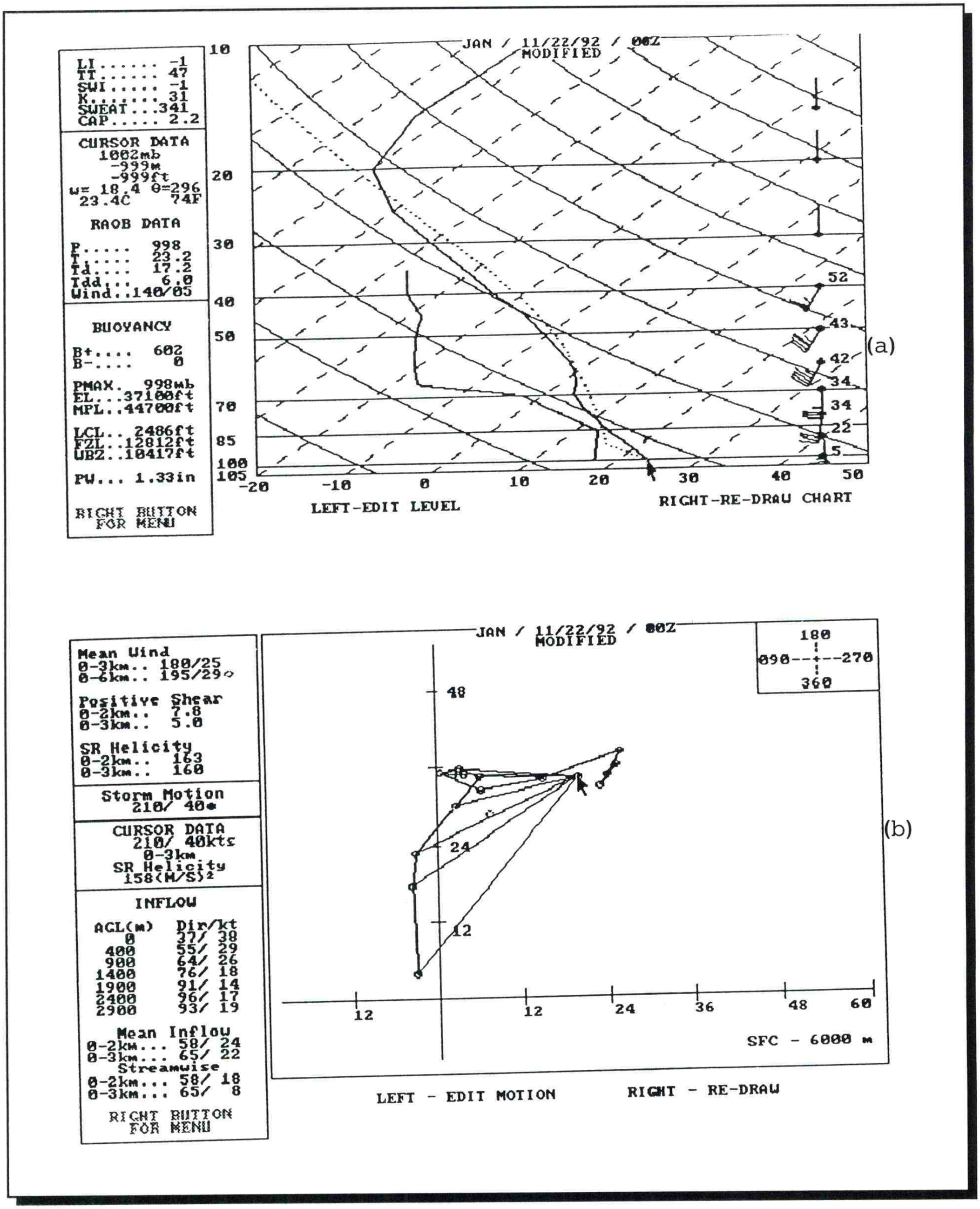


Figure 18. The same as Fig. 16 except for Jackson (JAN), Mississippi, valid at 0000 UTC, November 22.

Low-level moisture increased rapidly in advance of the squall line during the morning hours of the 22nd. At 0600 UTC surface dewpoint temperatures ranged from the middle 50sF across northern sections of Georgia to near 70F across the south. As the morning progressed, low-level southerly winds strengthened in response to the approaching squall line and synoptic-scale system allowing the moisture to spread northward and CAPE values to increase. Dewpoint temperatures by 1800 UTC were in the upper 60sF to lower 70sF throughout Georgia. The 1200 UTC Athens, Georgia (AHN) RAOB, modified to reflect surface winds, temperatures and dewpoints east of the squall line at midday, indicated storm relative helicity values of 153 m^2/s^2 and CAPE values of 2259 J/kg (Fig. 19).

Midnight-shift forecasters at WSFO Atlanta (ATL) utilized satellite and radar imagery to monitor the progress of the severe storms as they marched across Alabama early on the 22nd. Forecasters also examined numerical model guidance, ADAP, SHARP, surface, and upper-air data to assess the severe weather threat. Based upon these data and National Severe Storms Forecast Center (NSSFC) guidance, WSFO ATL issued statements and forecasts highlighting the severe weather threat several hours in advance of the tornado events. The thorough analyses by WSFO ATL forecasters also contributed to their ability to anticipate staffing needs and sensitize them to the potential for tornadoes.

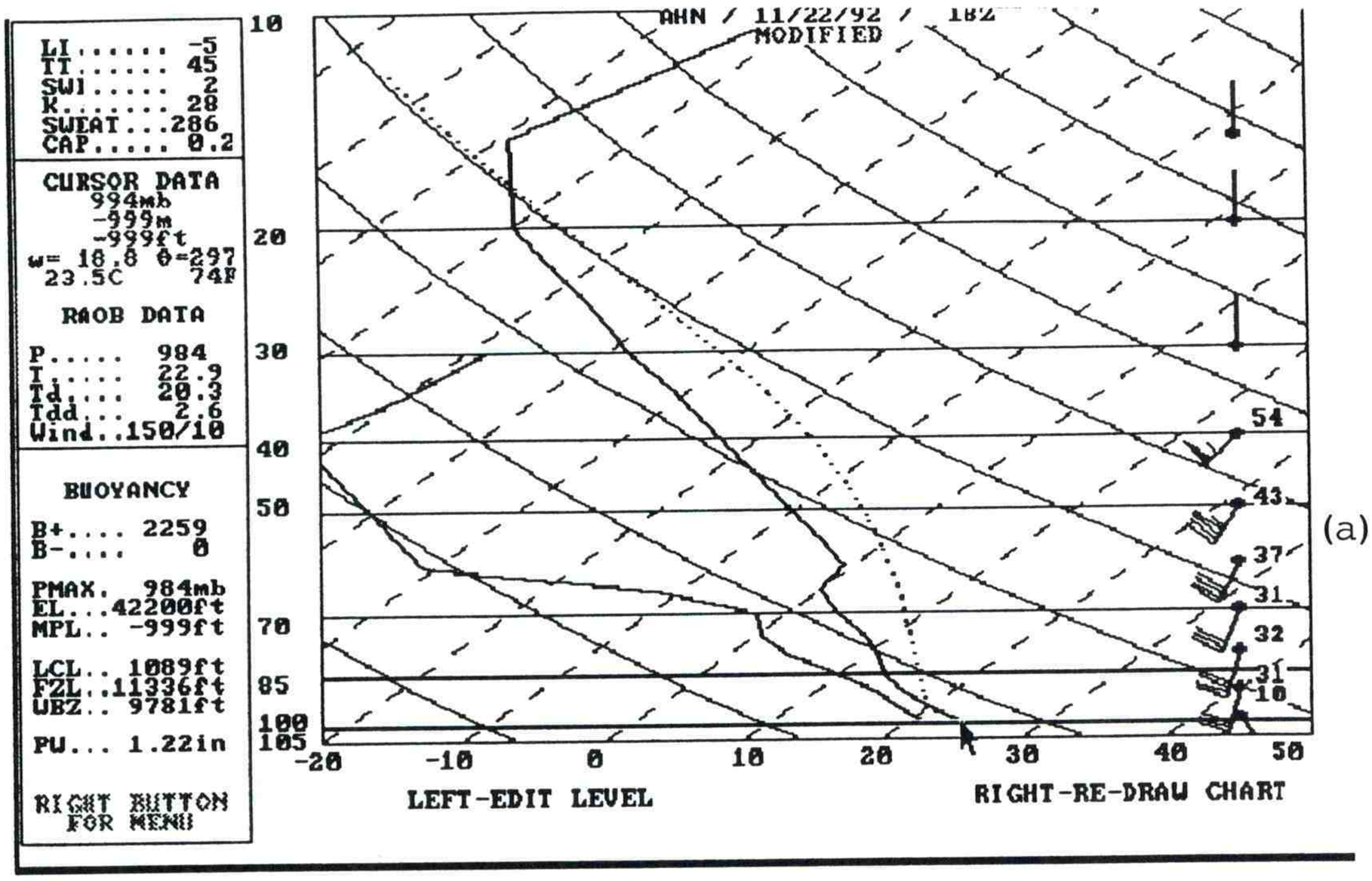
Kentucky

A second area of severe thunderstorms and tornadoes occurred over the Ohio Valley in the vicinity of the stationary front across Indiana, Kentucky and Ohio on November 22nd during the day.

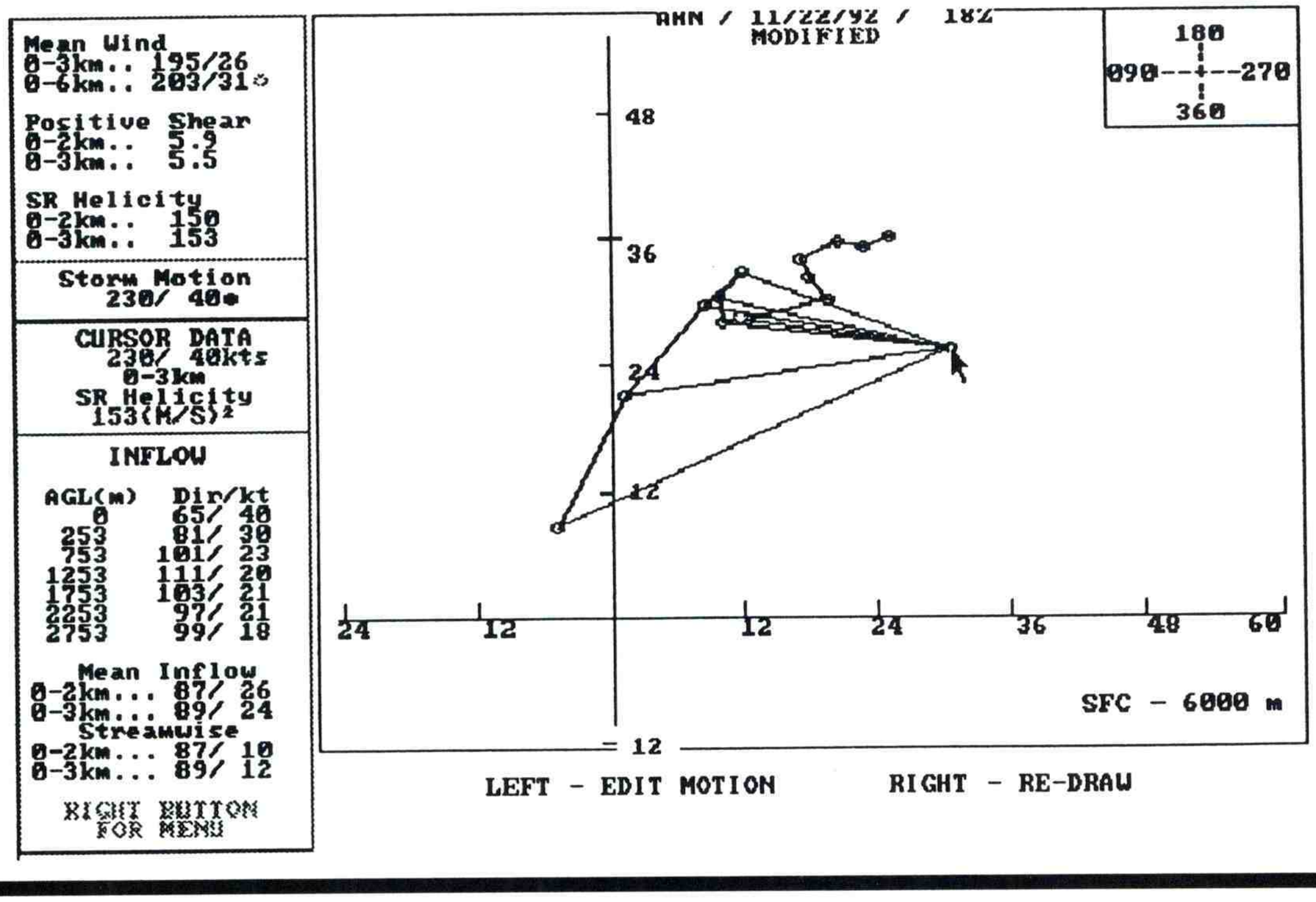
The Cincinnati WSO (CVG) was well prepared for the episode. The staff had analyzed the November 22, 1200 UTC Nashville (BNA), Tennessee RAOB using SHARP (Fig. 20). Although contaminated by convection, it revealed a CAPE and Lifted Index similar to those observed by RAOBs at Houston and Jackson. Wind shear continued to be the major concern with storm relative helicity from surface to 3 km greater than 500 m^2/s^2. They correctly expected a similar wind profile over their area of concern by afternoon.

A warm front was located south of Cincinnati across Kentucky during the morning. The staff expected it to lift north with low level moisture spreading back across their warning area.

ADAP was viewed frequently and in depth, concentrating on moisture convergence and Theta-E (Equivalent Potential Temperature) advection fields. The Theta-E advection field, with a ridge extending along the Ohio River from southern Indiana to southern Ohio, alerted the staff to anticipate development there. As the moisture convergence maximum shifted from southern Indiana toward



(a)



(b)

Figure 19. The same as Fig. 16 except for Athens (AHN), Georgia, valid at 1800 UTC, November 22.

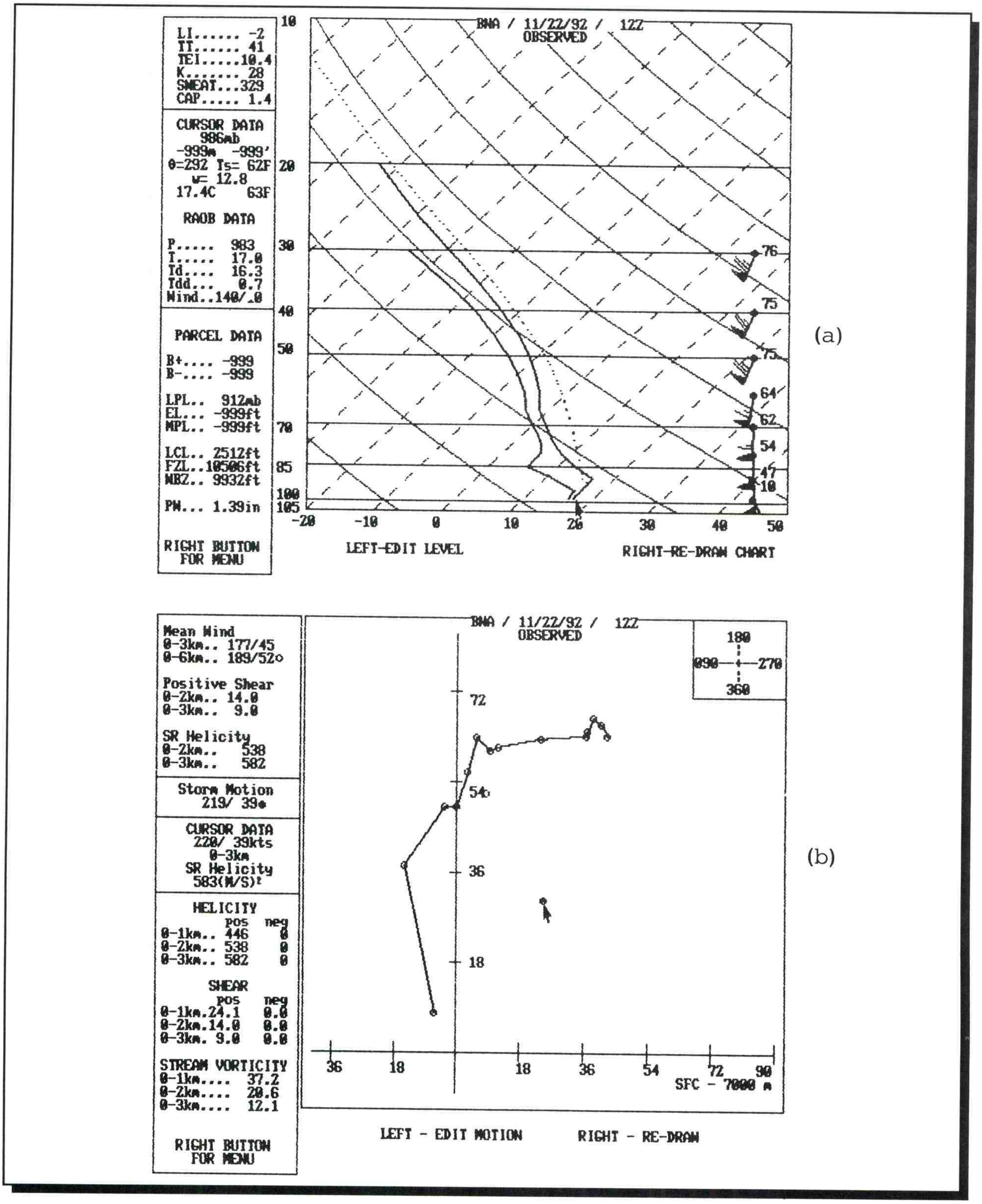


Figure 20. The same as Fig. 16 except for Nashville (BNA), Tennessee valid at 1200 UTC, November 22.

Cincinnati, the WSO staff determined severe weather would likely develop into their area. This analysis helped them take a rather subtle radar indication and determine the need to issue a tornado warning, with lead time, for the storm that resulted in a fatality.

North Carolina

The highly sheared environment continued ahead of the squall line into the Carolinas, where tornadoes again struck in the warm sector of the surface system just east of the frontal squall line. WSFO Raleigh examined the November 23, 0000 UTC Greensboro, North Carolina (GSO) RAOB using SHARP (Fig. 21) and found storm relative helicity in the lower 3 km at 442 m^2/s^2. An examination of ADAP found moisture convergence along the squall line and front but nothing to highlight a particular area for development.

FINDINGS AND RECOMMENDATIONS

Finding 2.1: Storm relative helicity proved especially useful for identifying the potential for mesocyclones and tornadoes. Strong vertically veering wind fields in the warm sector resulted in large values of storm relative helicity (at times exceeding 500 m^2/s^2 in the lowest 3 km). Parameters such as Lifted Index and CAPE indicated convection was possible, but values for these quantities were modest and not sufficient to discriminate between severe and non-severe convection.

Finding 2.2: National Weather Service Offices effectively utilized excellent, available guidance and tools, including SHARP and ADAP, to anticipate and monitor mesoscale meteorological developments. Forecasters in Houston also used VAD wind data from the WSR-88D radar to modify early morning helicity calculations and identify the increased tornado threat.

Recommendation 2.2a: Continue education, training and research in the area of mesoscale meteorology.

Recommendation 2.2b: Ensure the NWS Advanced Weather Interactive Processing System (AWIPS) provides a complete set of mesoscale analysis tools. These tools must be interactive, allowing modification of data and effective assessment of critical quantities like CAPE and helicity quickly.

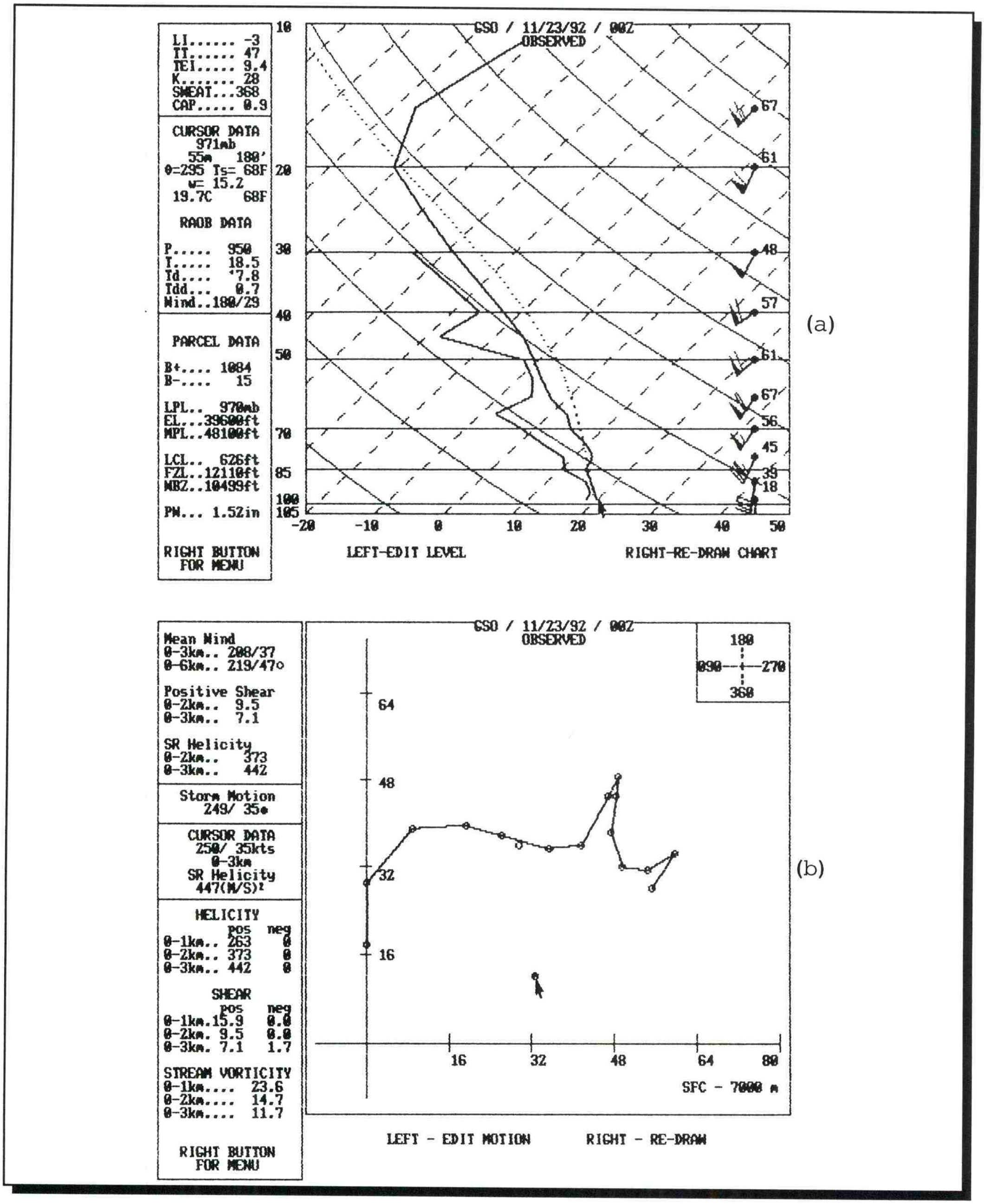


Figure 21. The same as Fig. 16 except for Greensboro (GSO), North Carolina, valid at 0000 UTC, November 23.

CHAPTER 3

WARNINGS, FORECASTS, AND GUIDANCE

Current NWS forecast procedures begin with centrally produced computer guidance at the National Meteorological Center (NMC) in Camp Springs, Maryland. National severe weather guidance is prepared at the NSSFC using the computer guidance. WSFOs, in turn, refine the guidance, issue detailed state forecasts, and along with WSOs are responsible for issuing local forecasts, statements, and short-fused warnings.

The warning and forecast process of the NWS worked exceptionally well during the November 21 through 23 outbreak of tornadoes. Computer guidance from NMC, national outlook and watch products by NSSFC, state products and forecasts issued by WSFOs and WSOs all highlighted the potentially dangerous weather situation.

Details of the warning process based on radar indications are presented in Chapter 4. Verification statistics for the warnings issued from WSOs and WSFOs are presented in Appendix B. A chronology of selected WSFO and WSO products is presented in Appendix C.

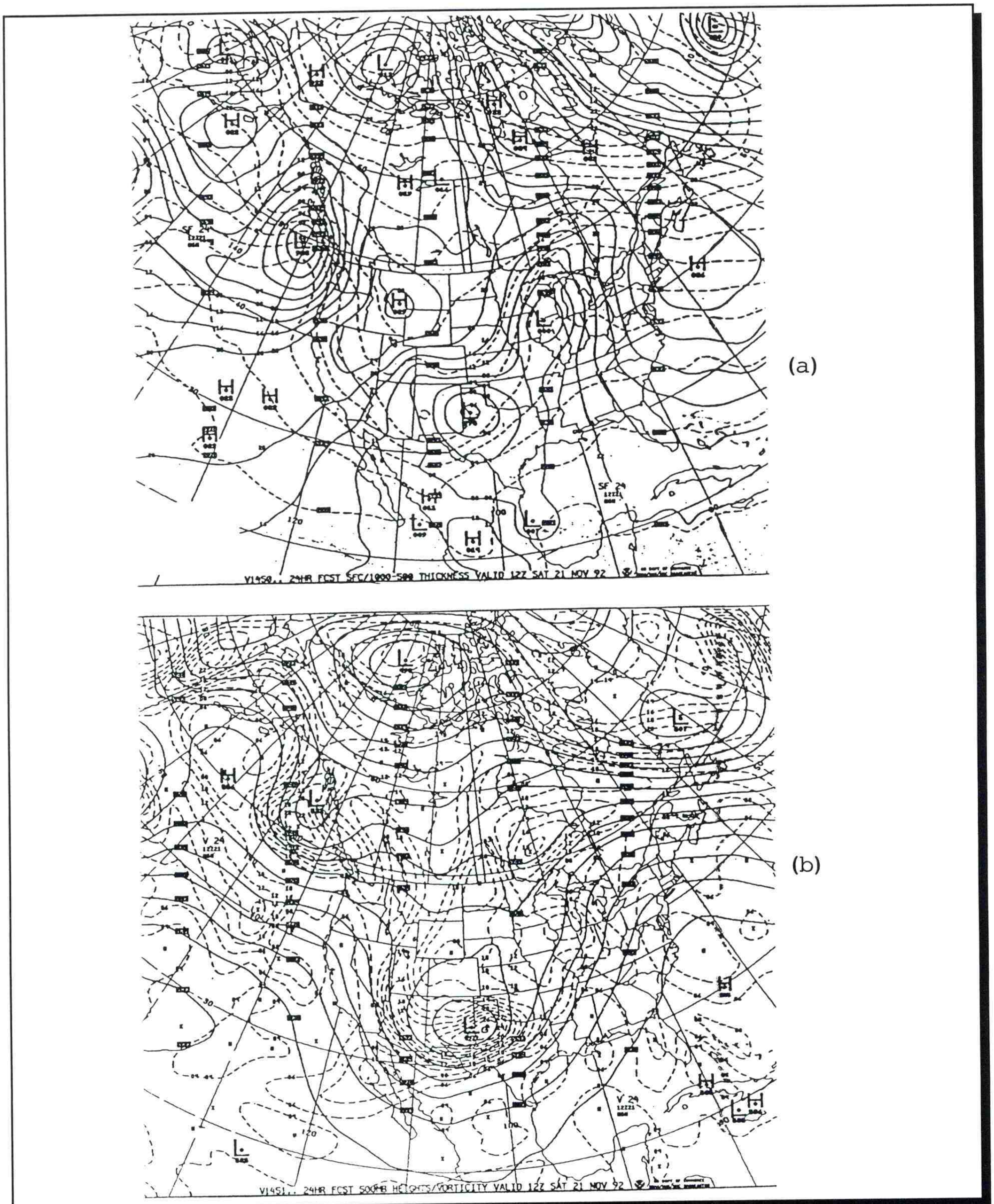
NMC

The primary short-range (through 48 hours) operational model used by the NWS forecasters is the Nested Grid Model (NGM). The NGM 24-hour forecast valid 1200 UTC, Saturday, November 21 indicated conditions conducive to severe weather from the eastern border of Texas to the western border of Georgia and northward to southern Illinois. Fig. 22 a,b show the forecast position of the surface low and middle level (500 mb) trough, respectively.

The 24-hour forecast valid 1200 UTC, Sunday, November 22 (surface and 500 mb [Fig. 23 a,b]) were excellent in terms of position and system development. The overall pattern was favorable for the development of strong thunderstorms, including the possibility of tornadoes, in those areas where the severe weather activity subsequently occurred. Numerical models are not expected to predict the exact location of thunderstorm development.

NSSFC

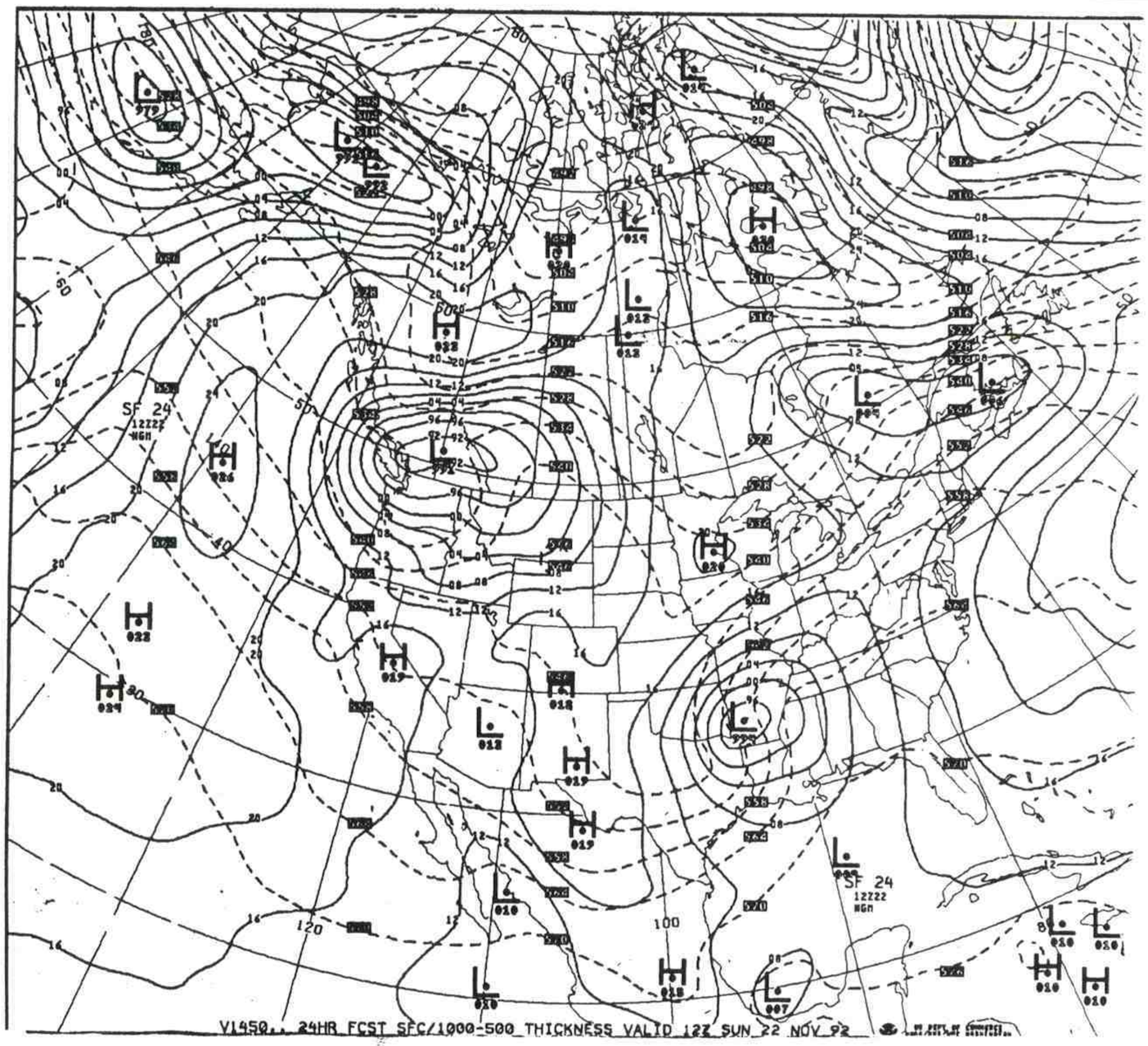
This major tornado outbreak began in the early afternoon of November 21, 1992 and ended nearly 48 hours later. Eighty-nine of the 94 tornadoes touched down in valid Tornado Watches, plus two that were partially in watch areas (that is, touched down outside the watch area but moved into it). Twenty-five of the 26



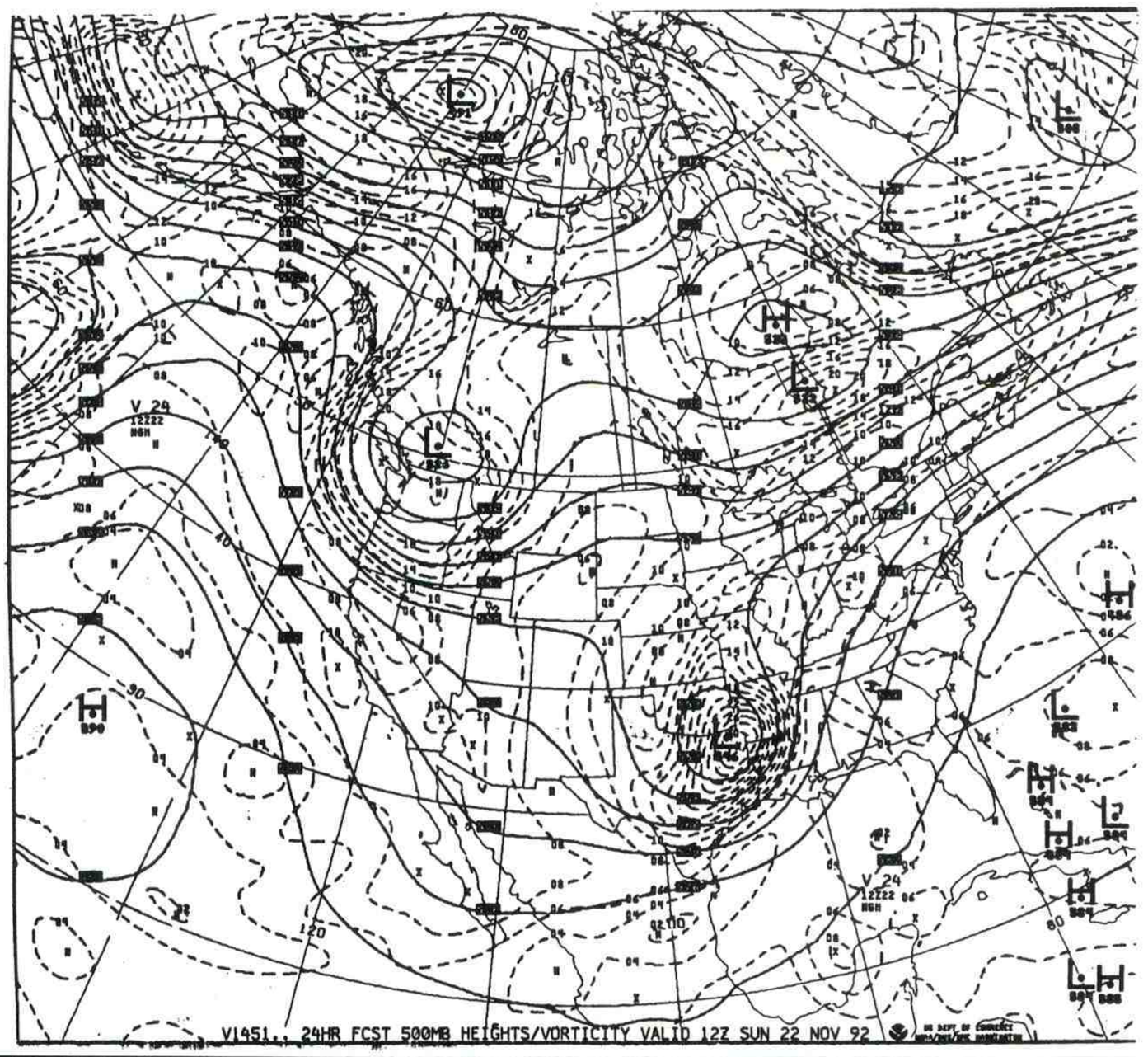
(a)

(b)

Figure 22. The 24-hr NGM forecast valid for 1200 UTC, November 21, 1992, for a) surface pressure/1000-500 mb thickness, and b) 500 mb height/vorticity.



(a)



(b)

Figure 23. The same as Fig. 22 except valid for 1200 UTC, November 22.

fatalities, and 623 of the 641 injuries occurred in valid Tornado Watches. Not only were these watches accurate and timely, but they were made under atypical circumstances, i.e., not a normal springtime scenario.

As early as Friday morning (2:00 a.m.) the potential for severe weather development was anticipated for Saturday afternoon over eastern Texas and western Arkansas. Throughout the outbreak, the severe weather guidance continued to stress the severity, location, and timing of the series of storms that raked the area.

It is also significant that two of the watches (914 and 916) contained the seldom-used, enhanced wording, "THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES," reserved for situations in which the NSSFC forecaster feels significant, life-threatening tornadoes are a distinct possibility.

Tornado Watch 914 captured all the killer tornadoes in Mississippi, including the one that killed 10 in Brandon. Tornado Watch 916 was issued over 5 hours before the tornado that killed one in Dahlonega, Georgia. The watch lead time is defined as the period between the watch issuance and the occurrence of the event. The lead time of the tornadoes in watch 914 ranged from 1 hour and 5 minutes to 5 hours and 58 minutes. The average watch lead time of all killer tornadoes was 3 hours and 53 minutes during this outbreak, an extraordinary time. A summary of the killer tornado events and watch lead time is given in Table 3.

Table 4 shows the watch lead time for the first tornado in the watches, the last tornado in the watches, and average lead time for all tornado events in the watches. All watches issued during this outbreak were tornado watches.

Texas

Excellent service was provided by NSSFC and the local offices well in advance of the event. NSSFC had placed much of southeast Texas in a moderate risk of severe weather in a Public Severe Weather Outlook (PWO) issued at 6:19 a.m. on the 21st. As the situation began to develop, Tornado Watch No. 912 was issued shortly after noon. WSO Houston also monitored the meteorological situation effectively prior to the onset of tornadoes. Using the morning atmospheric sounding data, forecasters anticipated that tornadoes may occur during the afternoon. A Special Weather Statement (SPS) was issued at 10:13 a.m. highlighting the threat of severe weather and was updated twice before Tornado Watch No. 912 was issued. Chapter 4 includes a detailed description of the use of the WSR-88D by the WSO Houston staff in the warning process.

The first tornado warning issued by WSO Houston was based on a spotter report. All subsequent warnings were based on WSR-88D radar data interpretation and confirmed by spotter reports.

Table 3. Killer tornado events of Nov. 21-23, 1992.

Date/Time	Location	Deaths	Watch	Issued	Lead Time
21/1137pm	Brandon MS	10	914*	825pm	3 hr 12 min
22/1227am	Carthage MS	1	914*	825pm	4 hr 2 min
22/0125am	Weir MS	1	914*	825pm	5 hr
22/0214am	Clarkson MS	2	914*	825pm	5 hr 49 min
22/0215am	De Kalb MS	1	914*	825pm	5 hr 50 min
22/0350am	Van Buren TN	1	None		
22/0110pm	Dahlonega GA	1	916*	629am	5 hr 41 min
22/0445pm	Eatonton GA	4	918	122pm	3 hr 23 min
22/0452pm	Worthville KY	1	920	232pm	2 hr 20 min
22/0507pm	White Plains GA	1	918	122pm	3 hr 45 min
22/0654pm	Saluda City SC	1	918	122pm	5 hr 32 min
23/0220am	Hillsborough NC	2	925	1219am	2 hr 1 min

*Watches using the enhanced wording..."THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES."

Table 4. Lead times by watch number.

Watch	First Event	Last Event	Average
912	1 hr 6 min	5 hr 36 min	2 hr 55 min
913	3 hr 30 min	6 hr 36 min	5 hr 29 min
914	1 hr 5 min	5 hr 58 min	3 hr 40 min
915	1 hr 2 min	7 hr 09 min	4 hr 16 min
916	2 hr 21 min	5 hr 41 min	3 hr 28 min
917	3 hr 28 min	4 hr 17 min	3 hr 59 min
918	52 min	6 hr 10 min	4 hr 6 min
919	1 hr 3 min	1 hr 38 min	1 hr 16 min
920	34 min	3 hr 25 min	2 hr 5 min
921	48 min	2 hr 3 min	1 hr 12 min
922	1 hr 35 min	4 hr 36 min	3 hr 11 min
923	no reported events		
924	47 min	47 min	47 min
925	46 min	4 hr 42 min	2 hr 40 min
926	no reported events		
927	23 min	2 hr 3 min	1 hr 17 min

In Harris County, a tornado warning saturated the area for almost 3 hours. The first warning was issued at 2:20 p.m. with expiration at 3:15 p.m. At 3:11 p.m., the warning was extended until 4:15 p.m. The warning extension's wording left no doubt regarding the dangerous situation: "...Numerous tornadic thunderstorms were moving rapidly northeast out of Fort Bend County..." The final extension occurred at 4:12 p.m. for eastern Harris County and lasted until 5:00 p.m.

Six separate tornadoes affected Harris County, and each was within the valid warning period. The first tornado started in northwest Fort Bend County and crossed into Harris County near Katy at 2:28 p.m. This was 8 minutes after the initial warning. The next tornado moved in from Brazoria County and crossed into Harris County at 3:12 p.m. Lead time was 52 minutes based on the initial warning. The most destructive tornado touched down near Channelview, in the eastern suburbs of Houston at 3:27 p.m. Lead time for the storm was 16 minutes, based on the warning extension (3:11 p.m.) and a Severe Weather Statement that mentioned, "Tornado on the ground near Almeada-Genoa Road and I-45...moving northeast at 25-30 miles per hour...", the distance being approximately 15 miles from Channelview. At approximately the same time (3:20 p.m.), two other tornadoes touched down, one on the northeast shore of Lake Houston, the second in the immediate downtown Houston area. Lead time on these storms, taken from the 3:11 extension, was 9 minutes. The last Harris County tornado touched down in the extreme eastern edge of the county at 4:15 p.m., 3 minutes after the final extension (4:12 p.m.).

Timely warnings were also issued for the surrounding counties. The lead time for the Fort Bend County storm was 20 minutes. The original warning, issued for neighboring Wharton County, was based on WSR-88D radar data interpretation. The two tornadoes that began near Houston in eastern Harris County continued eastward into Liberty County. One tornado, which earlier had produced widespread damage in Channelview, entered Liberty County near Dayton around 3:49 p.m., and swept across 10 miles of rural area. The second tornado, which originated on the northeast shore of Lake Houston, crossed into Liberty County near Cleveland and traveled 28 miles northeast before ending near Romayor. The history of the Fort Bend County and Harris County storms facilitated warning issuance for Liberty County. Lead time for the Dayton storm was 31 minutes, while lead time on the Cleveland/Romayor storm ranged from 9 minutes near Cleveland to 57 minutes near Romayor.

Mississippi

Forecasts and guidance highlighted the severe weather threat. NSSFC made Mississippi the focus for extremely dangerous thunderstorm activity, with the potential for damaging tornadoes, for the overnight period. The Severe Weather Outlook from NSSFC issued at 1:00 p.m. November 21 placed central and southern Mississippi in a moderate risk of severe thunderstorms. At 8:25 p.m., Tornado Watch No. 914 was issued for all but extreme northern Mississippi.

The watch included the seldom used wording "...THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES..." to highlight the life-threatening significance of the event.

Forecasters at WSFO Jackson were well prepared long before the event began. Public forecasts issued early on November 21 used the wording "...some may be severe..." in the "TONIGHT" section of all forecasts. SPSs issued during the daytime hours highlighted the coming severe weather threat.

When the tornado that killed 10 in Rankin County first touched down in Copiah County at 11:27 p.m., a Tornado Warning had been in effect for 31 minutes. However, the storm seemed to be weakening as it entered Rankin County and into the Jackson WSR-57 radar's ground clutter. Also, no ground-truth reports were received from spotters, the public, police, or HAMs. Therefore, the focus shifted from the central Mississippi storm to an intensifying supercell in southeast Mississippi. The combination of these factors resulted in no warning being issued for Rankin County (see Chapter 4, "Radar Analysis," for a thorough discussion of the factors in the warning decisions).

As spotter reports of damage to Brandon in Rankin County trickled in shortly after midnight, a Severe Thunderstorm Warning was issued for northern Rankin County. When the tornado crossed into Scott County, the severe thunderstorm warning had been in effect 7 minutes. Shortly after the parent thunderstorm exited the Jackson radar's ground clutter, a hook echo (suggestive of a low-level mesocyclone) was indicated. At this time, 12:24 a.m., a Tornado Warning was issued for Leake County. Lead times for this warning ranged from 3 minutes near Ludlow, to 32 minutes north of Barnes. As the storm continued tracking northeast, another Tornado Warning was issued, based on radar, for southern Attala County, at 12:58 a.m. Lead times ranged from near zero when the tornado entered the county, to 27 minutes at McCool. The Tornado Warning for Attala County was allowed to expire because the storm appeared to be weakening on the Jackson radar; therefore, warnings were not in effect for Choctaw County, where the tornado finally dissipated.

The same storm cell spawned weaker tornadoes farther north, in Webster and Chickasaw Counties. Although these storms were less potent (F0 and F1) and short-lived, two people were killed when one tornado destroyed a small wood frame home in extreme northeast Webster County at 2:14 a.m. Warnings were not in effect for any events in Webster or Chickasaw Counties (see Chapter 4 for a discussion of factors in the warning decision process).

While one supercell was causing death and destruction near Brandon, another was intensifying in southeast Mississippi. This storm spawned two impressive tornadoes that varied from strong (F3) to violent (F4). Tornado Warnings were in effect for all counties affected by this storm. Radar, satellite, and a favorable atmospheric environment indicated that the supercell would maintain strength as it moved northeast. The initial warnings were issued, based on radar observations

of the intensifying supercell, for Pike and Walthall Counties around 10:30 p.m. At 11:13 p.m., a tornado warning was issued for Jefferson Davis County. Ten minutes later, touchdown occurred near Carson. Based on radar observations and storm history, Tornado Warnings were issued in succession, for each county, during the remainder of the storm. The warning for Covington County verified with lead times ranging from near zero to 20 minutes; warnings for Smith County verified with a maximum lead time of 29 minutes. The storm then crossed into WSO Meridian's CWA. WSO Meridian issued radar-based warnings for Jasper and Newton Counties. Lead times in Jasper County ranged from 13 minutes near Ted to 32 minutes northwest of Baxter. In Newton County, lead times ranged from 20 to 31 minutes.

Remnants of this supercell later spawned a strong (F2) tornado at 2:15 a.m. which began in central Kemper County and moved into Noxubee County. One person was killed and another injured in Kemper County. A Tornado Warning had been in effect since 1:35 a.m., at least 40 minutes prior to the tornado strike near DeKalb in Kemper County; no warning was in effect for Noxubee County.

Georgia

Severe storms, producing widespread microburst and tornado activity, moved across large portions of Georgia between 7:00 a.m. - 7:00 p.m. on Sunday, November 22.

The Georgia State and Zone Forecasts at 5:00 a.m. on Sunday indicated the possibility of severe thunderstorms. At 5:00 a.m., NSSFC issued a PWO which headlined..SEVERE THUNDERSTORMS EXPECTED TODAY AND TONIGHT OVER MUCH OF THE SOUTHEASTERN UNITED STATES.. The PWO was retransmitted by WSFO Atlanta around 5:15 a.m. as a SPS. The WSFO Atlanta statement indicated that tornado watches would likely be issued for portions of Georgia during the day, and urged residents to review safety rules, and monitor radio, television, and NOAA Weather Radio (NWR) closely. An updated SPS issued by the WSFO at 8:00 a.m. indicated tornado watch No. 916 had been issued for a large part of western and northern Georgia, effective from 7:30 a.m. until 2:00 p.m. The NSSFC issued another PWO at 9:48 a.m., reemphasizing the severe weather threat over the lower Ohio Valley and the southeastern United States.

Given this high level of alert, the Atlanta WSFO and surrounding WSOs were well-prepared to handle the onslaught of severe weather. In all, 41 severe thunderstorm and tornado warnings were issued for the state, of which 15 verified. The most potent storms occurred within three offices' areas of responsibility: WSFO Atlanta, and WSOs Macon and Athens.

The most destructive tornado in WSFO Atlanta's area of responsibility developed shortly before noon near Powder Springs in the northwestern suburbs of Atlanta, in central Cobb County. The storm then raced northeastward into southern Cherokee County before dissipating shortly after 12:30 p.m. Based on damage

surveys, the storm was rated F4 as it passed through both counties. Accurate and timely warnings resulted in no deaths, but 46 persons were injured (34 in Cobb County) by the storm. Both counties were covered by appropriate warnings. A Tornado Warning, based on sheriff reports from neighboring Douglas County, had been in effect for Cobb County since 11:44 a.m. Lead times in Cobb County ranged from near zero near Powder Springs to 30 minutes in Kennesaw, where the majority of property damage occurred. Based on the radar indications and the storm history, a Tornado Warning was issued for neighboring Cherokee County at 12:14 p.m. Lead times ranged from 3 minutes at Woodstock to 24 minutes near Hickory Flats.

An offspring of the tornado family that devastated Cobb and Cherokee Counties affected the northwest portion of WSO Athens' area of responsibility. An F3 tornado developed at 1:10 p.m. north of Dahlonega in central Lumpkin County and moved northeast 10 miles, virtually destroying a resort ranch before dissipating around 1:25 p.m. One person was killed and seven injured at the ranch. A Severe Thunderstorm Warning had been in effect since 12:44 p.m., at least 26 minutes prior to the tornado strike at the ranch.

Georgia's deadliest and costliest tornado began at 4:45 p.m. near the Putnam/Jones county line, and continued northeastward through Putnam County and into Greene County before dissipating. Five people were killed and 86 others injured along the F4-rated storm's 32-mile path. Appropriate warnings were in effect well in advance of the storm. The local warning radar at WSO Macon clearly indicated a hook echo over Jones County at approximately 4:03 p.m. A Tornado Warning was issued for Putnam County at 4:16 p.m. based on the radar signature and spotter reports of funnel clouds. A warning lead time of 29 minutes was realized at Eatonton. Shortly thereafter, the Macon radar was becoming inoperative. WSO Macon alerted WSFO Atlanta about the possible radar failure. Atlanta then relayed this information to WSO Athens (which has responsibility for Greene County) to assist in backup radar coverage for WSO Macon. Atlanta also advised Athens about the tornadic storm in Putnam County. Since the network radar at WSO Athens did not indicate a tornado, a Severe Thunderstorm Warning was issued for Greene County. A lead time of 59 minutes occurred at White Plains in southeast Greene County.

Kentucky

An area of severe weather developed rapidly in the western Ohio Valley during the early afternoon on Sunday, November 22. The threat of severe weather was indicated well in advance; the region was under a moderate risk outlook for severe weather, outlined by NSSFC, as early as 10:00 a.m. Tornado Watches Nos. 920 and 921 were in effect when the most dangerous storms struck.

Four tornadoes touched down in Kentucky between 4:20 p.m. and 5:25 p.m. Three were weak storms (F0 or F1) and caused minor damage but no injuries. The other was a killer tornado which developed in southern Carroll County west of

Worthville and moved northeast crossing the Ohio River east of Ghent. For a 2-mile stretch near Easterday, Kentucky, F4 damage was noted, and it was in this area that an elderly woman was killed, nine other persons were injured, and numerous residences were destroyed.

Initial warnings for the parent thunderstorm associated with the above killer tornado were issued by WSFO Louisville when the storm first developed in western Henry County. An F0 intensity tornado was reported in extreme northern Henry County at 4:40 p.m., 30 minutes after a Severe Thunderstorm Warning was issued. WSO Cincinnati, which had warning responsibility for Carroll County, issued a Tornado Warning at 4:47 p.m. Lead times ranged from 5 minutes in southwestern Carroll County to 18 minutes near Ghent. Lead time was estimated to be 11 minutes near Easterday. The killer tornado crossed the Ohio River into Switzerland County in extreme southeastern Indiana at 5:05 p.m. After traversing nearly 10 miles, the storm crossed back into Kentucky, not far from the Cincinnati/Covington airport. A Tornado Warning was issued at 4:59 p.m. by WSO Cincinnati, giving a lead time of 6 minutes.

North Carolina

Severe weather swept northeast up the southern Atlantic coast during the late evening of November 22 through the early morning of November 23. NSSFC continued disseminating excellent guidance to affected NWS offices and the public. Tornado Watches Nos. 922, 924, 925, 926, and 927 covered nearly all events that occurred between 6:00 p.m. November 22 and 7:00 a.m. November 23. Furthermore, WSFOs Raleigh/Durham, North Carolina, and Columbia, South Carolina issued several statements early on Sunday, November 22, emphasizing the severe weather threat. For example, WSFO Raleigh indicated the potential for severe thunderstorms for later Sunday and Sunday night in their early morning zone package issued at 3:50 a.m. Sunday morning. Also, a Special Weather Statement emphasizing a potentially dangerous weather situation and the threat of "strong damaging tornadoes" was issued at 6:20 a.m. Sunday morning.

Five tornadoes struck North Carolina between 10:15 p.m., November 22 and 7:25 a.m., November 23. The storms killed two persons and injured 74 others. Most of the tornadoes tracked northeast through the western Piedmont before midnight on the 22nd; however, the last tornado began shortly after 4:00 a.m. and traveled 160 miles east-northeast, from the Sandhills region to just north of the Albemarle Sound before lifting. Warning services were provided by WSOs Greensboro and Charlotte during the pre-midnight hours. WSFO Raleigh provided warning service for the 2:20 a.m. killer tornado in Orange County, as well as for much of the last, pre-dawn tornado.

The one killer tornado occurred in the extreme northwest portion of WSFO Raleigh's CWA, in Orange County, at 2:20 a.m. Although it lasted for only 10 minutes and traveled only 5.5 miles, this strong (F3) storm ravaged a subdivision in Hillsborough, about 15 miles west of Durham. Two persons died, and 10 more

were injured. A Severe Thunderstorm Warning had been in effect 17 minutes prior to tornado touchdown. The cell that produced this short-lived but powerful tornado had no history of severe weather and never demonstrated any radar signatures indicative of a tornado. The decision to issue the Severe Thunderstorm Warning was based on a vigorous analysis of storm structure. The warning clearly indicated the storm would move across Hillsborough by 2:30 a.m., strongly conveyed the fact that a tornado could develop without warning, and included a strong call-to-action statement.

This outbreak delivered its final blow in the form of a North Carolina-record, 160 mile-long tornado. The tornado, which varied in intensity, injured 49 people. The continuous path affected nine counties, including six in WSFO Raleigh/Durham's CWA. Nearly half (22) of the injuries occurred at the onset, in Harnett and Johnston Counties, where the tornado reached F3 intensity. News footage, however, focused on the Elizabeth City (Pasquotank County) area, where a school bus was hurled 75 yards, injuring 21 people. Shortly thereafter, the tornado dissipated while crossing the Pasquotank River.

No warnings were in effect when the tornado first began in Harnett County; however, a string of Tornado Warnings was issued for each affected county thereafter. The first warning was posted for Johnson County at 4:34 a.m. When the tornado reached Wilson's Mills in central Johnston County, the warning had been in effect for 6 minutes. The warnings continued (all lead times estimated from selected locations): at 4:46 a.m. for Wilson County (lead time near Wilson: 19 minutes); at 5:20 a.m. for Edgecombe County (lead time: 5 minutes); at 5:36 a.m. for Martin County (lead time: 4 minutes); and at 5:56 a.m. for Bertie County (lead time at Windsor: 29 minutes). At this point, WSO Cape Hatteras took over, issuing tornado warnings for Chowan, Perquimans, and Pasquotank Counties, all effective at 6:48 a.m. The warning had been in effect approximately 36 minutes when Elizabeth City was struck.

FINDINGS AND RECOMMENDATIONS

Finding 3.1: The NSSFC provided excellent guidance and watch products to WSFOs, WSOs and the public throughout the outbreak. NSSFC correctly identified the threat of tornadoes and severe storms more than 24 hours in advance of the episode. NSSFC also accurately forecast relatively rare, late-season tornadoes in the Ohio Valley. Field forecasters interviewed by the DST believed NSSFC's watches and guidance products were vital to their ability to anticipate the magnitude of the event and to issue timely forecasts, statements, and warnings.

Finding 3.2: The performance of WSO Houston was exemplary. Several tornadoes struck in the Houston metropolitan area, producing the vast majority of the damage in Texas. Despite the numbers and strength of the storms there were no fatalities.

Finding 3.3: The single greatest number of deaths associated with one tornado was 12 in Mississippi. Ten of these deaths were in Rankin County, which is in WSFO Jackson's CWA. When the tornado that killed 10 in Rankin County first touched down in Copiah County a Tornado Warning for Copiah County had been in effect. However, no Tornado Warning was in effect in Simpson County or Rankin County as the storm moved from Copiah County through those counties.

Finding 3.4: One of the factors in the decision not to issue a warning for Rankin County, Mississippi, where 10 people were killed, was that no ground truth reports were received from spotters, the public, police, or HAMs. Ground truth severe weather reports are often critical in the NWS warning process.

Recommendation 3.4: The NWS should continue to help establish and train new spotter groups plus provide refresher training to the existing spotter networks. The emphasis for continued feedback of severe weather information from spotter networks, Emergency Management Agency officials, and law enforcement personnel must be continued and strengthened.

CHAPTER 4

RADAR EVALUATION

NWS forecasters rely on radar and ground truth reports (from spotters, law enforcement officials, the public, etc.) to evaluate the potential for thunderstorms to produce tornadoes and other forms of severe weather. The widespread nature of the November 21-23, 1992, outbreak resulted in the use of nearly every variation of weather radar currently in use in the NWS.

The new WSR-88D, 10-cm wavelength radar proved invaluable to forecasters at WSO Houston as they issued warnings for rapidly moving tornadic thunderstorms in the Houston metropolitan area. The WSR-88D's narrow 0.95 degree, half-power beam width and volumetric scanning technique allowed forecasters to examine the three-dimensional structure of storms in more detail than was available from the 2-degree beam width WSR-57 at nearby WSO Galveston. Radial velocity data (a measure of speed and direction of movement of raindrops and other particles), which are not available from conventional radars, allowed forecasters to identify mesocyclone signatures when conventional reflectivity signatures were absent or ambiguous. The WSR-88D also provided many other products and enhancements not available from conventional NWS WSR-74C and WSR-57 radars.

Elsewhere, the NWS radar network is primarily composed of WSR-57 10-cm wavelength radars installed in the 1960s. The WSR-57 has a half-power beam width of 2.0 degrees and provides only reflectivity information. This evaluation includes information obtained from WSR-57s at Jackson, Mississippi; Athens, Georgia; Cincinnati, Ohio; Volens, Virginia; and Wilmington, North Carolina.

The NWS also employs an array of Local Warning Radars across the country. These WSR-74C, 5-cm radars have a half-power beam width of 1.6 degrees and provide only reflectivity data. This evaluation includes information from WSR-74Cs at Meridian, Mississippi; Atlanta, Georgia; and Raleigh, North Carolina.

Radar camera film and Plan Position Indicator (PPI) overlay tracings were not available in all instances, and portions of this evaluation were based upon information received from WSI NOWrad radar imagery. NOWrad is a composite radar product derived from the NWS network of conventional radars.

In order to simplify this evaluation of radar applications, each NWS location surveyed is examined separately.

Texas

Supercell thunderstorms that developed about 30 miles ahead of the frontal squall line spawned 12 tornadoes across the Houston area the afternoon of November 21, 1992, between 1:30 pm and 4:30 p.m. Despite the high population density and the

strength of the tornadoes (up to F4), no fatalities resulted and injuries were limited to less than 40. In the opinion of the DST, effective warnings based largely upon interpretation of the WSR-88D radar helped to minimize injuries in the Houston area.

The Houston WSO staff realized the potential for danger hours before the tornadoes occurred. The volume of data available from the WSR-88D required dedication of one meteorologist to the interpretation of the radar data. At times, the meteorologist was assisted by another staff member.

Radial velocity data available from the WSR-88D proved essential for the detection of mesocyclones and their potential to produce tornadoes. Reflectivity data (all that is available from conventional radars) alone would in many cases not have been enough to issue effective warnings. Tornado Warnings issued by the Houston WSO were more timely and accurate as a result of effective interpretation of the WSR-88D.

The WSR-88D Storm Relative Map (SRM) product proved to be the most effective tool in identifying tornadoes. The SRM is a display of mean radial velocities with storm motion subtracted and is especially useful when storms are moving rapidly, as was the case in this episode. SRM velocity couplets (regions of adjacent inbound and outbound velocities indicating rotation) with gate-to-gate rotational velocities greater than 50 knots appeared with most of the tornadoes. SRM data often identified mesocyclonic rotation prior to the appearance of the characteristic "hook echo" in reflectivity fields. The mesocyclones associated with most of the larger tornadoes exhibited SRM velocity couplets more than 18 minutes (3 volume scans) prior to tornado touchdown. The data showed no couplet with the first tornado of the episode, a small, short tornado (F1) track near Wharton. A few other tornadoes also occurred when velocity couplets were present less than 12 minutes before touchdown.

The primary WSR-88D products and displays used were the SRM and a time-lapse animation of base reflectivity. The SRM was especially effective when viewed as a "four-panel" display of the four lowest elevation angle scans. By viewing multiple elevation angles at the Principal User Processor (PUP), the radar interpreter was able to quantitatively assess three-dimensional storm structure and mesocyclone rotational velocities. A corresponding "four-panel" reflectivity was often used to supplement the velocity data and provide additional insight into storm intensity and structure. The PUP time lapse feature provided valuable information regarding movement of the storms and their temporal evolution.

A detailed examination using Houston WSR-88D data (Figs. 24 through 30) of three storms that hit Houston and caused the majority of the damage follows. This examination uses many of the products and techniques employed by the Houston staff. It is an examination of a small part of the total episode, however.

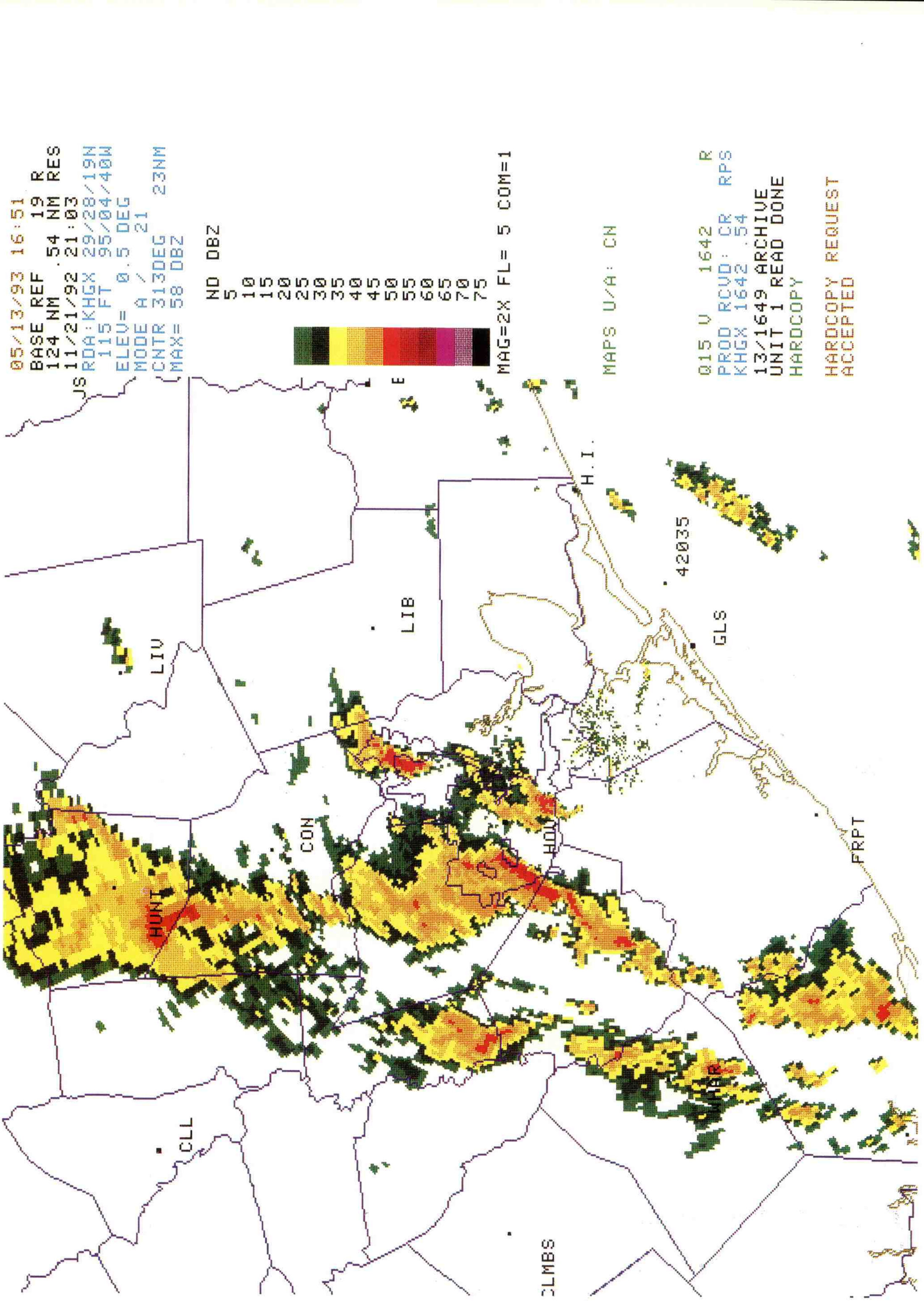


Figure 24. The 3:03 p.m., 124nm Base Reflectivity from the Houston WSR-88D.

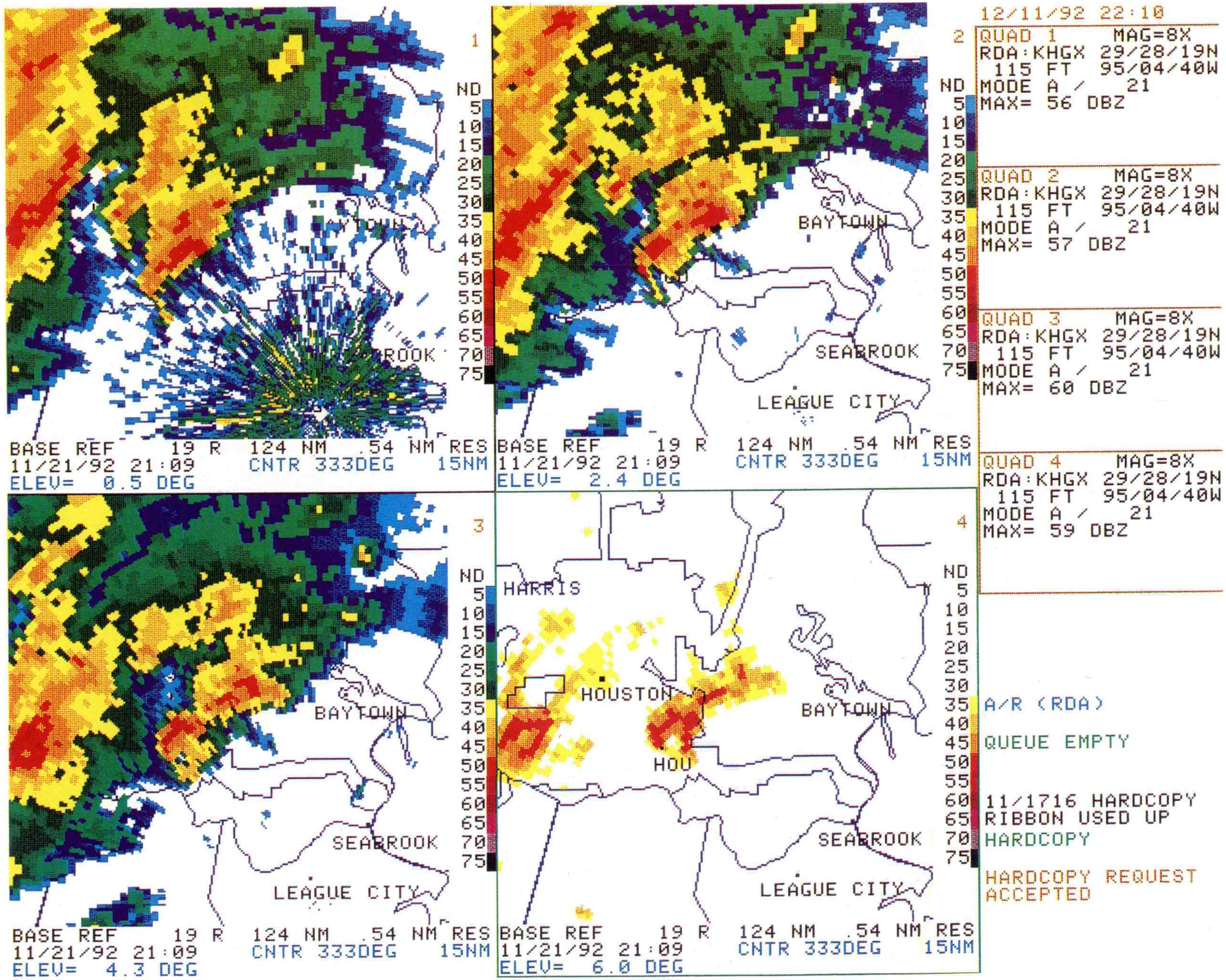


Figure 25. The 3:09 p.m., four panel, magnified eight times, Base Reflectivity from the Houston WSR-88D.

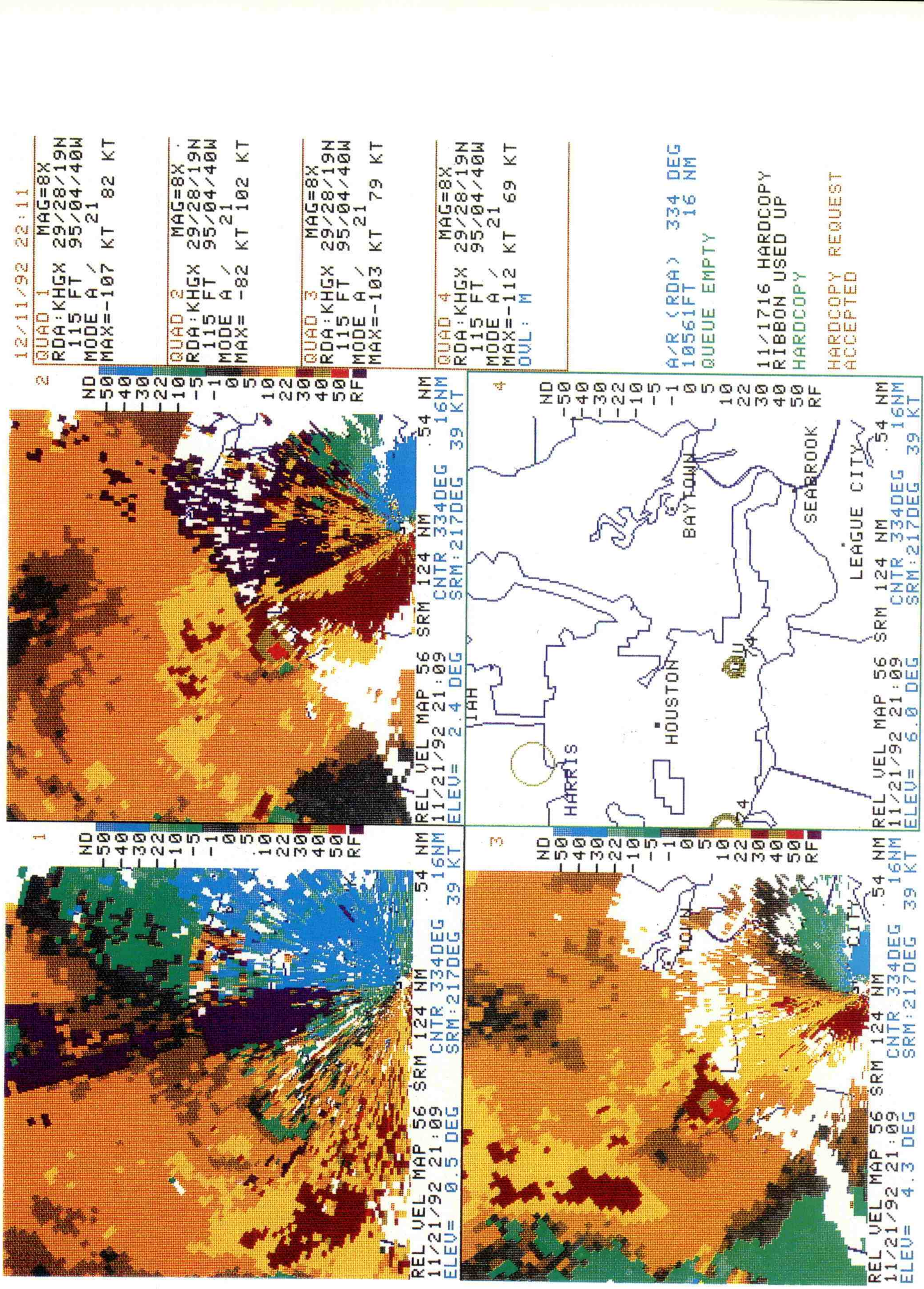


Figure 26. The 3:09 p.m., four panel, magnified eight times, Storm Relative Velocity from the Houston WSR-88D.

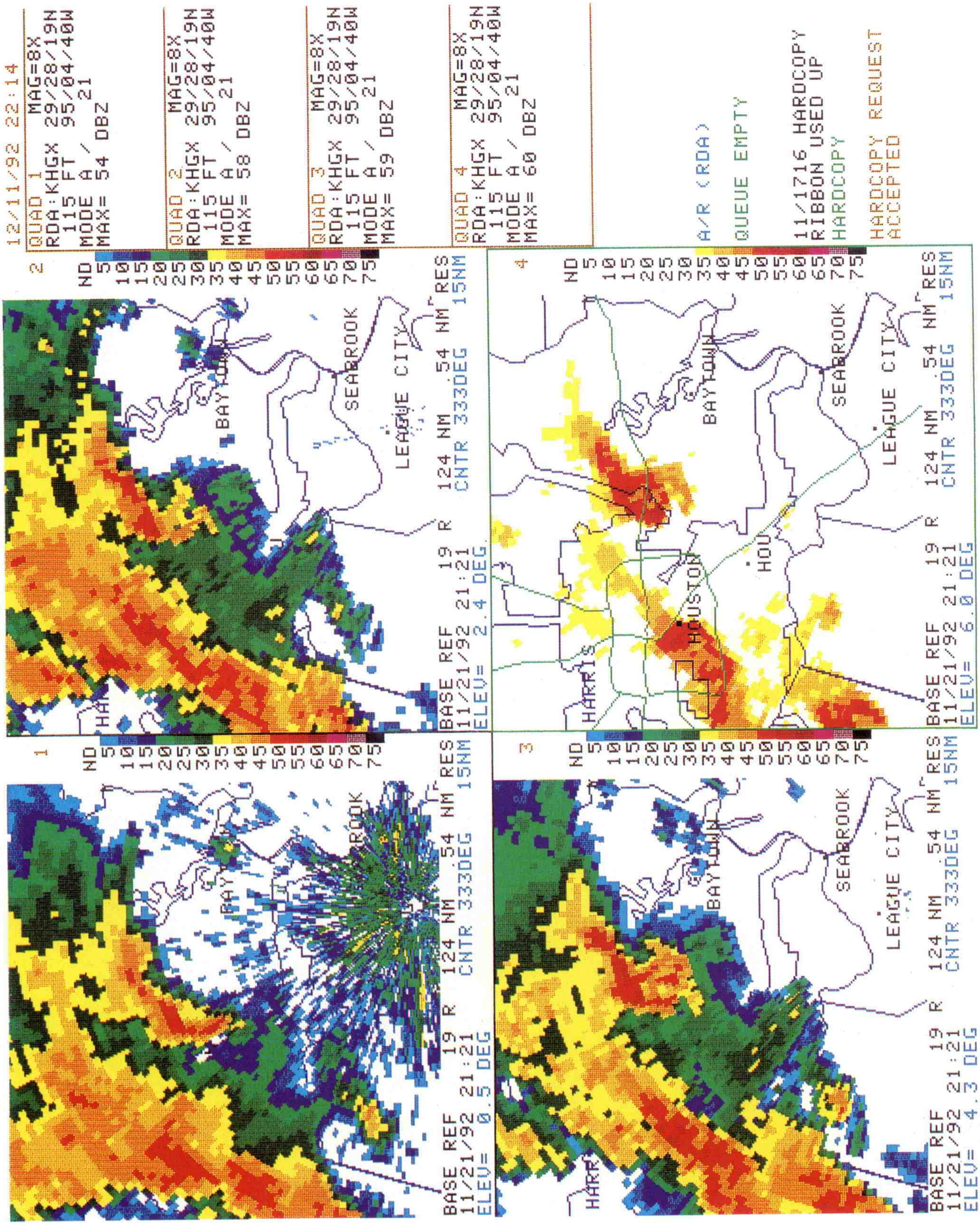


Figure 27. The 3:21 p.m., four panel, magnified eight times, Base Reflectivity from the Houston WSR-88D.

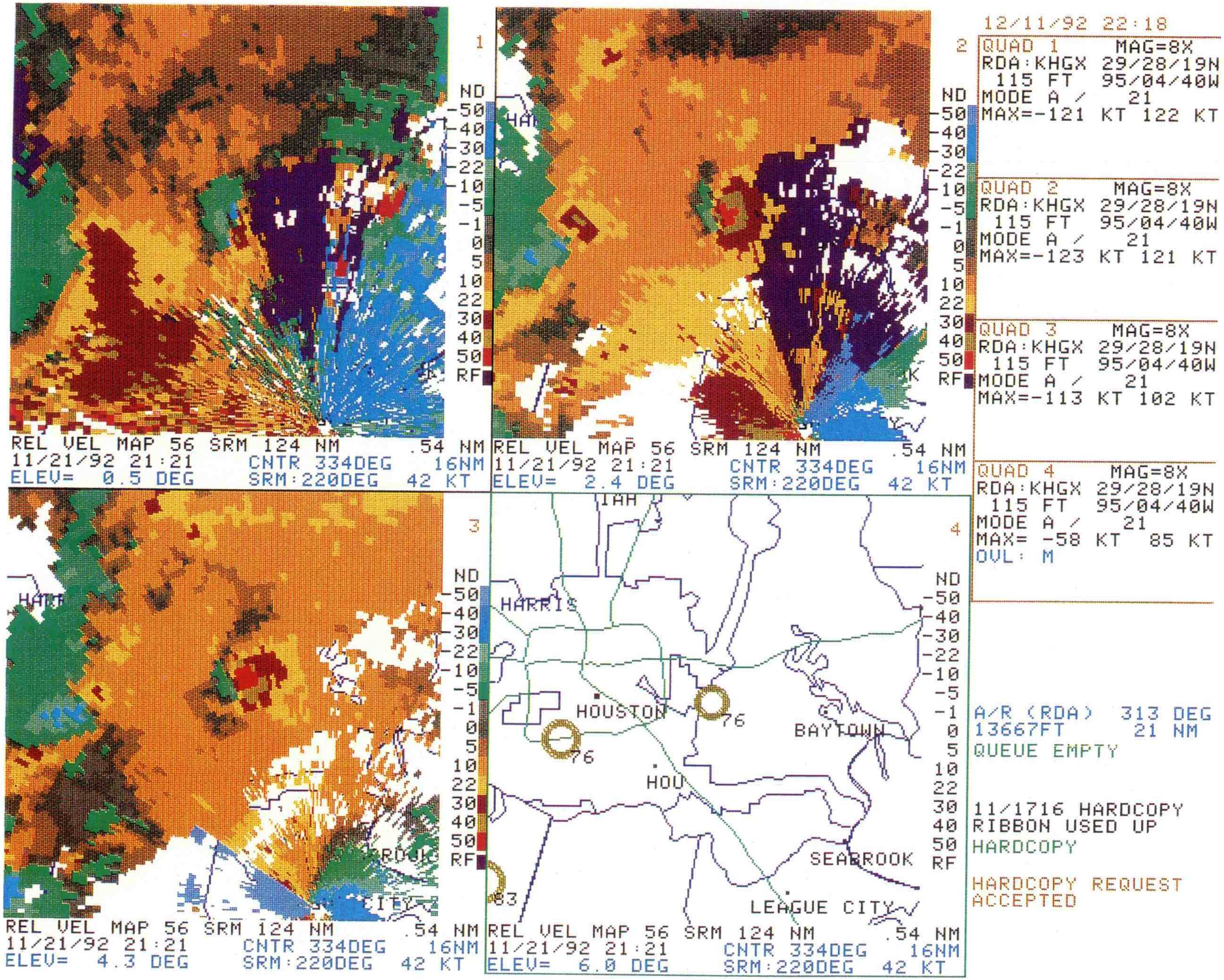


Figure 28. The 3:21 p.m., four panel, magnified eight times, Storm Relative Velocity from the Houston WSR-88D.

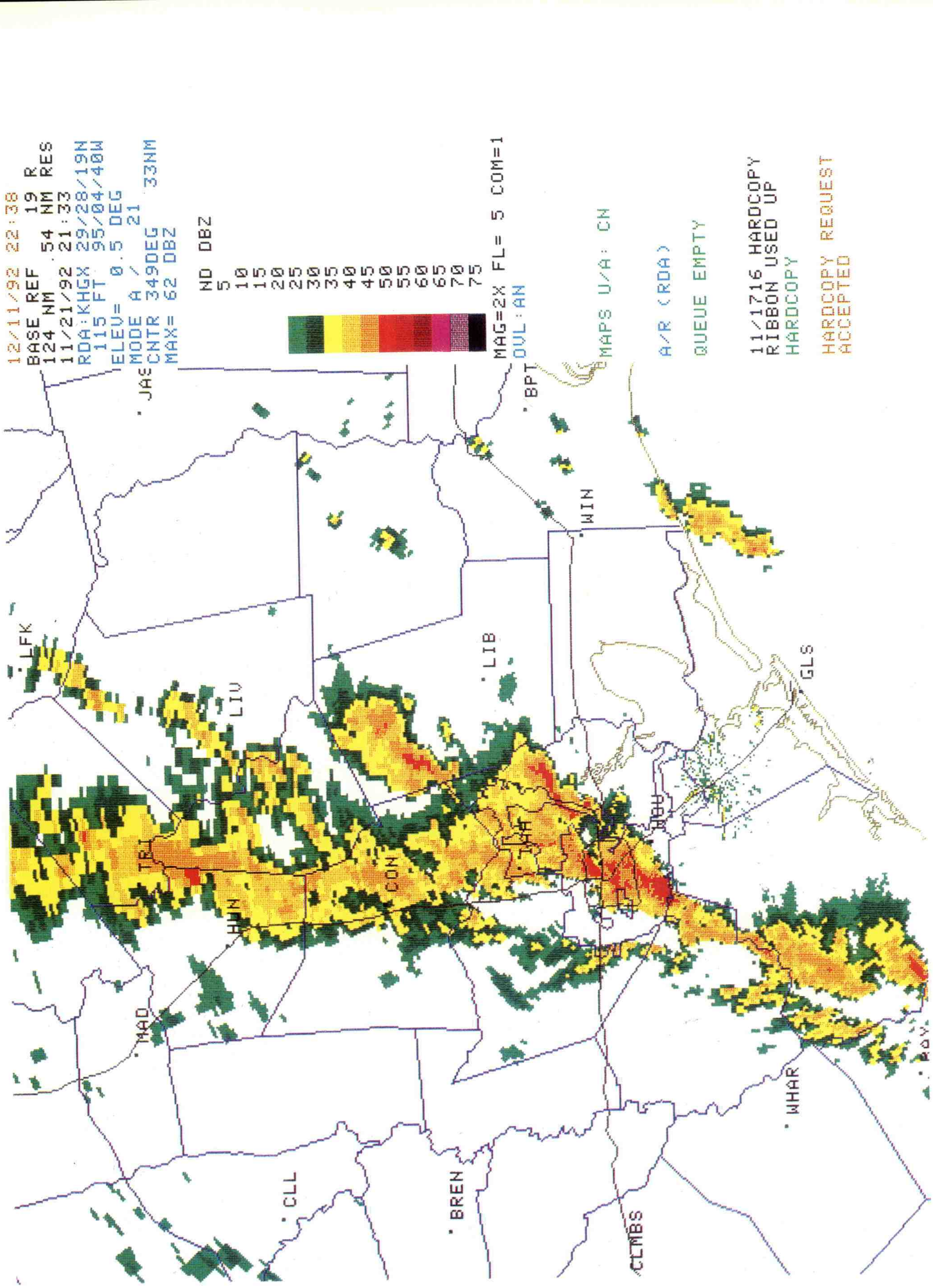


Figure 29. The 3:33 p.m. Base Reflectivity from the Houston WSR-88D.

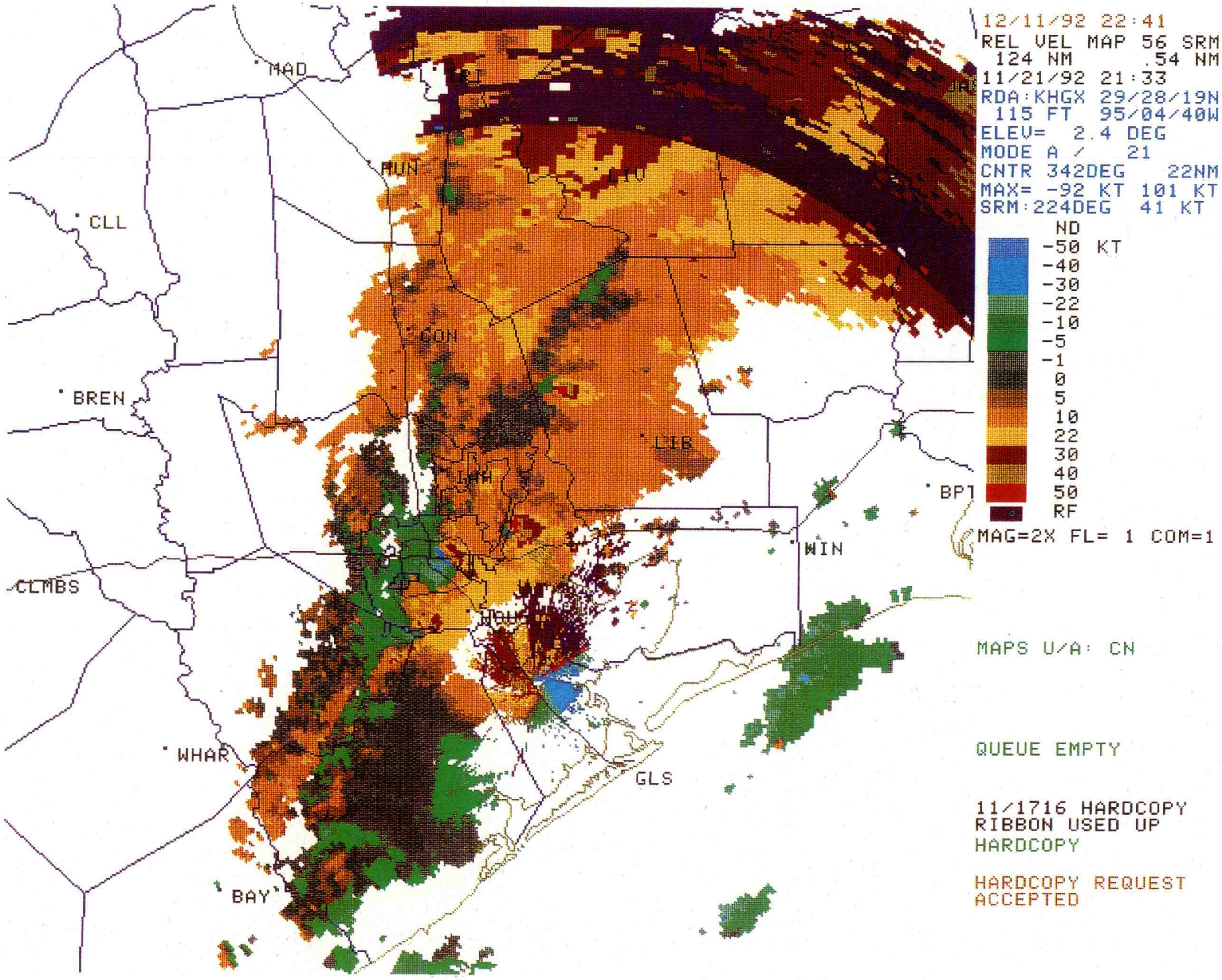


Figure 30. The 3:33 p.m. Storm Relative Velocity from Houston WSR-88D.

Fig. 24, the 3:03 p.m., 124nm Base Reflectivity, shows the general areas of storms in the Houston area. The F4 Channelview Tornado struck at 3:27 p.m., and the F2 Downtown Tornado touched down at 3:20 p.m.

The 3:09 p.m., four-panel, magnified eight times, Base Reflectivity is shown in Fig. 25. At 0.5 degree (upper left), the subtle hook echo just south of Houston (HOU in this Fig.) (compare to 6.0 degree display) suggests the presence of a low-level mesocyclone. A Bounded Weak Echo Region (BWER), indicating the presence of an intense updraft and possibly a mesocyclone, was indicated by lower reflectivity (green) inside higher levels (yellow) at 4.3 degrees. Even using conventional reflectivity interpretation techniques, the WSR-88D with its greater resolution and convenient display features proved a more effective warning tool than conventional radars.

Fig. 26 presents the 3:09 p.m., four-panel, magnified eight times, Storm Relative Velocity. A velocity couplet often identifies a mesocyclone (small scale rotation within a thunderstorm) and a point where tornadoes frequently form. Corresponding velocity couplets at more than one elevation scan indicate an organized circulation, and a greater chance for tornadic development. No organized couplet was indicated at 0.5 degrees elevation, but a velocity couplet (note the region of red next to the green, with red indicating particles moving away from the radar at 50+ kts and green showing particles moving toward the radar at about 30 kts) was apparent almost directly over HOU at 2.4 and 4.3 degrees. Note also the circle over Houston where the WSR-88D algorithm has identified a likely location of a mesocyclone. This mesocyclone was associated with the F4 Channelview Tornado some 18 minutes later. Note also the velocity couplet on the left edge of the 2.4 degree display. This mesocyclone spawned the Downtown Tornado 11 minutes later.

The Channelview Storm north of Houston (Fig. 27, the 3:21 p.m., four-panel, magnified eight times, Base Reflectivity) exhibited a pronounced hook shape in the reflectivity field at low-levels, and a high reflectivity extension (overhang) on the southeast (inflow) side at higher elevation angles. A BWER is also noted in the small green dot (lower reflectivity) inside the yellow at 2.4 degrees, and also in a yellow area inside the red at 4.3 degrees. These radar signatures are indicative of a supercell with a low-level mesocyclone and possibly a tornado. Note also the lack of any similar defining reflectivity feature in the storm southwest of Houston. The Downtown Tornado had just touched down at the time of this display.

The Channelview Storm's velocity couplet is easily identified at all three levels in Fig. 28 (the 3:21 p.m., four-panel, magnified eight times, Storm Relative Velocity). This display preceded touchdown by 6 minutes. The purple area identifies a region where the radar was unable to assign velocity measurements due to range folding.

Another velocity couplet was apparent with the storm immediately southwest of Houston. The couplet was evident at 2.4 and 4.3 degrees, and even at 0.5 but on a

somewhat broader scale. The Downtown Tornado was associated with this signature. Both couplets showed vertical continuity and the algorithm identified likely mesocyclones (ring in lower left display) with both storms.

At 3:33 p.m. (Fig. 29, Base Reflectivity), the Channelview and Downtown Tornadoes were on the ground as was another tornado in Liberty County. Well-defined hook echoes are associated with the Liberty County (west-northwest of LIB) and Channelview (north-northeast of HOU) storms. An inflow notch of lower reflectivity was indicated with the Downtown Tornado, northwest of Houston, but no definite hook.

Velocity couplets were evident even on the unzoomed, full-scale Storm Relative Velocity product at 3:33 p.m. (Fig. 30). Note areas of red (outbound 50+ kts) next to areas of green (30 kts inbound) west-northwest of LIB, north-northeast of Houston, and northwest of Houston. Each of these velocity couplets identified mesocyclones producing tornadoes at the time of the SRM product. Although a weak mesocyclone was also apparent west of Houston, no tornadoes were occurring with this signature.

The WSR-57 Galveston, Texas (GLS) radar detected occasional hook echoes, as well. The Galveston Official-In-Charge (OIC), who was on duty that day, was interviewed. In the opinion of the OIC, warnings issued during the episode would not have been nearly as accurate or timely if they had been issued from the GLS WSR-57 alone. A few hook echoes were noted, but tornadoes were already on the ground in most cases by the time the hooks appeared. The first hook echoes were recorded on the GLS Radar Form (MF7-60) at 3:24 p.m.

A photo of the 3:30 p.m., GLS WSR-57 display (Fig. 31) shows the Liberty County and Channelview hook echoes. They did not appear nearly as distinctly as they did on the Houston WSR-88D.

Mississippi

During the late evening of November 21 and the early morning of November 22 two supercell thunderstorms tracked across southern and eastern Mississippi producing several tornadoes. The westernmost supercell (Cell 1) was responsible for the violent F4 tornado which struck Brandon, Mississippi, shortly before midnight on the evening of the 21st.

The first Severe Thunderstorm Warning of the evening was issued for Amite and Franklin counties at 10:21 p.m. for a thunderstorm crossing into Mississippi from southern Louisiana. Shortly thereafter, at 10:24 p.m. and 10:29 p.m., tornado warnings were issued for a second storm (Cell 2) moving through Pike and Walthall counties, respectively. The WSR-57 radar at Jackson (JAN) provided the basis for both warnings. The warning for Cell 1 was based on the vertical extent of the DVIP 5 core; while the warning for Cell 2 was based upon a hook echo (JAN form MF 7-60) which suggested the presence of a low-level mesocyclone. Both

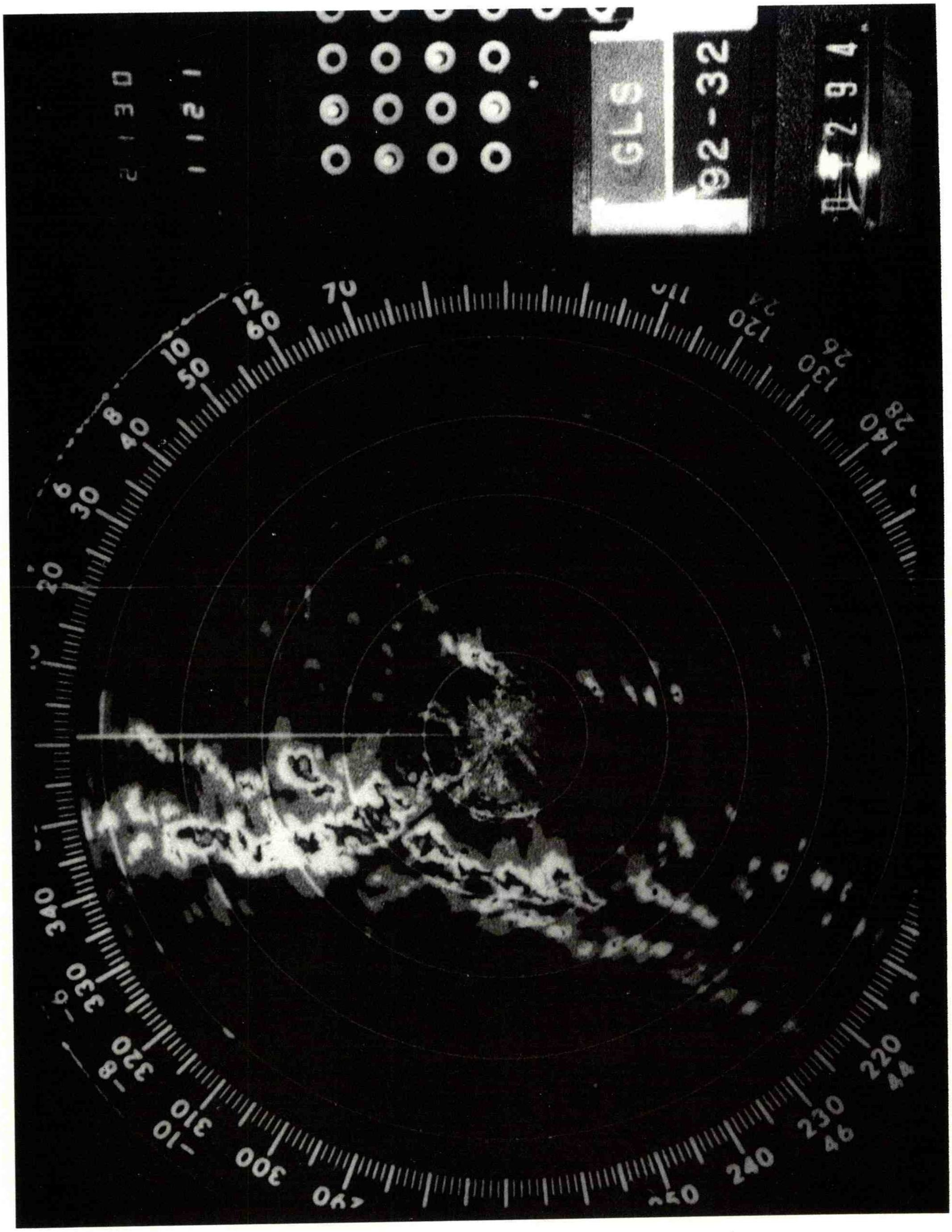


Figure 31. The 3:30 p.m., Galveston, Texas, WSR-57 display.

storms moved along parallel paths from approximately 210 degrees at 40-50 knots over the next few hours.

Reports of a possible tornado were received from Summit in Pike County (Cell 2) at 10:43 p.m. Although no reports of severe weather had been received from Cell 1, a Severe Thunderstorm Warning was issued at 10:49 p.m. for Copiah and Lincoln Counties in advance of the storm based upon information from the Jackson WSR-57. At 10:50 p.m., reports of tree damage and a possible tornado were received from 3 miles west of Brookhaven in Lincoln County (Cell 1). A hook echo (JAN form MF 7-60) and BWER were observed with Cell 1 at 10:50 p.m., and at 10:56 p.m. the warning for Lincoln and Copiah Counties was upgraded to a Tornado Warning. Additional delayed reports of damage were received along the path of Cell 1 between and 11:00 p.m. and 11:30 p.m. A Tornado Warning was extended into Jefferson Davis and Lawrence Counties at 11:13 p.m. for radar signatures associated with Cell 2.

As Cell 1 approached Rankin County at 11:30 p.m., no additional warnings were issued for Cell 1 since the echo top had lowered and reflectivity values on the JAN radar had fallen from DVIP 6 at 11:04 p.m. to DVIP 4 at 11:30 p.m. A coordination call received from WSO Meridian (MEI) at 11:29 p.m. notified Jackson forecasters that Cell 1 was still DVIP 5 through 23,000 feet MSL from the MEI WSR-74C radar. The storm was again examined with elevated scans as it entered the ground clutter pattern of the JAN radar and again reflectivity values were DVIP 4 with no signatures associated with severe storms discernible. A follow-up coordination call from JAN to MEI at 11:35 p.m. indicated that Cell 1 was now DVIP 4 on the MEI radar and attention was focused on Cell 2.

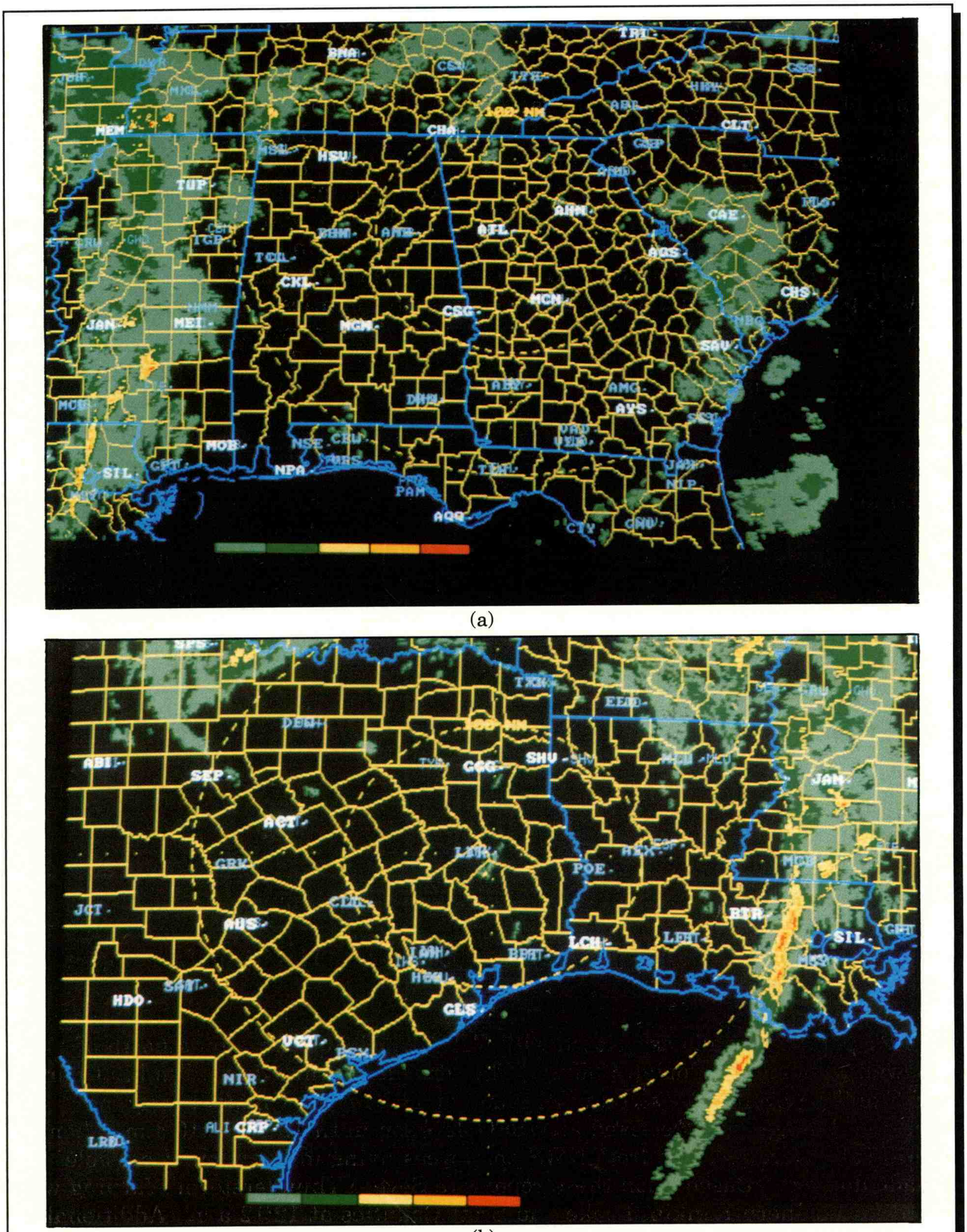
Post-event examination of the JAN WSR-57 radar camera film was difficult since the camera range was set at 250 nm and the film was over-exposed. However, examination of NOWrad data[2] by the DST indicated Cell 1 was DVIP 5 as it entered Rankin County at 11:30 p.m. (Fig. 32a), but that reflectivity values decreased rapidly to DVIP 3 as the storm passed over Brandon (Fig. 32b).

Additional Tornado Warnings were issued for Cell 2 at 11:45 p.m. based upon storm structure on the JAN WSR-57.

At 11:27 p.m., a tornado associated with Cell 1 touched down 1 mile north of Hopewell in northern Copiah County. The tornado continued into Rankin County near Florence, eventually striking Brandon at 11:53 p.m. Unfortunately, no reports of damage were received at WSFO Jackson until 12:00-12:10 a.m. when several calls were received from NWS employees living in Brandon of possible tornado damage. Based upon these reports, a Severe Thunderstorm Warning was issued for northern Rankin, Leake and Scott Counties at 12:12 a.m. Additional reports of injuries were received from Brandon at 12:20 a.m., and a Tornado

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[2]NOWrad data courtesy of Weather Services International.



(a)

(b)

Figure 32. NOWrad composite radar imagery valid at a) 11:30 p.m., and b) 12:00 a.m.

Warning was issued for Leake County (Cell 1) at 12:24 a.m. A special radar observation (JAN form MF 7-60) was taken at 12:35 a.m. for hook echoes with both Cell 1 and Cell 2 suggesting low-level mesocyclones were present with both storms. PPI overlay tracings from the JAN WSR-57 for Cell 1 and Cell 2 are shown in Fig. 33. Well-defined hook echoes are clearly visible with both storms.

A Tornado Warning was issued for southern Attala County at 12:58 a.m. based upon the JAN WSR-57 radar. Reflectivity values for Cell 1 again appeared to decrease slightly as it moved through Attala County, and warnings for the storm were not continued as it tracked into Choctaw and Webster Counties. The PPI overlay tracing at 1:25 a.m. (Fig. 34) indicated a diminished DVIP 5 core with an apparent inflow notch and weak echo region on the southeast flank of Cell 1 as it tracked into Choctaw County. This reflectivity configuration is frequently associated with severe storms and suggests a low-level mesocyclone was present. NOWrad data again confirmed the decreased reflectivity values (as low as DVIP 3) as the storm moved across Choctaw and Webster Counties, but, because the data are composite, meaningful storm-scale structures could not be discerned. Damage reports received from Attala and Choctaw Counties were delayed and were not useful for warning decisions.

Tornado Warnings were issued in advance of Cell 2 as it entered the Meridian CWA based upon the MEI WSR-74C and the storm's previous history. All of these warnings verified with damage. One fatality was associated with Cell 2 in Kemper County before the storm crossed into Alabama.

Paper overlay tracings of the JAN WSR-57 PPI were made intermittently through the evening and early morning hours. Such tracings are important to the evaluation of three-dimensional storm structure and determination of storm type or severity. Examination of these overlays by the DST indicated detailed evaluations were made of three-dimensional storm structure for Cell 2 throughout its lifetime in the Jackson CWA. However, detailed tracings of three-dimensional storm structure were not performed for Cell 1 while the storm was within 25 nm of the JAN radar.

Georgia

During the morning and afternoon of November 22, 1992, four supercell thunderstorms tracked across central and northern Georgia spawning 11 tornadoes which resulted in six fatalities (see Fig. 3 for storm tracks).

The WSR-74C radar at Atlanta and reports from spotters and law enforcement officials provided the primary basis for warnings issued by WSFO Atlanta (ATL). Forecasters also considered the history of each storm to decide on the potential for tornado production and SHARP products from regional morning soundings, which indicated high values of storm relative helicity.

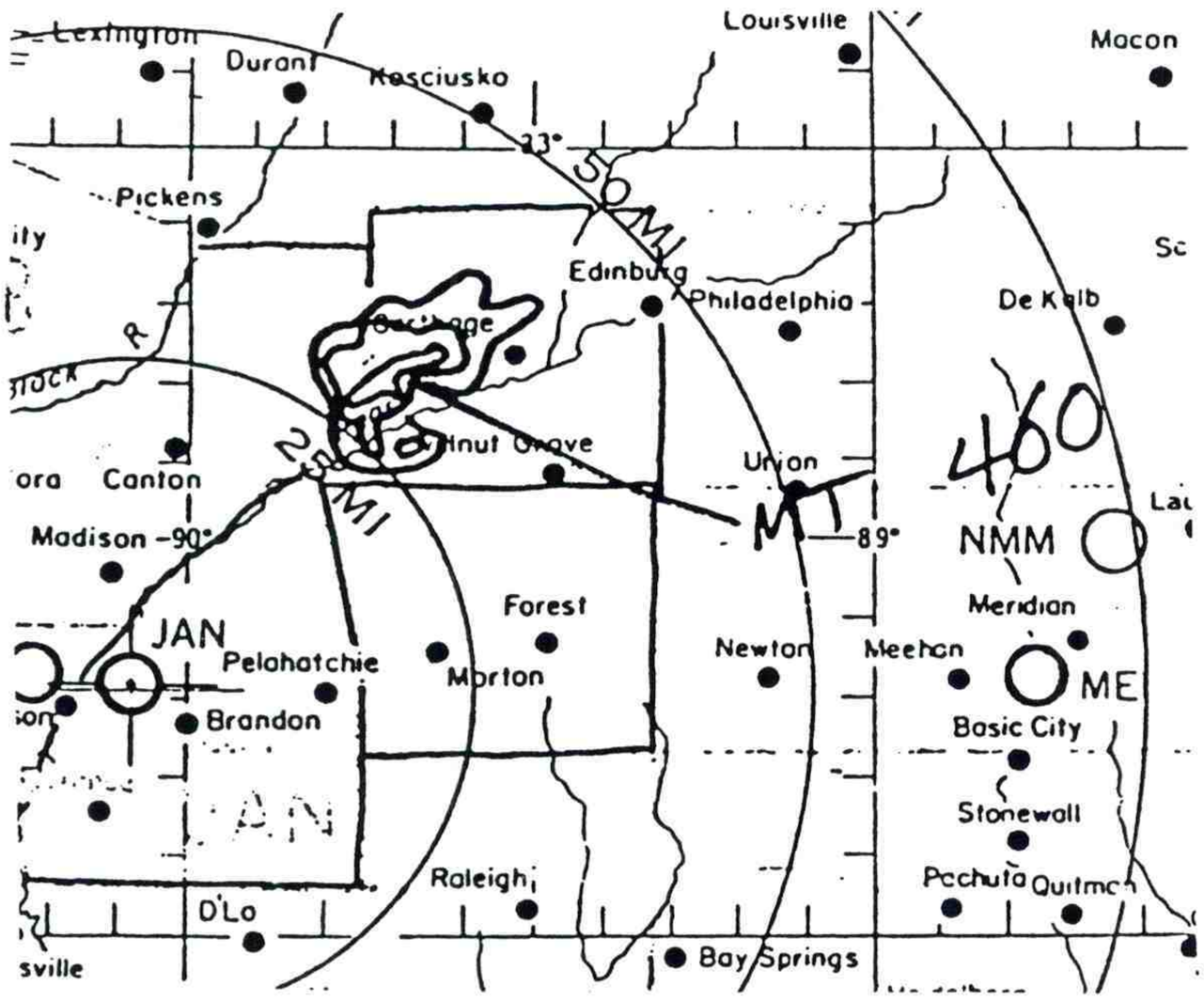


Figure 33. PPI overlay tracings from the Jackson, Mississippi, WSR-57 valid at a) 12:30 a.m. centered on the Leake County storm, and b) 12:25 a.m. centered on the Smith County storm.

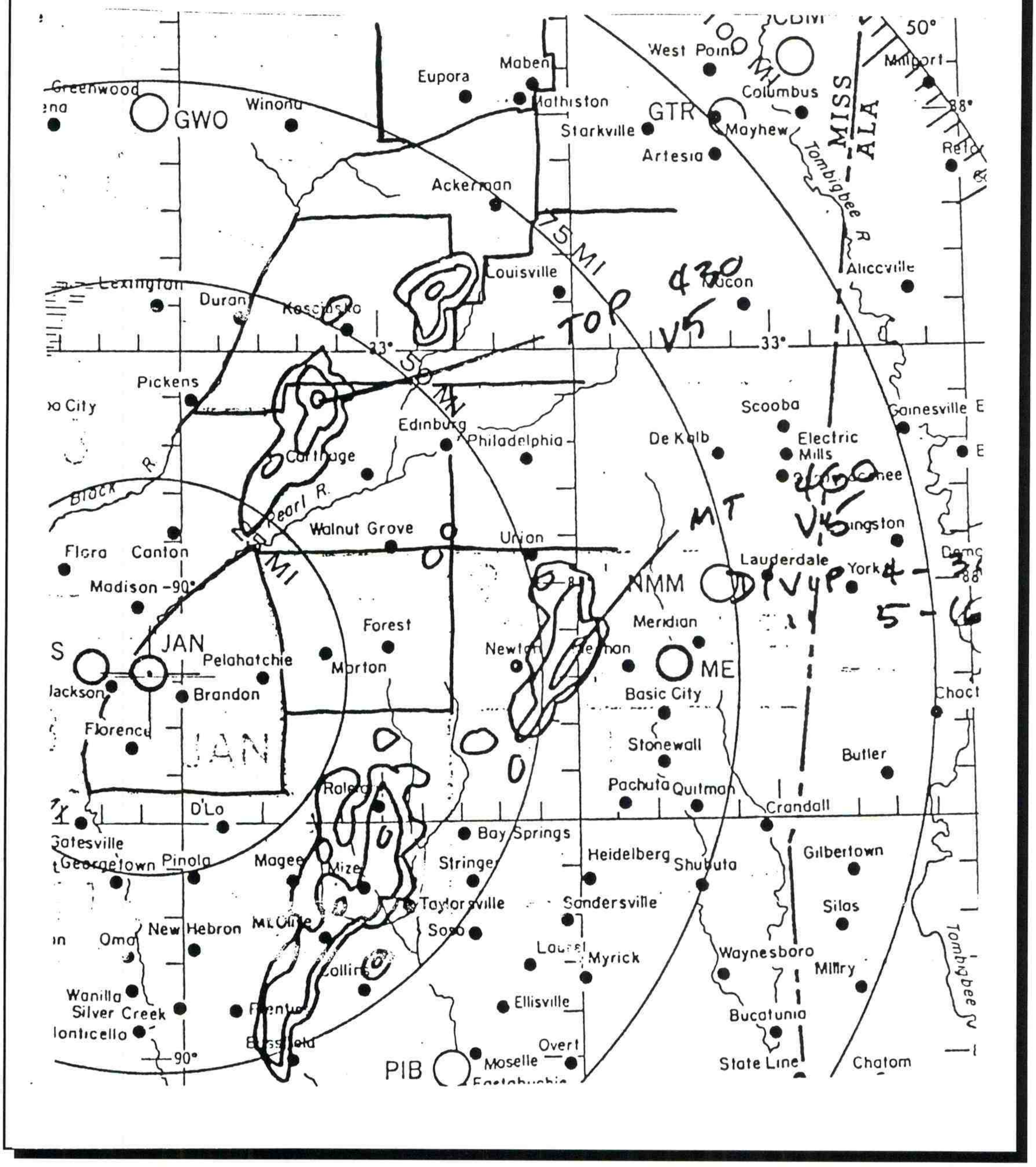


Figure 34. Same as Fig. 33 except valid at 1:25 a.m. for the Atalla County storm.

Radar at 9:30 a.m. indicated a broken line of thunderstorms, some with reflectivity values in excess of 50 dBZ (DVIP 5), moving into western Georgia (Fig. 35). Observations recorded by the radar operator at Atlanta indicated the individual storm cells were moving rapidly from 230 degrees at 40 knots.

The first, fatality-producing supercell (Cell 1) crossed into Carroll County from Alabama and tracked across portions of Douglas, Haralson, Paulding, Cobb, Cherokee, Forsythe, Dawson, Lumpkin, Union and Towns Counties. A Severe Thunderstorm Warning was issued for the storm as it entered Carroll County where apparent macroburst wind damage occurred. A report of a tornado in western Douglas County from the Douglas County Sheriff's Department prompted an upgrade to Tornado Warning for Douglas, Cobb, and Paulding Counties at 11:44 a.m. The tornado was briefly rated F4 as it passed through Kennesaw in Cobb County.

A Severe Thunderstorm Warning was issued for Dawson and Lumpkin Counties by WSO Athens, Georgia (AHN) at 12:44 p.m. as Cell 1 entered the AHN CWA. The warning was based upon a DVIP 4 reflectivity from the AHN WSR-57 radar, an echo top to 43,000 ft MSL and a "hail indication" (likely side-lobe echo). Personnel at WSO AHN had not received any reports of damage in neighboring sections of Cherokee County but were aware of the previous tornado in Cobb County. Based in part upon this history, law enforcement authorities in Dawson and Lumpkin Counties were contacted and severe weather reports were solicited. No reports were received until 1:20 p.m. when the Lumpkin County Sheriff's Department relayed a report of a tornado in northern Lumpkin County. The Severe Thunderstorm Warning was upgraded to Tornado Warning for Towns, Union, and White Counties upon receipt of the report.

Although elevated scanning techniques were used by Atlanta to assess the three-dimensional structure of Cell 1, no signatures indicative of a mesocyclone were evident until the storm reached Cobb County where a hook echo was observed at 12:08 p.m. (ATL form MF 7-60).

A second intense supercell thunderstorm (Cell 2) tracked from Alabama across central Georgia then into South Carolina. Several tornadoes accompanied Cell 2, the most notable being an F4 tornado in Putnam and Greene Counties which killed five people.

A Severe Thunderstorm Warning issued for Monroe County by WSO Macon, Georgia (MCN) at 3:25 p.m. was upgraded to Tornado Warning at 3:37 p.m. based upon reflectivity signatures on the MCN WSR-74C radar.

At 4:03 p.m. a hook echo was observed with Cell 2 from the ATL WSR-74C radar (ATL form MF 7-60). WSO Macon, Georgia (MCN) was notified of the hook echo by ATL, and the Tornado Warning was extended into Jasper and Jones Counties. This warning included a report of damage near Smarr, Georgia. A third Tornado Warning based on radar signatures and spotter reports of a funnel was issued by MCN at 4:16 p.m. as the storm entered Putnam County.

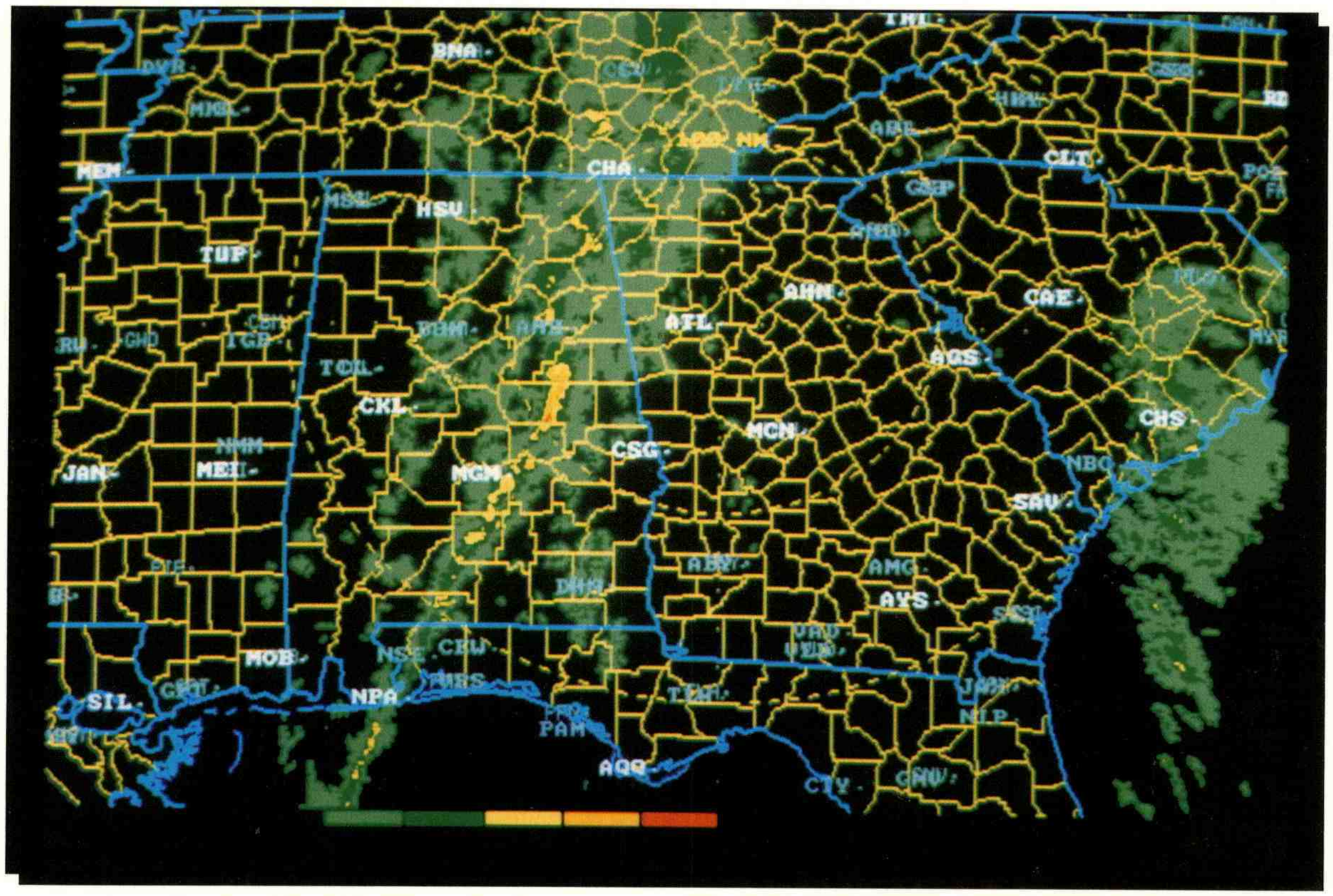


Figure 35. NOWrad composite radar image at 9:30 a.m., November 22.

A Severe Thunderstorm Warning was issued by WSO AHN for Cell 2 as it approached Greene County at 4:21 p.m. The decision to issue a Severe Thunderstorm instead of Tornado Warning was based upon a DVIP 5 maximum storm reflectivity, no discernible hook echo from the AHN radar, and an echo top of 53,000 ft MSL.

The MCN WSR-74C radar failed at 4:25 p.m., and WSFO ATL continued to relay critical radar information for MCN warning operations. At 4:25 p.m. the ATL radar indicated (ATL form MF 7-60) both a hook echo and BWER associated with Cell 2. The presence of the hook echo and BWER suggests a well developed mesocyclone and intense updraft were present.

WSO AHN was advised by ATL of the MCN radar failure at 4:30 p.m. AHN was also advised that the ATL radar indicated tornadic cells were approaching the AHN CWA (ATL activity log).

No reports of damage had been received and no hook echo was apparent from the AHN radar at 4:58 p.m., thus the Severe Thunderstorm Warning was continued into Taliferro County by WSO AHN.

Analysis of a time lapse image of the WSO AHN WSR-57 radar by the DST indicates Cell 2 was characterized by DVIP 5 reflectivities, a very sharp gradient of reflectivity on the southeast (inflow) flank, and a large weak echo region. These characteristics, in combination with the previous storm history and ATL radar observations, are consistent with accepted conceptual models of supercell thunderstorm evolution.

The F4, Putnam-Greene County tornado occurred between 4:45 p.m. and 5:20 p.m. over a path length of 32 miles. Four fatalities occurred in Putnam County. One woman was killed and extensive damage was done as the tornado struck the small town of White Plains in Greene County.

Kentucky

In addition to the tornadoes that affected the southern United States, a secondary area of tornadoes developed over Indiana, northern Kentucky, and southwest Ohio the afternoon of November 22. The Cincinnati Weather Service Office (WSO CVG) anticipated the threat quite well (see Chapter 2) with diligent mesoanalysis.

The Cincinnati staff utilized ADAP to identify the most likely area within their CWA for tornadoes to form. When the storm developed ahead of the squall line in the area they had identified, they acted quickly.

With regard to the tornado that killed a person in Carrol County, Kentucky, the Cincinnati area WSR-57 radar image (Fig. 36) indicated a subtle hook echo, a maximum echo top of just 31,000 feet, and 50 dBZ (equivalent reflectivity)

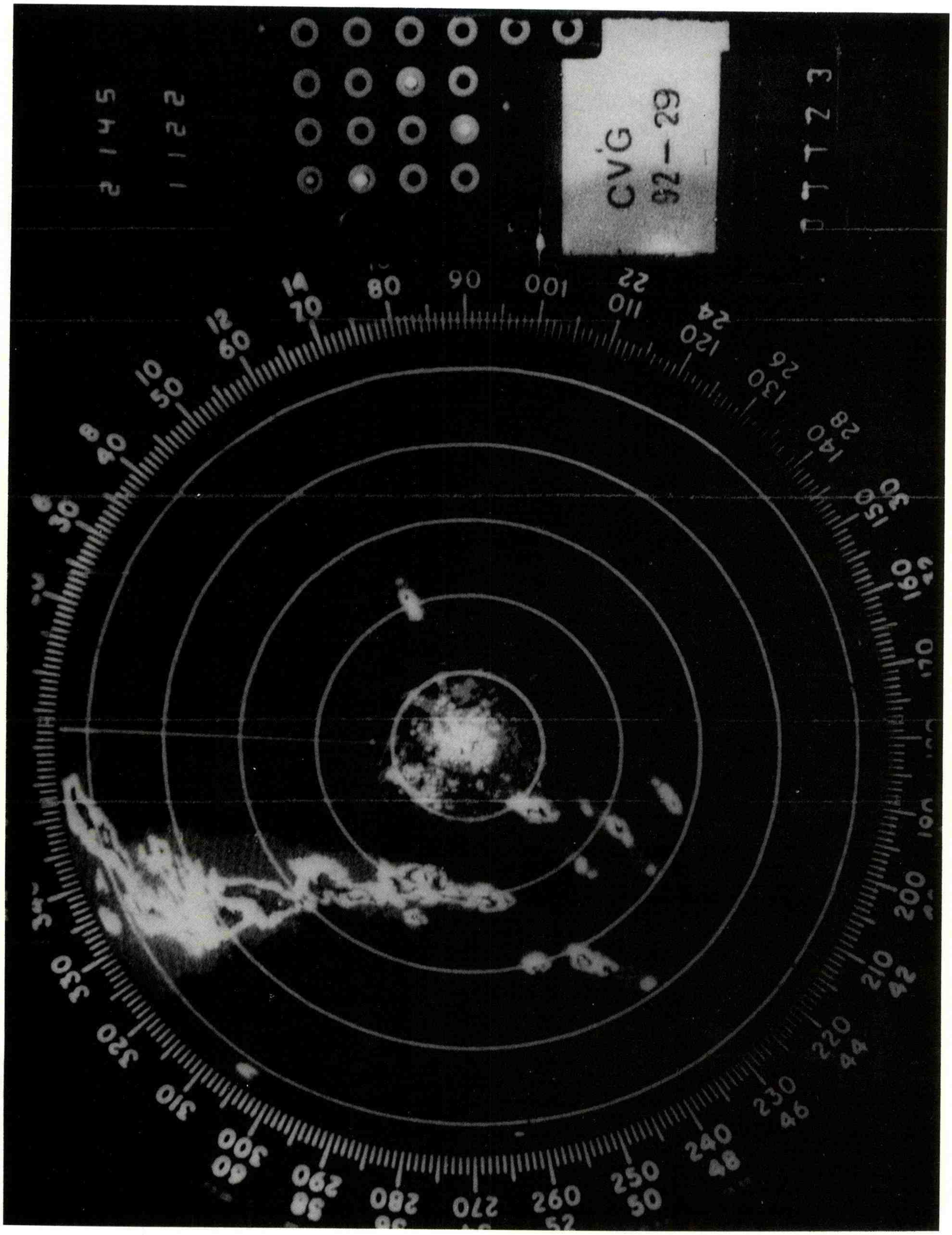


Figure 36. Photograph of Cincinnati, Ohio network WSR-57 radar display at 4:45 p.m., November 22, 1992.

vertically only to 14,000 ft. A Tornado Warning was issued based upon the radar characteristics in combination with knowledge of the mesoscale environment. WSO CVG continued to monitor the cell on radar issuing advance warnings downstream along the storm's path (see Fig. 4). The tornado was sighted visually from the WSO 7 minutes after the initial warning was issued, and it continued in sight until it lifted at 5:27 p.m.

North Carolina

Tornadoes touched down in central and eastern sections of North Carolina during the early morning hours of November 23rd (see Fig. 5).

The Raleigh WSFO (RDU) utilized its WSR-74C conventional local warning radar to support warning operations. They also assisted Charlotte and Greensboro WSOs earlier in the evening when a series of F0 and F1 tornadoes struck the western section of the state. Although storm reflectivities had diminished between 12:00 a.m. and 1:00 a.m., a Tornado Watch was expanded into the north central section of the state including part of the Raleigh CWA about 1:30 a.m.

As the line of storms crossed Virginia and northcentral North Carolina a strong cell developed on the southern end of the line. The south end of a convective line is recognized as a favorable area for severe weather development.

Raleigh radar did not show any hook echoes or overhang with the storm that produced the F3 Hillsborough tornado at 2:20 a.m. However, a DVIP 5 reflectivity was observed vertically to a height of 22,000 ft MSL, the strongest signature of any storm that night. Severe Thunderstorm Warnings were in effect for Chatham, Durham and Orange (Hillsborough's County) Counties between 12:13 a.m. and 3:00 a.m.

Radar reports (MF 7-60) from Volens, Virginia (VQN) indicated the Hillsborough storm had a top of 45,000 feet with intensities increasing between 1:30 a.m. and 2:30 a.m. The 2:20 a.m. photograph of the Volens radar display (Fig. 37) indicated the storm (located south-southwest of the radar) had a maximum reflectivity of DVIP 5, but no characteristic hook echo was discernible.

The storm that produced the long-track (160 miles) across eastern North Carolina from 4:10 a.m. until approximately 6:25 a.m. also failed to show radar characteristics normally associated with supercell thunderstorms and tornadoes.

The initial Tornado Warning (Johnston County) for the eastern North Carolina storm was issued in response to reports of damage in Harnett and Johnston Counties. From that point, warnings were issued in advance of the storm cell. The radar showed the cell as a large mass of DVIP 2-3 intensity at 4:30 a.m.; the cell became slightly stronger by 5:30 a.m. A faint indication of a hook echo was observed over Wilson County about 5:00 a.m.

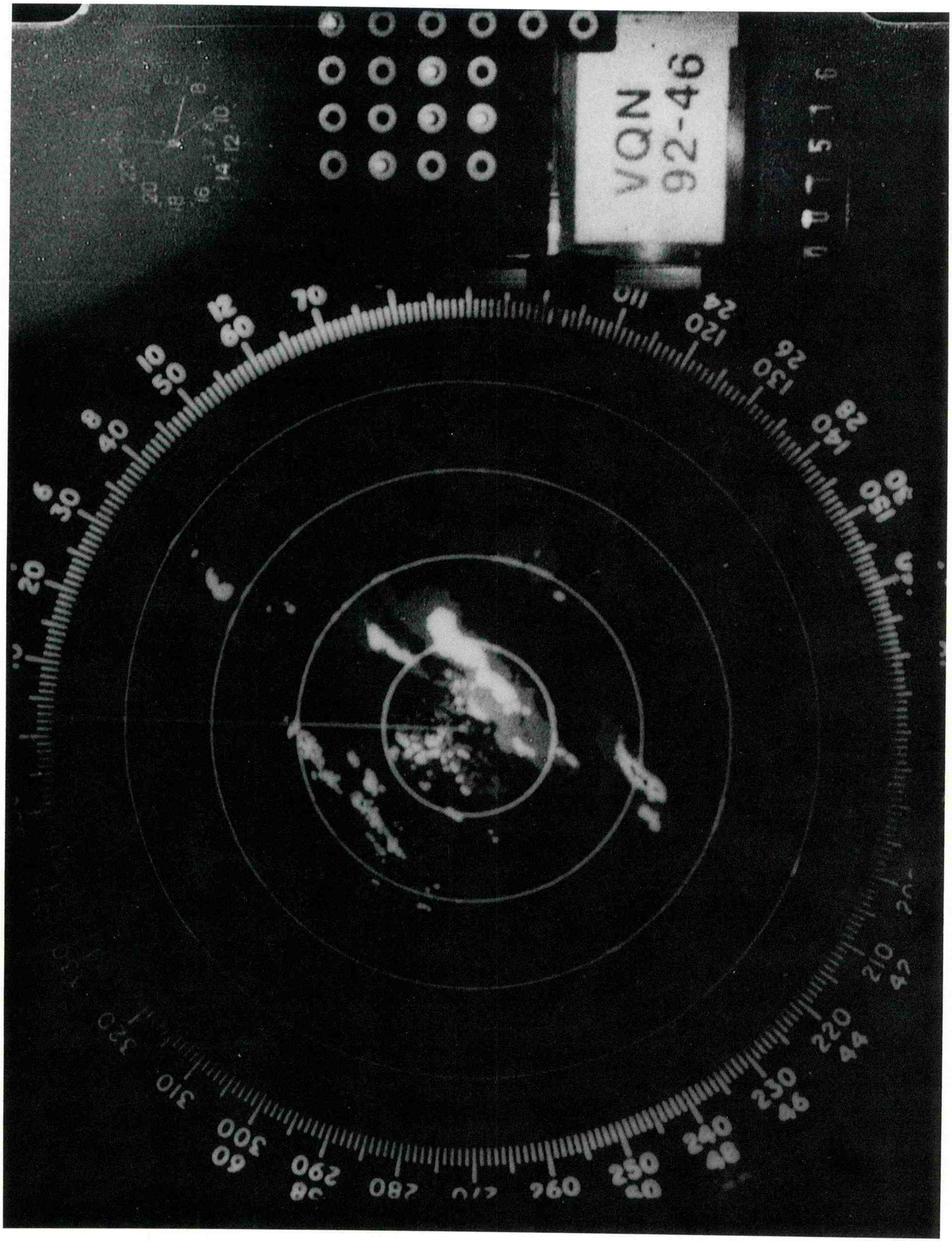


Figure 37. Photograph of Volens, Virginia, WSR-57 radar display at 2:20 a.m., November 23, 1992.

The Wilmington, North Carolina, network WSR-57 radar also failed to show reflectivity signatures typically associated with severe thunderstorms as the cell passed northwest of the radar (Fig. 38). It was the most intense cell within range at the time, and the radar report (MF 7-60) indicated an echo top of 40,000 ft MSL. Subsequent, hourly radar reports showed the cell maintained an intensity of between DVIP 3 and 5 and tops at or above 40,000 ft MSL from 4:30 a.m. until 7:30 a.m.

FINDINGS AND RECOMMENDATIONS

Finding 4.1: WSR-88D radar at WSO Houston performed well. Velocity data (particularly the storm relative data) proved extremely valuable in evaluating tornadic potential. The WSR-88D was clearly superior to conventional WSR-57 and WSR-74C radars in use at other locations.

Finding 4.2: Multiple elevation angle displays (four-panels) of reflectivity and velocity data proved extremely valuable to the Houston Office during this episode. The data, and other products provided by the WSR-88D, required intense analysis by a highly skilled radar interpreter to accurately determine the likelihood that a tornado would develop. Proper interpretation of WSR-88D data during active events requires dedication of at least one staff member to that task.

Recommendation 4.2: At least one skilled radar interpreter should be dedicated to the radar, whether it is a WSR-88D, WSR-74 or WSR-57 any time severe weather threatens (including times when severe weather watches are in effect) and thunderstorms are present.

Finding 4.3: Meteorologists who interpreted the Houston WSR-88D felt training they received at the Norman, Oklahoma WSR-88D OSF Training Branch provided a strong base upon which to build their skills. The value of that training was measured in the effective warnings issued November 21, 1992.

Finding 4.4: No warnings were in effect for the fatality-producing tornadoes in Rankin, Choctaw, and Webster Counties in Mississippi. The no-warning decision was, in part, due to radar indications the storm was decreasing in intensity. The decreased reflectivity of the storm as it tracked into Rankin then Attala Counties suggests the storm updraft weakened briefly as the mesocyclone occluded in each case. Such an evolution is consistent with tornadic supercell thunderstorms.

Recommendation 4.4a: The NWS should continue to improve instruction on severe storm evolution and radar structure. Although such instruction may be performed on-site by the SOO, the instruction should be in addition to the resident WSR-88D course, with content formulated by subject matter experts.

Recommendation 4.4b: The NWS should ensure that future radar display systems (e.g. WSR-88D PUP, AWIPS) provide the tools necessary to quickly and easily assess three-dimensional storm structure and evolution.

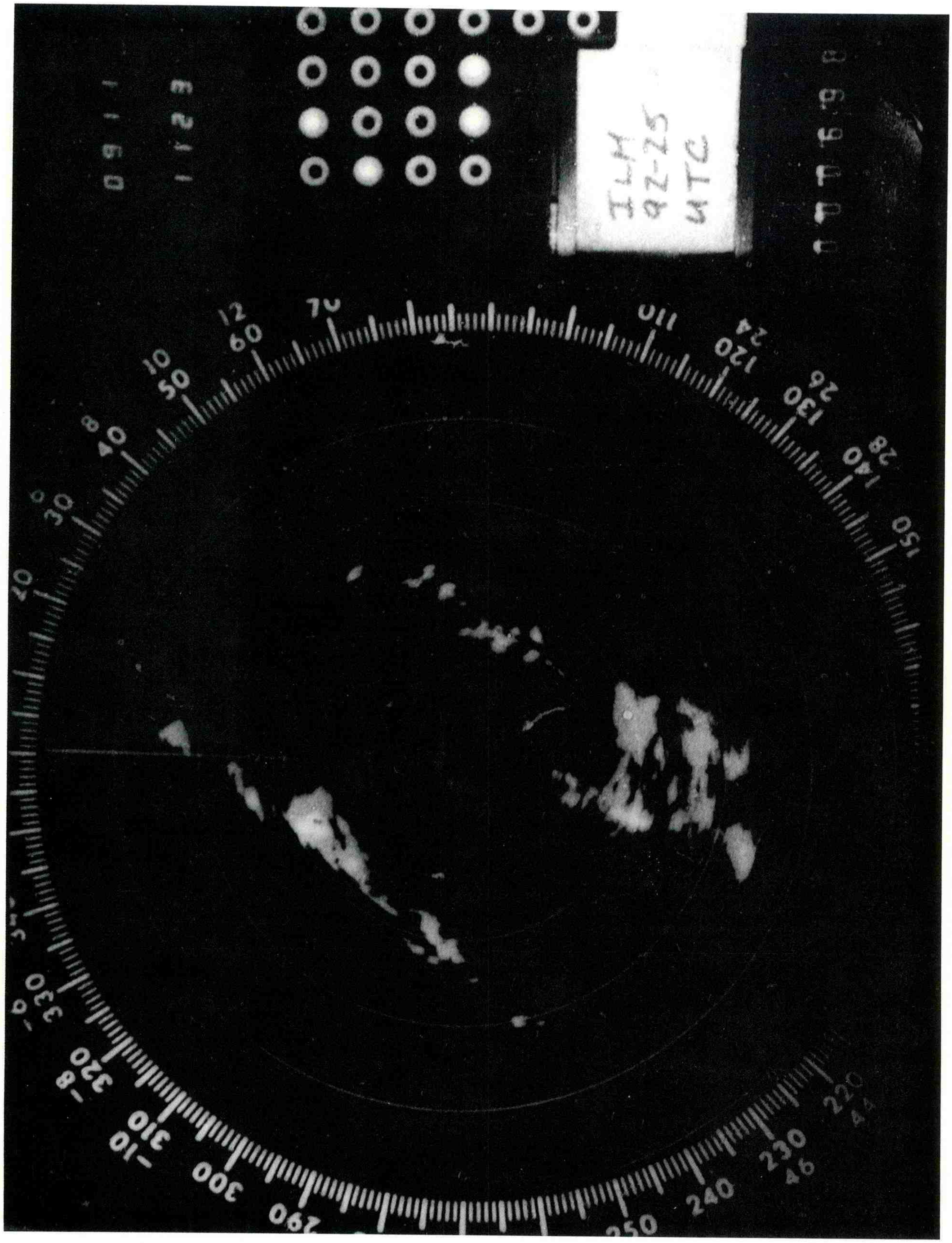


Figure 38. Photograph of Wilmington, North Carolina network WSR-57 display at 4:11 p.m., November 23, 1992.

Finding 4.5: Despite using conventional radar that did not always identify characteristics normally associated with tornadoes, the Cincinnati WSO issued effective warnings. They used an intensive mesoanalysis effort that helped to identify the area where the tornado developed. The mesoanalysis directly contributed to the effectiveness of the Tornado Warning they issued.

Recommendation 4.5: All radar-related training should emphasize mesoscale analysis as an important aspect of radar data interpretation.

CHAPTER 5

PREPAREDNESS

The primary mission of the NWS is the issuance of watches and warnings to protect life and property. It is not sufficient to simply issue warnings to the public; citizens must know what to do once the warning has been issued. The NWS is only one member of the hazards community, which consists of all organizations involved in the warning process. These organizations include Federal, state, and local agencies; emergency managers; elected officials; the media; volunteer groups; and private sector meteorologists. Educating the public to the hazards of severe weather is a vital part of the lifesaving mission of the NWS.

The NWS recognizes the need to educate the public and the hazards community and performs this service through preparedness. Preparedness activities include recommending safety actions to be taken during severe weather events and managing extensive spotter training and preparedness programs to educate emergency management officials and the public to the hazards of severe weather.

Texas

WSO Houston's internal preparedness activities included a severe local storm drill in March, 1992 and an update of the Station Duty Manual (SDM) in July, 1992. The SDM clearly lays out the need and process to augment the regular shift staff during severe weather operations and the job assignments of each position.

The NWR is tested weekly between 11:00 a.m and noon, weather permitting. Though backup power was not used during this tornado event, it is tested every 2 weeks.

Due to the hurricane threat, a Warning Preparedness Meteorologist (WPM) had been on station for many years. That person now has the title of Warning Coordination Meteorologist (WCM) as the office transitions into the modernized NWS. Preparedness activities with the state and County emergency managers included the development, coordination and initiation of a unique new Community Severe Weather Involvement Plan. This Community Weather Plan (CWP) directly involves the County emergency management coordinators in Houston's CWA. Each County has its own local emergency plan which includes severe weather and interaction with WSO Houston.

Fort Bend and Harris Counties have their own spotter network. Fifty eight spotters from Fort Bend County received NWS training earlier in the year.

A 2-meter amateur radio is located at WSO Houston. The local Amateur Radio organization has established a pool of operators who are available to serve as a

communications liaison between the NWS and the spotter groups within range of the Houston repeater. The HAM spotter network is well organized in Harris County which includes the city of Houston, with various types of networks in the other four Counties. Houston area repeaters can be accessed by amateur radio spotters in at least nine surrounding Counties. These vary from various law enforcement agencies to other less organized HAM groups. A greater emphasis by local management at WSO Houston has begun to assist surrounding Counties in establishing and organizing additional spotter groups. Spotter training had been offered to all Counties; however, none had been performed during the past 2 years other than for Fort Bend County. Most other spotter groups from the surrounding areas relay information to their centralized law enforcement agency. The information is then forwarded via telephone to the NWS. The Houston area HAM coordinator was contacted between 10:30 a.m. and 11:00 a.m., Saturday, November 21. The network was established by 1:00 p.m.

Of the seven media (radio and television) outlets questioned, all stated they did not participate in NWS annual severe weather preparedness week activities. Five have had contact with the local NWS office. WSO Houston staged a 4-day, coordination and liaison meeting in September 1992 with the local emergency managers, the media, and private sector meteorologists. These meetings stressed the importance of the WSR-88D, ground truth information for verification, and the role of the media. Approximately 100 attended with interviews given to radio, television and newspaper representatives.

Only a couple of the media have their own spotter networks, which consist mainly of rainfall observers. The other media contacts stated they did not have the time or budget to initiate a spotter network. Of the media groups contacted, five receive their weather information via GTE Contel NWWS, three through NWR, three through Weather Services International, three through Associated Press, one through Universal, one through Accu-Weather, one through Kavouras, and one stated they rely on the Emergency Broadcast System (EBS) station.

Other external activities included awareness and preparedness training to the general public or targeted groups. These activities are conducted by the WCM and MIC. Over 100,000 people were exposed to severe weather awareness information at the January 1992 Houston Boat Sport and Travel Show. WSO Houston also prepares a local publication "Storm Signals" which is mailed quarterly to over 900 individuals and organizations. Numerous industries and businesses then reprint them, making them available to their employees. Monthly, weekly, and sometimes major daily newspapers and magazines print the feature article contained in each newsletter. That accounts for at least a 30,000 circulation. Apparently the word is getting out; all those interviewed at the damage area knew what proper actions to take when the tornado approached.

Mississippi

Not only does Mississippi lead the nation in the total number of tornado deaths, but the state frequently experiences flooding and hurricanes. All these factors have created a heightened awareness of weather for citizens of Mississippi.

To meet the need and challenge to better educate residents and train storm spotters, an active preparedness program has existed at WSFO Jackson since 1974. A dedicated WPM position has been on station for the past 18 years. WSFO Jackson is responsible for severe weather warnings, weather preparedness, and warning coordination for 42 Counties. In addition, the MIC and the WPM assist in the preparedness activities, as needed, for WSOs Meridian and Tupelo.

The level of preparedness activities fluctuates depending on the staffing level at the WSFO. Ideally, the WPM should work operational shifts about 25 percent of the time, but often this figure may be closer to 75 percent or higher.

WSFO Jackson's internal preparedness activities included a severe weather "roundtable discussion" (station meeting) in February 1992. At this meeting, all severe weather operational procedures were reviewed. A severe weather drill was conducted in early March 1992, and the severe weather section of the SDM was updated in March and again in November, 1992.

Operational policies and procedures were also reviewed in at least four memos from local management in March and April 1992. Tours of the Hinds County Emergency Operations Center (EOC) were also arranged for all WSFO Jackson staff members in February and early March 1992 in order to familiarize the WSFO staff with EOC operations and to enhance coordination between the two units.

There are also external preparedness activities. Annually, WSFO Jackson, in conjunction with the Mississippi Emergency Management Agency (MEMA) conducts a Severe Weather Awareness Week. This is normally held in February. A different weather topic is highlighted each day. During these weeks, people are encouraged to become familiar with severe weather safety rules. (In Rankin County, where 10 deaths occurred, the schools do participate in Mississippi Severe Weather Awareness Week activities.) WSFO Jackson mails out around 1300 information packages to Emergency Management Agencies (EMAs), news media outlets, and schools across the state. These packages provide information on severe weather and severe weather safety. Included in preparedness activities is a statewide practice tornado watch and warning drill (usually conducted jointly with WSFO Birmingham and Alabama). WSFOs Jackson and Birmingham hold joint Awareness Weeks for Mississippi and Alabama.

Severe storm spotter training is a major aspect of Jackson's preparedness program. Four hours of weather spotter training are given to trainees at the Mississippi Highway Patrol Headquarters in Jackson. Training sessions had been

conducted in each of the Counties which experienced fatalities. The date the training was given and the group receiving the training were:

County	Date	Number	Organization
Rankin County:	12/91	8	Multcraft, Inc.
	11/90	43	Fire Academy
	2/90	42	HamRadio Club (Advanced Spotter Training)
	2/89	19	Ham Radio Club
	11/88	21	Mississippi State Fire Academy
Leake	2/88	23	EMA and interested citizens
Choctaw	1/90	16	Nostalgia Amateur Radio Club
	4/89	25	Ham Radio Club
	1/89	22	Ham Radio Club
Webster	9/90	22	NE Ham Radio Club (Advanced Spotter Training)
Kemper	2/87	36	Volunteer Fire Dept. (De Kalb)

Rankin County's part-time Emergency Management Director, Mr. Charlie Wilkinson, was in the process of establishing an EMA office in Rankin County. The EOC had no communications system (no CD radio) or staff. There was no room for a HAM base station. A warning system and spotter network for Rankin County were not yet centralized or organized.

If an active and well organized amateur radio group exists, room is normally made available for the organization in an NWS office. During this event, WSFO Jackson was in temporary quarters while the old office was being refurbished into their new Weather Forecast Office (WFO). Originally, there was space in the temporary quarters for the HAM base, but it was lost to communications needs for the phone company and radar users. Another factor contributing to the absence of a HAM group at the WSFO was the fact that the local club had become disorganized (changeover in officers, etc.).

Georgia

As in Mississippi, WSFO Atlanta has a dedicated WPM position to focus on preparedness functions within the WSFO's County warning area and to assist WSO MICs/OICs as necessary. Likewise, annual Severe Weather Awareness Weeks are conducted.

WSFO Atlanta conducts regular drills designed to refresh the staff on procedures and basic information that would be needed or applicable during severe weather events. The drills are conducted each spring. Besides drills for the WSFO, each WSO in Georgia participates in drills.

The warning alarm tone for all NOAA Weather Radios serving Georgia are routinely tested each Wednesday at midday (weather permitting).

A copy of the SDM for all Georgia WSOs is on file at WSFO Atlanta. Numerous Chapters of the WSFO SDM pertaining to severe weather have been updated in the past 3 years.

The majority of the storm spotters in Georgia are HAMS; however, the network also includes law enforcement officials, fire officials, forestry personnel, private citizens, Civil Air Patrol, and others.

Recent Georgia "Awareness Week" dates have been:

1989 February 20 - 24
1990 February 26 - March 2
1991 February 25 - March 1
1992 February 24 - 28; and for
1993 February 22 - 26; targeted groups were
all Georgia Amateur Radio Clubs
all registered hospitals/medical centers
Georgia Extension Offices

Severe Weather Awareness Week campaigns have been very successful over the past several years. Each year the goal has been to reach more of Georgia's residents and to provide concise information for use in weather emergencies.

For Severe Weather Awareness Week 1992 the emphasis was changed slightly in that a new format was developed, and the information layout was changed to achieve greater readership and understanding of the facts and safety rules presented. The new format was well received, but the added cost permitted only 1,000 packets to be printed. Data were requested for all of Georgia's agricultural extension offices, amateur radio clubs, and hospitals.

Feedback from the packets showed that tornado watch and warning drills were conducted efficiently and successfully throughout the state. Only five schools complained of not receiving the warning portion of the drill. The clipping service forwarded 98 articles in February and early March related to the information packets/drills. Articles published during the spring and summer months often used the data verbatim.

The NWS in Atlanta has maintained a close and beneficial working relationship with many Georgia Amateur Radio Operators (HAMS) over the years. Over 440 spotters are registered at the WSFO, and HAM participation has increased. The Atlanta Radio Club owns the equipment presently in the WSFO. The equipment was originally installed at the Forecast Office at the previous permanent site. The system remained operable until early 1992 when the office was moved to the present temporary quarters. Dialogue was initiated with Club members about re-

installing the unit at the temporary WSFO quarters. The Club desired to update their equipment with computers which required equipment not available at the WSFO. In early November 1992, the group advised the WSFO that they planned to utilize their equipment at a north Atlanta school.

As a result of earlier discussions with the Atlanta Radio Club, along with an IBM group, and a Gwinnett County packet radio group, plans were underway to have a packet system installed in the Forecast Office by early spring 1993. This system will allow HAM operators from several areas of north and central Georgia to relay information, by computer, to a printer located in the WSFO.

The fact that HAM radio was not installed at the WSFO did not hamper the SKYWARN network. Spotters have been activated during almost every severe weather event and have efficiently provided pertinent and timely weather data. During the severe weather outbreak on November 22, 1992, four SKYWARN spotters called WSFO Atlanta. The station log also indicates that several governmental groups (police, etc.) contributed to the warning effort. From statements and warnings issued by the NWS in Georgia, it appears that spotters participated actively across the state during this outbreak.

The information below pertinent to preparedness was received from visits made by the DST members to various officials in Georgia.

Larry White, Assistant to the Chief of the Cobb County EOC, was interviewed. The County Emergency Management Agency has a good community outreach program to inform the public about warnings from sirens and actions public should take. The Cobb County Emergency Management Agency has very good relations with the NWS, and Mr. White indicated the NWS provided great service during this event.

Survey Team members talked with Mr. James Gregory, Director, Putnam County Emergency Medical Services (EMS) and Mr. Troy Reynolds, Fire Chief, Putnam County Fire Department. Both Mr. Gregory and Mr. Reyonlds would like the WPM/WSFO Atlanta to contact them about a new/upgraded Spotter Training Session. This request was passed-on to the MIC/WPM at WSFO Atlanta.

Kentucky

Preparedness activities, both internal and external, are comprehensive at WSO Cincinnati. Internal written drills covering many subjects including severe weather procedures are conducted each month. The last monthly drill before the tornado event was completed in October 1992. The SDM was updated earlier in the year clearly spelling out the severe weather operating procedures.

The NWR is tested weekly between 11:00 a.m. and noon on Wednesdays. There are two levels of backup power, and the NWS generator is scheduled for testing 10 or 20 minutes each month. Backup power was not used during this event.

Through the concerted, coordinated effort of the entire staff at WSO Cincinnati all Counties in their CWA were visited during the spring of 1992. This entailed visiting County emergency managers in 22 Counties covering the three states of Ohio, Indiana, and Kentucky. In a statewide effort, the WSO participated in the 1992 Ohio Tornado Safety Awareness Week which was held March 22-28, 1992. Public participation was on March 25th. A comprehensive awareness package was prepared for the week's activities. The staff of the WSO prepared test warning messages during the drill.

Aggressive SKYWARN training during the late winter and spring months resulted in 1,185 individuals being reached. This training was provided by seven different members of the WSO Cincinnati staff during 41 meetings. Due to this training, a comprehensive, trained spotter network was in place in all 22 Counties. The WSO has an exceptionally well equipped amateur radio station in its own separate room in the office. It has multi-band capabilities including a packet station. This system is called the Weather Amateur Radio Network (W.A.R.N). They also have a drop on the radar so the radio operator can see significant echoes and request spotter information in areas of significant radar activity. Amateur radio personnel are called in during weather emergencies. Additionally, weekly weather training sessions for the amateur radio community are held via the radio network. These sessions are taught by the staff of the WSO. The SKYWARN network was activated at 2:55 p.m., Sunday, about 2 hours before the first tornado touched down. Two amateur radio operators came in and staffed the WSO SKYWARN amateur radio station during the episode.

The media also participated in the Ohio Tornado Safety Awareness Week activities. Just 3 days prior to the tornado event, Erik Pytlak, a meteorologist intern, made the semi-annual visit to all news radio and television stations in Cincinnati, as well as two Cincinnati newspapers.

North Carolina

External coordination, especially on the state level is excellent. The Governor declared February 24-29 Severe Weather Awareness Week. In conjunction with the North Carolina Division of Emergency Management and Department of Public Instructions, the NWS conducted a statewide tornado drill on Wednesday, February 28, 1992. The test watch and warning messages were carried on NWR, NWWS and via the EBS in addition to the Associated Press, and United Press International. The media participated in the awareness week.

At the County level, the coordination is more variable. The DST visited Johnston County and were informed the County did not participate in the NWS drills earlier in the year. They don't have NAWAS and don't use public alerting sirens. A meeting was held with the Johnston County HAMS in April 1992 to discuss severe weather and reporting.

The NWR tone alert is tested every Wednesday at noon, while the backup power is actually used two to three times a week at WSFO Raleigh, especially when thunderstorms are around.

WSFO Raleigh has a relatively dense HAM radio spotter network within about 50 miles of the office. Once staffing at WSFO Raleigh was up to the full level, a push for additional spotters was started in October 1992. Spotter training is provided through a 3-hour mini course. During 1992, 283 people completed this course. A SKYWARN newsletter was started in February 1992 and is jointly written by Rod Gonski, WSFO Raleigh's WPM, and the amateur radio operators. It is issued three times per year. The first issue targeted the spring severe weather season.

During the event, the HAM radio coordinator, Mr. Jerry Stuckle, was briefed more than 24 hours in advance of the possibility of severe weather occurring in the area. The SKYWARN amateur radio net was run from Mr. Stuckle's home who then telephoned significant spotter reports to WSFO Raleigh. Other spotters relayed their information to local law enforcement agencies. At 5:00 a.m. Monday morning, HAMS were performing outstandingly in relaying tornado information downstream and to WSFO Raleigh.

FINDINGS AND RECOMMENDATIONS

Finding 5.1: Overall, a vigorous Warning and Preparedness program existed in the areas visited. However, in Rankin County, Mississippi, (WSFO Jackson's responsibility) the Emergency Management Agency was just getting organized. The County's storm spotter network needed to be reorganized and trained. Also, spotter training in WSFO Raleigh's area of responsibility was limited due to minimum staffing, and the spotter network for WSO Houston's CWA was sporadic in some locations.

Recommendation 5.1: To allow the WPM/WCM more time to perform his/her preparedness duties, efforts should be increased to limit shift work by the WPM/WCM to no more than 25 percent of the time. Spotter training and organization is an indispensable part of each NWS Office's program and must be given a high priority, even in times of limited staffing. Staffing should be brought up to full complement where insufficient staffing has a negative effect on WPM/WCM duties.

Finding 5.2: WSFO Raleigh placed a low priority on logging information during the event. Many telephone calls and conversations were recorded after the event from the memory of individuals working the event. WSFO Raleigh has since instituted procedures to enhance their real-time logging of events during severe weather episodes including the addition of a voice-activated recording device.

Recommendation 5.2: A greater importance should be placed on logging events, particularly severe weather information.

Finding 5.3: The preparedness effort was, in general, well rewarded during this outbreak. Interviews and individual accounts indicated people were generally aware of the threat, the warnings, and of the proper safety measures to take.

Recommendation 5.3: The NWS, along with the entire hazards community, needs to continue and enhance preparedness and educational activities to minimize loss of life.

Finding 5.4: NWS offices often have a HAM base station in the operations area. HAM radio operators provide some of the most timely and accurate storm information. WSFO's Jackson and Atlanta were in temporary quarters with limited space, and no HAM base station was in service. Both offices plan space for a HAM station at their new facilities.

Recommendation 5.4: NWS offices should make every effort to provide space for HAM radio, even while occupying temporary quarters.

CHAPTER 6

DISSEMINATION AND COMMUNICATIONS

The following sections discuss the various dissemination and communication systems and services utilized in association with the tornado outbreak. Due to the vast areas affected by the storms, all dissemination aspects of this disaster could not be covered or evaluated in depth.

NOAA Weather Wire Service (NWWS)

The old, landline, Weather Wire was discontinued in the late 1980's. It was replaced by a new satellite delivery system which makes NWWS available almost anywhere. The receiving equipment may be leased or purchased and is operated by GTE/Contel in Chantilly, Virginia. Forecasts, statements, watches, and warnings are transmitted via the AFOS network to selected NWS offices (normally WSFOs) where they are uplinked to the NWWS.

There are about 1300 NWWS subscribers. The NWS provided a "gift" NWWS to each state. This unit normally went to the state Highway Patrol or Emergency Management Agency (EMA) which could fan-out the data to other emergency management, law enforcement, or government agencies which could effectively utilize the information.

Periodically, it is necessary for GTE/Contel to briefly shut-down NWWS to perform essential maintenance. Messages are sent to subscribers in advance notifying them of the time the outage will occur. The NWWS was stopped for maintenance from 3:00-5:00 a.m. EST on Saturday, November 21. It was about 12 hours later that the tornadic storms struck southeast Texas. If the planned outage had occurred about 24 hours later, NWWS would have been out of service when tornadoes were in progress in eastern Mississippi and Alabama. To ensure that scheduled NWWS maintenance does not occur when severe weather is forecast or in progress, procedures are needed whereby contacts are made between GTE/Contel and the NWS before the system is turned off.

Texas

There are 128 NWWS subscribers in Texas (32 in Houston's CWA). The EBS station in Houston (KTRH) is on the NWWS. The system operated with acceptable performance. The Harris County Emergency Coordinator noted there appeared to be a few minutes delay between the reception of the warnings on their NWWS and the receipt on another circuit. This comment was not noted at the other GTE/Contel subscribers contacted in Houston, but it was mentioned in Raleigh, North Carolina. NWS Headquarters was made aware of the comment.

Mississippi

Mississippi has 46 subscribers (14 in the Jackson, Choctaw, Webster, Leake, Meridian-Kemper area). The EBS lead station in Jackson (WJDS) is on NWWS. The warnings received on NWWS "beep" plus a video scroll arrangement is in place for the staff to see the warning text. The DST was not made aware of any problems with NWWS in Mississippi.

Georgia

There are 33 subscribers in Georgia (9 in the Atlanta and Macon area). While no problems were noted with the GTE/Contel system during this event, the GEMA periodically experiences a problem with NWWS. When the alarm goes off and the reset button is pressed, occasionally the whole system shuts-down. Despite the addition of another rug to reduce static electricity, and efforts by the local GTE/Contel maintenance personnel, the problem persists. NWS Headquarters has been made aware of the problem and will advise GTE/Contel Headquarters in Washington. Elsewhere, newspaper articles indicate that Georgia residents were appraised of the inclement weather as it developed from NWWS and other sources.

Kentucky

The GTE/Contel NWWS has 25 customers in Kentucky. No problems were noted. Tornado Warnings were issued on NWWS.

North Carolina

The GTE/Contel NWWS has 27 listed customers in North Carolina. The system operated with acceptable performance. The TV station at Durham, WTVD, stated they received the warnings 3 to 4 minutes sooner on Associated Press compared to their stand-alone GTE/Contel NWWS.

NOAA Weather Radio (NWR)

There are 386 NWR stations capable of reaching about 90 percent of the people in the United States. Severe weather watches and warnings are preceded by a warning alarm tone. While many EMAs, law enforcement agencies, utilities, schools, and large industries frequently are aware of and utilize NWR, probably less than 25 percent of the general public know of NWR or have a home receiver. Nevertheless, NWR often reaches many people as a voice override on a radar picture on a CATV channel, or other secondary communications systems, including live or taped relay on commercial radio/tv stations.

The Atlanta Journal
THE ATLANTA CONSTITUTION

Doppler system might have given more warning

By Charles Salter
STAFF WRITER 3000AM

The state-of-the-art Doppler radar would have allowed forecasters to issue warnings of approaching deadly storms had they been in place when tornadoes struck Georgia last month, an Atlanta meteorologist said Friday.

"The Doppler radar would give us an additional 10 to 15 or even 30 minutes of warning time as compared to what we are using today," said Carlos Garza, head of the National Weather Service (NWS) forecasting office here. "That certainly would help to save lives due to the fact you have more lead time to get the warning out to the public."

The NWS office in Atlanta will replace its 1974 radar system with the Doppler radar by April 1994.

Mr. Garza commended his forecasting staff Friday as a weather service disaster team held a news conference after completing a survey of several areas of Georgia damaged by tornadoes Nov. 22. They will evaluate the effectiveness of forecasting services, broadcast warnings, and public responses.

The team also visited storm-damaged areas of Texas, North Carolina, Kentucky and Mississippi.

While tornadoes killed six people in Georgia Nov. 22., tornadoes and flash floods claimed 26 lives and injured more than 250 people in five states Nov. 21-23.

Joseph R. Bocchieri of Silver Spring, Md., disaster team coordinator, said the warning system "was accomplished quite well here in Atlanta."

He said, "I think the warnings put out from this office had ample lead time . . . civil defense people reacted appropriately, and TV and radio stations did have time to get the word out."

News Media played key role.

Texas

The WSO Houston NWR station covers eight Counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. There are gaps in the coverage due to the high-rise buildings in the downtown Houston area. Watches and warnings are taped and played on NWR with the tone alert activated. A "Quick Warn" format is not used. The tapes are played until the valid time on the watch/warning expires or until superseded by a Special Weather or Severe Weather Statement or another warning. All indications show that warnings were issued in a timely manner. The WSO keeps a NWR log for the time products were broadcast.

Mississippi

Rankin County is served by the NWR transmitter located in Hinds County (Jackson). Programming originates from WSFO Jackson. The Rankin County EMA Director has an NWR receiver from which he knew of the forecast for severe weather, the Tornado Watch, and the Tornado Warning until 11:30 p.m. for the County adjacent to and southwest of Rankin County. In addition to NWR, he receives weather information via calls from the Sheriff's Office, or MEMA. The Brandon Police Department, some schools, and Fire Departments in the County have NWR. The Rankin County EMA Director "preaches" NWR whenever he gets a chance and wishes more people had a receiver. NWR and radio/TV are the only direct source of weather warnings. A resident in northeast Brandon, next door to the home in which four people died, had NWR, but the unit was not "on" the night of the storm.

WJDS, the Emergency Broadcast Station serving the Jackson area, utilizes NWR. The station Director heard the NWR alarm tone for the tornado warning for Copiah County at his home south of Jackson and decided to come to the office.

Many of the NWR antennae in the state are located on Mississippi Educational Television (ETV) network towers. ETV has an FM radio service which covers a large portion of the state from their towers. MEMA and ETV are talking with the NWS about the possibility of having NWR "override" the ETV FM programming anytime the NWR alarm tone is sounded.

Leake County is served by the Jackson NWR programmed by WSFO Jackson. Webster and Choctaw are served by the Ackerman NWR programmed by WSO Meridian. Kemper County is served by the Meridian NWR programmed by WSO Meridian.

NWR in Mississippi functioned normally. NWR logs were kept. WSFO Jackson normally gives an abbreviated "Quick Warn" on NWR first (type of warning, County, time of expiration), stating additional details will follow soon. These are usually first broadcast live. Once the hard-copy of the warning is available, the "long" version of the warning is recorded.

Georgia

The GEMA does not have NWR in its communication room; however, there is a unit in the Chief of Operations' Office. The Communications Office is able to monitor NWR through the cable system installed in GEMA's communications sections.

All warnings issued by WSFO Atlanta, and WSOs Macon and Athens were disseminated immediately on NWR. WSO Athens kept a log of NWR issuances. Generally, NWS offices kept a severe weather log and attempted to log NWR issuances.

Cobb, Cherokee, and Carroll Counties are served by the Atlanta NWR programmed by WSFO Atlanta. In Cobb County, NWR is one of the main sources of information along with The Weather Channel and GEMA. One citizen interviewed said the radio and TV were off and the house was insulated too well to hear any sirens. He intends to purchase an NWR receiver. During the day of the severe weather, Meteorologist Glenn Burns of TV-2, WSB in Atlanta, held up an NWR receiver and told his audience to "get one." Lumpkin County is not in the service area of any Georgia NWRs.

Putnam County is served by the Macon NWR programmed by WSO Macon. The Eatonton Police Department does not have NWR, yet all the police cars (except 4 older models) have the frequency on their radios. Patrol cars with the Sheriff's Office also have NWR on their scanner. The Eatonton Police Chief, who was out deer hunting, learned of the storm on his scanner with the NWR frequency. The Emergency Medical Services in Eatonton has NWR on their scanner.

Greene County is in the service area of the Athens NWR programmed by WSO Athens. The Athens NWR is monitored by the Sheriff's Office.

Kentucky

The Cincinnati Weather Service Office (WSO CVG) is located in Covington, Kentucky. WSO CVG has one NWR console. The NWR transmitter and antenna are located on a hill in the southern outskirts of Covington with a slightly higher hill to the west somewhat dampening the signals going into southeast Indiana. During this episode the staff used a "Quick Warn" method for getting the warnings out. As soon as the decision is made to issue a warning, a staff member presses the alarm and broadcasts live, "A Tornado Warning has been issued for ... County. Details to follow!" At the same time another staff member using SRWARN composes the warning on a personal computer (PC). Then the alarm is sounded again on the NWR with the completed warning read over the NWR. This has allowed the media to cut their lead time by as much as 2 minutes, because they are able to react faster when hard copies of warnings are received via the NWWS. The local radio and TV personnel all commended the WSO CVG staff for this innovation and the extra lead time it generated.

During the past year, WSO CVG completed a very comprehensive study which lead to improving the NWR broadcast based upon user-expressed needs. Improvements include broadcasting radar and surface reports every 15 minutes and updating damage reports from severe weather and tornadoes during severe weather episodes. These changes have been appreciated by the media and public.

North Carolina

All warnings were issued in a timely manner on NWR from WSOs Greensboro, Charlotte, Asheville, Cape Hatteras, and from WSFO Raleigh. Logs of warning issuances were kept at the WSOs, but not at WSFO Raleigh.

The NWR is an integral part of the public warning system in the Greensboro - Winston Salem area. The Emergency Broadcast System (EBS) is activated for Tornado Watches on request by the NWS. The NWS also telephones the EBS stations and advises them of possible future warnings. The CPCS-1 (Common Program Control Station-1) radio stations and commercial TV stations turn on their NWR receivers and set the tone alert feature. When subsequent Tornado Warnings are issued over the NWR with the "A-burst" (1050 Hz) tone alert signal, the radio and TV stations then record the warnings and activate the EBS system for their listening areas.

WSO Greensboro's County Warning Area has 16 Counties with four CPCS-1 EBS radio stations. The warnings issued over NWR by WSO Charlotte were heard in Fallston, Cleveland County, according to a HAM radio operator. The warnings were also heard over the SKYWARN network in Cleveland County.

Mr. Chip Paterson, Chief of Operations, North Carolina Division of Emergency Management in Raleigh indicated a need for NWR in western North Carolina.

National Warning System (NAWAS)

NAWAS is a voice warning dissemination system operated by the Federal Emergency Management Agency (FEMA). Operational procedures vary from state to state. Because of early warnings in most cases, the 2-day time period over which this outbreak took place, and the availability of NWWS, NWR, EBS, etc., NAWAS did not appear to have been a major or critical factor in the dissemination of weather information during this outbreak.

Texas

In Texas, warnings are rarely read on NAWAS due to the size of the state, the number of NWS offices which could utilize the system, and the traffic it would produce. There is one NAWAS drop in Texas; within that, 60 TEWAS (Texas Warning System) drops are located primarily at Department of Public Safety offices, NWS offices, and (to a lessor extent) at various County offices. WSO

Houston has a drop but it is used infrequently. Very few users have drops on the system, and those that do usually receive the information by some other means.

Mississippi

In Mississippi, watches and warnings are usually read on NAWAS by the NWS. There are 79 NAWAS drops in the state; however, there is not a NAWAS in the Rankin County Sheriff's office or the Rankin County EOC. NAWAS was utilized in its prescribed manner during the tornado event.

Georgia

There are 47 NAWAS drops in Georgia (this includes nine NWS offices that have warning responsibility in Georgia). NAWAS was not available in any of the Counties in which fatalities occurred.

NAWAS is always utilized during hazardous weather events. No problems were registered with any of the equipment used by GEMA during the severe weather episode of November 22.

The GEMA Communications Office is usually staffed with at least two people during inclement weather. Weather information received from the NWS is faxed by GEMA to the Georgia State Patrol and simultaneously broadcast on NAWAS. State Patrol rebroadcasts the information over the National Crime Institute Computer (NCIC .. GCIC for Georgia) to all GSP posts, County sheriffs, and police offices on the system.

Kentucky

WSO CVG has three NAWAS lines (Indiana, Kentucky, and Ohio) which were used extensively during this outbreak. At 4:42 p.m., the Kentucky State Police in La Grange reported a tornado in Trimble County, Kentucky to the WSFO Louisville, Kentucky; this report was heard by WSO CVG. AT 4:45 p.m., WSO CVG issued a Tornado Warning for Carroll County, Kentucky. Additional calls were made for ensuing tornadoes. The calls on the Indiana NAWAS went to the State Police in Versailles, Indiana. Calls on the Ohio NAWAS went to the Ohio State Police at Wilmington, Ohio for the Highland County, Ohio Tornado Warning.

North Carolina

North Carolina uses NAWAS at 41 locations for verbal notification. The North Carolina NAWAS system gives the North Carolina Division of Emergency Management a "heads up" on the tornado warnings and is followed by additional details on the NWWS. NAWAS was used for this tornado outbreak. Calls were made for all WSOs and WSFO Raleigh's warnings to the NAWAS State Warning Point (SWP) for North Carolina over the NAWAS hot line, advising them to get hard copies of the warnings from their NWWS receiver printers. The SWP then

relayed the warnings back to the warned Counties via the Division of Criminal Information (DCI) network. The relaying of warnings from the NWWS of the North Carolina SWP back to the Counties being warned is a manual operation and may delay delivery of warnings by 15 or 20 minutes.

Emergency Broadcast System (EBS)

EBS activation is normally requested by the NWS for Tornado and Flash Flood Warnings. Evidence indicates that EBS worked as planned during this outbreak, but did not play a major role.

Texas

The EBS station in Houston is KTRH; the EBS was activated for this severe weather event. No problems were noted. The news director for KTRH was very pleased with the coordination and information received from WSO Houston.

Mississippi

There are three EBS stations serving the Jackson area (WJDS - AM along with WJDX - FM and WMSI). The News Director of WJDS (Jackson's lead EBS station) said the weekend programming tendency to include more music and less news could result in less advance "build-up" about coming severe weather. Any "outlook" and "watch" information is given with the forecast. WJDS utilizes NWWS and NWR. The warnings received on NWWS "beep" plus a video scroll arrangement is in place for the staff to see the warning text. WJDS always activates EBS when requested by the NWS.

To the DST's knowledge, EBS elsewhere in Mississippi functioned as designed.

Georgia

In years past, Georgia has expressed and demonstrated, perhaps, a conservative trend regarding activation of EBS to avoid "over use" and the "cry wolf" syndrome.

The EBS station serving the Atlanta area is WSB. There was no indication that WSB activated EBS during this severe weather event. WMAZ radio in Macon is the EBS station for Putnam County. A visit was not made to WMAZ, but other information indicates WMAZ does activate EBS when requested. Green County is served by WGAU in Athens. No visit was made to Athens.

Kentucky

In WSO CVG's CWA, there are two EBS stations, WCKY-AM and WLW. WCKY-AM was first called at 4:46 p.m. to activate EBS for the Carroll County, Kentucky

Tornado Warning. According to Brian Combs, of WLW, the EBS from WLW was used two to three times during the tornado outbreak.

North Carolina

In North Carolina, EBS was used. WSFO Raleigh notified various CPCS-1 stations via telephone. The North Carolina Division of Emergency Management said it worked well.

Law Enforcement Teletype System (LETS)

To encourage all states to utilize LETS for relay of weather information to other governmental agencies, the NWS arranged to provide one agency per state with a free NWWS. To a large degree, this works well, with the understanding that Highway Patrol or Emergency Management business, naturally, has first priority. In return for the NWWS, the NWS receives valuable information such as road conditions, flood information, and damage reports.

Texas

In Texas, the gift NWWS went to the Texas Department of Public Safety in Austin. The information on the NWWS is transferred to the Texas Law Enforcement Teletype System (TLETS) for statewide distribution. All the affected Counties in this event received information via TLETS.

Mississippi

The Mississippi Highway Patrol (MHP) Headquarters in Jackson was the recipient of the free NWWS. This has proven very beneficial in relaying NWS warnings and other weather information to decision makers. Via the Mississippi LETS, weather warnings are distributed to each County on the state NCIC (National Crime Institute Computer) thus reaching all Sheriffs' Offices and most Police Departments. The MHP also disseminates a general weather briefing early each morning on LETS. Weather data are not automatically relayed to the Mississippi LETS. It must be retyped. Nevertheless, this system and service has proven to be very beneficial by delivering needed information to Mississippi decision makers. The system performed as designed during this tornado event.

Georgia

The gift NWWS in Georgia went to the GEMA. NWWS data are disseminated by GEMA on the Georgia NAWAS. Passing the data on to other dissemination circuits would require that the information be retyped. At this time there are no plans to automate the relay of the data from NWWS.

The Georgia Highway Patrol obtains its weather information by facsimile or the GEMA radio network. It is then passed on to Sheriff's Offices via the GA Crime

Institute Computer (GCIC). GEMA hopes to become a drop on GCIC and will then be able to enter data.

The Sheriff in Greene County said a GCIC message (in addition to word over the statewide EMA radio band) advised them of the Tornado Watch and Severe Thunderstorm Warning for Greene County. Another way his office knew of the tornado in the area was from 911 calls to his office from nearby Putnam County residents.

There were no known problems associated with the Georgia LETS during this severe weather episode.

Kentucky

In Kentucky, the Department of Emergency Services and Sheriffs receive their weather warning information via NWR, NAWAS and telephone. The Department of Emergency Service's Officers in each County are then contacted by telephone. There is no LETS.

North Carolina

The North Carolina Division of Emergency Management (the state designated weather distribution point) has NWWS, but must manually retype warnings into the State Bureau of Investigation's Division of Criminal Information Circuit. Many law enforcement officials depend on this circuit for receiving weather information. Minutes are lost with this manual transfer of information.

Television/Radio

A survey of more than two dozen weathercasters and news directors in the states hardest hit in the November 21-23 tornado outbreak indicated the broadcast media, including The Weather Channel, and, to an extent, local cable TV operators, generally did a good job alerting the public to the threat posed by the widespread severe storm activity. However, as discussed below, there were some problems.

Starting with dissemination early Saturday, November 21, of severe weather advisories for a multi-state area from NSSFC, the broadcast media kept reminding their viewers-listeners that severe weather was in the area, with the possibility of tornadoes. NWS Tornado Watches and Warnings were broadcast quickly.

A dissemination problem cited by a number of TV broadcasters is that when severe storms occur on weekends or after midnight their viewing audience is small. Radio stations more often stay on late at night, but their night and weekend staffs are dwindling as they become more automated.

Many of the TV broadcasters run "crawl" messages across their screens during regular programming whenever a severe storm watch is issued, as was the case November 21-23. These generally take 5 to 15 minutes to produce and are repeated every 15 minutes.

Most broadcasters rely on NWWS for emergency weather information more than any other service. About two-thirds retain commercial weather services, such as Kavouras. A private weather service in Jackson, Mississippi area uses satellite uplinks to service up to 200 broadcast and other clients.

Most TV and radio broadcasters rely on the Associated Press as a backup information service to NWWS or NWR. Some claimed that weather tends to have lower priority than news dispatches on the wire service, resulting in delays for severe weather messages.

Many of the radio-TV stations canvased have backup power in case of area power failure.

More detailed information for individual states follows.

Texas

Of the media interviewed, five receive their weather information through GE/Contel NWWS; three from NWR; three from Weather Services International; three from Associated Press; one from Universal; one from Accu-Weather; one from Kavouras; and one stated they rely on the EBS station.

All of the five TV stations contacted placed a crawl across their programming; however, they noted that all warnings may not have been placed on the screen during this event. The preempting is selective; some stations are not allowed to run crawls during commercials or certain newscasts.

Neil Frank, meteorologist for KHOU TV, has completed a survey of average time delays between the reception of warnings from the NWS and the dissemination via live transmissions and crawls among the three network stations in Houston. Crawls were used most with an average delay of 15 minutes. The delay in live transmissions was 14 minutes. There are now at least three companies which offer a solution. An incoming warning signal is diverted through a small computer which automatically generates a crawl. The crawl can be sent directly to air, or be stored and monitored before airing. KHOU purchased one of these systems and reduced their delay in transmission to a little over 2 minutes. There have been cases when they were on the air in 30 seconds.

Three radio stations in addition to the EBS station were questioned. The first stated they broke into their programming, a second stated they read weather information once per hour, and the third said they had to call someone in to read the warnings as the D.J. had no time to read them.

Mississippi

The EMA Director in Rankin County stated that there were three Cable TV systems (CATV) serving the area: Rankin County CATV, Capitol CATV in Jackson (Hinds County), and American CATV (no scroll at the bottom of the screen for warnings; but, American CATV does broadcast NWR on Channel 12, 24-hours a day). All the CATV systems carry The Weather Channel. The Hinds County EOC can override some CATV programming in the metro area.

Mississippi ETV (general hours of 9:00 a.m. - 11:00 p.m.) with broadcasts covering most of the state will interrupt regular programming and pass on NWS warnings.

Many radio stations are daytime only. Others reduce power at sunset. Some operate in an "automated or canned" non-staffed fashion. The EBS stations maintain their normal schedules. The Mississippi ETV radio service which covers much of the state will interrupt regular programming to announce NWS warnings.

Georgia

Several people interviewed in Putnam and Greene Counties in Georgia acknowledged learning about the severe weather warnings for their area from watching WMAZ TV Channel 13 in Macon. In Putnam County, TV Channels 2-5-11 in Atlanta and Channels 24 and 41 in Macon also serve the area. The Weather Channel is also available in Putnam County on Southern CATV. The Sheriff in Greene County said his office normally watches WAGA Channel 5 in Atlanta.

Although no count or exact survey is available, radio broadcasts of the severe weather were heard on some stations. Many radio stations in metropolitan Atlanta and other parts of the state utilize NWR. A few have NWWS. The majority depend on the Associated Press wire service for NWS weather messages. Others utilize information from WGST Radio, an NWWS subscriber, in Atlanta. WDEN - AM from Macon serves Putnam County. People buried in their mobile home ruble on River Oaks Drive heard the warning via radio.

Upon its departure from Atlanta, the DST conducted a news briefing which was well attended by television, radio, newspaper, and wire service reporters. Most papers reported a job well done by the NWS, albeit under difficult circumstances with obsolete equipment.

Kentucky

Three TV stations in the Cincinnati area were contacted. All receive their weather information from WSI, NWWS, and NWR with a tone alert. In addition, WLWT-TV uses NOWrad and AP, while WKRC-TV has its own doppler radar. During Tornado Warnings, WKRC and WCPO-TV will break into programming and go live. The "Quick-Warn" format used by WSO Cincinnati on NWR has

enabled the TV stations to reduce their lead time by as much as 2 minutes because they are able to react faster when warning hard copies are received via the NWWS.

Radio broadcasts of the Tornado Warnings were heard on some stations. One station in particular, WLW-AM, provided live briefings from the WSO in Cincinnati.

North Carolina

TV Channel 2 - WFMY (a CBS affiliate in Greensboro) uses STORM ALERT, which is an automated system triggered by NWS warnings. The warnings for this tornado event were shown on TV as a crawl. STORM ALERT also prepared a map, which was displayed on TV, showing the Counties affected by the warnings. Greensboro viewers watching Channel 2 saw the crawl and map display. WSO Greensboro's other two commercial TV stations (Channel 8 - WGHD, an ABC affiliate; and Channel 12 - WXII, an NBC affiliate) do not have automated STORM ALERT, but can prepare crawls manually if personnel are available.

In the Charlotte area, TV Channel 3 - WBTV, Channel 9 - WSOC, and Channel 36 - WCNC all use manually prepared crawls for warnings. WSO Charlotte has the capability of overriding all CATV channels through telephone voice announcements of tornado warnings in the Charlotte area.

In the Raleigh area, TV Channel 11 - WTVD (ABC), Durham's Channel 5 - WRAL (CBS), and Channel 22 - FOX 22 (independent) all have manually prepared crawls and a beeper. In addition, Channel 22 can be activated by NWR tone alert, after which the entire screen displays an emergency message with the voice of WSFO Raleigh's NWR explaining the situation. FOX-22 went off the air at 1:30 a.m. before the Orange County and Johnston County tornadoes.

In all areas serviced by CATV with The Weather Channel, the warnings were displayed by The Weather Channel.

Special Cases

Texas

Public Information Emergency System (PIES) is an official supplemental communication system to the Houston Area EBS. It is comprised of emergency managers and media outlets (21 total). Each location can activate the system with a tone alert, much like that used with NWR. It can be activated for weather events, explosions, toxic spills, or other disasters. WSO Houston uses this for a backup only and did not use it for this event.

Mississippi/Georgia

Both the MEMA and the GEMA have statewide low-band frequency radio networks reaching County EMAs and many law enforcement offices.

MEMA radio is available to about 75 percent of Mississippi EMA offices. This system functioned as designed during the tornado event. MEMA is also developing a state RACES (Radio Amateur Civil Emergency System) high-frequency network which should be in use soon with the goal of having a RACES office in every County.

The GEMA Radio Network consists of six transmitters providing service areas covering 120 Counties. EMA's and law enforcement agencies within range of the signal can receive weather data from this source. The Putnam County Police Department monitors the GEMA radio. Overall, the warning system was efficient and effective. Warnings were disseminated in time for preparedness actions to be taken, as confirmed by the DST and newspaper accounts. Additionally, the media provided good coverage to developing weather events, as well as to those events that were imminently dangerous.

Both MEMA and GEMA have monitors for The Weather Channel and a Kavouras drop showing the Jackson and Atlanta (respectively) NWS radar display.

Kentucky

WSO Cincinnati has a local drop on the Kentucky Emergency Warning System (KEWS). This is a microwave based communication system that is utilized in warning situations. Included on the network are the Kentucky State Police, Department of Military Affairs-Division of Disaster and Emergency Services, Kentucky Educational Television stations, Department of Transportation, National Weather Service, and several other state agencies.

The WSO also has an extensive HAM radio network, Weather Amateur Radio Network (WARN) that not only covers their CWA, but extends out into other areas.

North Carolina

In North Carolina, watches and warnings are coded by County and are distributed on the North Carolina State Bureau of Investigation's Division of Criminal Information (DCI) network. Most of the law enforcement agencies have a drop. The watches and warnings are first received by the North Carolina Department of Emergency Management via the NWWS. They must then be manually retyped on the DCI.

Sirens

There are arguments for and against the effectiveness of sirens as a modern day method of warning people of an emergency situation.

They are not always the best or most feasible warning system. Some of the cons are the high expense (around $15K minimum; 50 percent matching funds from the Government no longer available), maintenance, limited range, and the ability to hear sirens in today's highly insulated houses with the heating/air-conditioning systems and other appliances in operation.

If one is outside, or inside with the TV/radio turned off, sirens offer a means to become aware of something unusual happening, and one is encouraged to turn on the radio, TV, or NWR for additional information.

Texas

In general, warning sirens are not activated for weather events in the Houston area, and WSO Houston is not aware of any activation for this event.

Mississippi

There are five municipalities in Rankin County with outdoor sirens (Florence, Pearl, Richland, Flowood, and Brandon). There are three sirens in Brandon which are activated by the Police Department. The Duncan Mobile Home Park was about 3 miles from the nearest sirens (one woman interviewed by the DST and whose son and family lived there stated the siren could be heard when tested the first day of each month). No central agency has control of the sirens County-wide. Since there was no early warning for southern and central Rankin County, sirens in those sections of the County were not sounded prior to the tornado.

Georgia

There are 48 sirens in place and used in Cobb County near Atlanta. In addition to hearing the warning on radio/TV, one person interviewed by the DST stated the sirens were heard 35-40 minutes before the tornado hit. He was well prepared and had high praise for the warning service. Another person did not receive the warning because the radio/TV was off and the house too well insulated to hear sirens.

There is a siren system in Eatonton, Georgia, (Putnam County). It is activated by the Police Department. However, on Sunday (the day the tornado struck), no one was in the office as all officers were on patrol.

Kentucky

The Cincinnati Airport sirens were sounded at 5:21 p.m. as a tornado approached the airport. Fortunately, the tornado lifted as it passed over the airport.

North Carolina

There is no longer a working siren system in the Greensboro-Winston Salem area. After testing in the 1980s, 90 percent of the sirens were found to be defective. Because the sirens were located in the now relatively deserted center part of Greensboro, and because of lack of adequate funding, the siren warning system was abandoned in the late 1980s.

Fire sirens were sounded for the tornado in Fallston, Cleveland County. Sirens were also activated in Claremont, Catawba County. There was no siren activation for the Hillsborough, Orange County tornado. In Johnson County, sirens were not used.

News Wire Services

The NWS relies heavily on the news wire services and mass media to disseminate our products to their viewers and listeners. Many radio and TV stations must depend on Associated Press (AP)/United Press International (UPI), etc., for their weather information if they cannot afford both the wire service and NWWS. With advance forecasts, public severe weather outlooks, statements, and watches, available to and disseminated by the wire services, information on the severe weather outbreak should have been available to people before they encountered inclement weather.

Texas

Of the eight electronic media polled in the Houston area, three responded that they receive their warning and statement information via AP. No problems were noted.

Kentucky

Radio and TV stations in the Cincinnati area use AP and/or WSI. UPI is contacted in Cleveland when the first warning is issued. No problems were mentioned.

North Carolina

The North Carolina Division of Emergency Management has a continuous WSI display in the emergency operations center showing all the latest information. Most of the news stations receive their information via AP, GTE/Contel, or Kavouras.

FINDINGS AND RECOMMENDATIONS

Finding 6.1: GTE/Contel performed 20 minutes of maintenance on the weather wire system at 3:00 a.m., November 21. Advance notice of this 20 minutes of down time was supplied to users, but no procedure was established to assure there was no weather threat before taking the system down. This shut-down occurred before the start of the outbreak and did not affect dissemination of critical NWS products, but it could have been dangerous if the maintenance had occurred on November 22.

Recommendation 6.1: Routine NWWS maintenance must not be performed when severe weather threatens. NWS must establish a procedure with GTE/Contel to avoid routine outage during critical weather situations.

Finding 6.2: Only manual or semi-automated systems for relay of NWS data to law enforcement officials were in operation in Texas, Mississippi, Georgia, and North Carolina. In North Carolina distribution was accomplished by manually typing products received from NWWS.

Recommendation 6.2: The NWS should encourage state agencies to incorporate automatic relay of NWWS information on LETS so that minutes and possibly lives may be saved.

Finding 6.3: Many people were aware of NWR, but the majority of citizens do not own an NWR receiver.

Recommendation 6.3: The NWS, emergency management officials, the media, etc., should cooperate in promoting NWR. The NWS should increase public education about the NWR system.

Finding 6.4: The North Carolina Division of Emergency Management in Raleigh noted the coverage of NWR in western North Carolina is poor and additional transmitters are needed.

Recommendation 6.4: Investigate NWR coverage in western North Carolina and determine the need and feasibility of installing additional transmitters. Also, investigate coverage nationwide to determine unserviced areas with significant need.

Finding 6.5: WSO Cincinnati received positive feedback with their NWR "Quick Warn" program. Many users stated they believed issuing the warnings with the quick format saved lives.

Recommendation 6.5: Continue using the "Quick Warn" format. Other offices with adequate NWR coverage should consider using this type of broadcast.

Finding 6.6: None of the media in the areas visited utilize WR-SAME (Weather Radio Specific Area Message Encoder) for the automatic "override" of their audio to transmit warnings from NWR.

Recommendation 6.6: Increase efforts to make the media (especially automated radio stations), emergency management agencies, schools, law enforcement officials, etc., aware of WR-SAME and the benefits it provides.

Finding 6.7: The EBS serving the Texas, Mississippi, Georgia, and North Carolina areas appears to have performed well.

Finding 6.8: Television stations commonly used either text crawls or "live" broadcasts to alert the public to impending severe weather. In many instances, the crawls were produced manually resulting in delayed dissemination to the public.

Recommendation 6.8: The NWS should encourage TV stations to increase the use of the automatic production of text crawls.

Finding 6.9: Leading radio news people in two states stated that because of a budget squeeze many radio stations forego NWWS and rely on the Associated Press (AP) for weather and other news. They observed that AP gives priority to hard news stories and scheduled daily summaries and weather alerts are apt to be held up.

Recommendation 6.9: At national, regional and state capitol levels, NWS should discuss this assertion with AP leaders.

Finding 6.10: The media often does not break into certain programming even for urgent weather messages. Television stations may limit the time a crawl can be broadcast. Automation of radio stations leave limited personnel available to broadcast critical weather information.

Recommendation 6.10: The NWS should point out the importance of the media's role in delivering warnings, and stress the need to avoid limiting times that information can be broadcast. The NWS should also promote use of new techniques like WR-SAME and electronic switching systems that help deliver critical messages in seconds.

CHAPTER 7

USER RESPONSE

The DST conducted a number of interviews with people involved in the tornadic outbreak. These included the general public who were in the storms' paths, media personnel, and emergency management and law enforcement officials.

Most of those interviewed were aware of the forecast, watches, and/or warnings for severe weather in their area. Television and radio were the primary sources for weather information while sirens and NWR also played a role. Even without the presence of a warning in some instances, many people responded appropriately to the dangerous storms (by seeking shelter on lower floors or interior rooms such as a bathroom). In areas where the stormy weather occurred during daylight hours, those in harms way could better assess the degree of danger in order to take safety actions. However, where tornadoes struck at night (in Mississippi, for example where tornadoes struck between 11:30 p.m.-3:30 a.m.), it was difficult for people to recognize the danger.

Comments from those interviewed by the DST are presented below.

Emergency Managers

Texas

A consensus of the emergency managers questioned were happy with the information they received. They stated that they received "plenty of warning" and "good information." They felt the short format (several lines) severe weather and special weather statements were extremely helpful to update the situation.

Harris, Brazoria, and Ft. Bend Counties increased staffing as a result of the watches/warnings associated with this tornado event. It is standard procedure for the Counties to augment staffing.

Mississippi

The DST interviewed the new, part-time Emergency Management Director of Rankin County, Mr. Charlie Wilkinson. Mr Wilkinson was in the process of establishing an EMA office in Rankin County. The EOC had no communications system (no CD radio) or staff. Emergency information generally comes from the Hinds County EOC, Jackson media, contacts with WSFO Jackson, CATV, and The Weather Channel. Ultimately, the Rankin County EOC wants to improve the County's ability to feedback severe weather reports to WSFO Jackson.

Mr. Wilkinson receives warnings by listening to the Jackson NWR, or gets a call from the Rankin County Sheriff's Office or MEMA. He was aware of the Tornado Warning valid 11:30 p.m. for Copiah County which borders on the southwest corner of Rankin County. He placed no blame on the NWS for the lack of a specific warning for Rankin County. He acknowledged that there had been a forecast of severe thunderstorms all day and that a tornado watch was in effect for the area. He feels services will be improved once the EOC is staffed and has communications, and the NWS WSR-88D is operational.

The next visit was with Mr. Leon Schaffer, Deputy Director of MEMA headquartered in Jackson. Mr. Schaffer stated that from an operational perspective he understands the NWS system and knows what our equipment capabilities are. He is trying to establish a statewide warning system for MEMA and the NWS, instead of relying as much on local governments for this function. Mississippi has 82 Counties, and resources vary in each (38 of the 42 Counties in WSFO Jackson's County Warning Area lack resources, like Rankin County). Mississippi ETV may help in the statewide warning capability, using their statewide FM radio network. Mr. Schaffer stated storm spotter networks are invaluable.

The Duty Officer at MEMA called WSFO Jackson around 4:00 p.m., Saturday, November 21 for the forecast and weather status (severe storms forecast with a tornado watch likely later in the evening). MEMA contacted their Deputy Director around 8:15 p.m. as the stormy weather began. MEMA opened their office at 8:50 p.m.

Georgia

In a visit to Putnam County, Police Chief Kent Lawrence was interviewed. Chief Lawrence had been out deer hunting but heard of the storm on his scanner, which picks up NWR, in his personal car. All police cars, except the older models, have the ability to pick up NWR. His office does not have an NWR receiver (they are served by the Macon NWR). They do monitor the GEMA radio frequency. He did not have NAWAS. The Weather Channel is available on Southern CATV along with statements from WSO Macon. He said Eatonton has a siren system. It is activated by his office, but, on Sundays (the day the storm struck), no one is in the office. All are out on patrol. The area monitors/receives TV-13 (WMAZ from Macon).

In Greene County, DST members stopped by the Sheriff's office in Greensboro, Georgia. Sheriff J. Finch stated they monitor the Athens NWR and usually watch TV-5 in Atlanta for their weather. A GCIC (Georgia Crime Information Center) message advised them of the Tornado Warning in effect for their area. He also heard the warning over the statewide Sheriff's Office's band. Numerous 911 calls were also received from Putnam County residents. Nevertheless, he stated the storm hit quick.

In a visit to the GEMA, DST members spoke to Mr. Gary McConnel, Executive Director, and with Mr. Bob Miles and Mr. Lawrence Thompson. Mr. Thompson said he spoke with many media during and after the day of the tornado and indicated EBS worked well. He feels that the effectiveness of sirens vary (common sentiment). Mr. McConnel stated the NWS did well during this severe weather outbreak. WSFO Atlanta alerted GEMA officials around 7:00 a.m., Sunday, November 22, that severe weather was likely over Georgia during the day. Based on this information, GEMA called-in an extra person to work. The communications center is open 24-hours per day and is normally staffed with two people.

In a visit to the Cobb County EOC, DST members interviewed Mr. Larry White, Assistant to the Chief, who indicated the NWS provided great service in this event. The County has 48 sirens, which were sounded about 30 minutes before the event. The County EMA has a good community outreach program to inform public about warnings from sirens and actions public should take. The EOC has a NWR, which is the main means of getting NWS warnings. Information is also received from GEMA and The Weather Channel. The EMA has a very good working relationship with WSFO Atlanta.

Kentucky

During a storm survey conducted by staff at WSO Cincinnati, Gary Wentworth, Director of Emergency Services (DES) of Switzerland County, Indiana was contacted. Mr. Wentworth recalled seeing the tornado many miles away. "It looked like two or three tornadoes wrapping around each other at first." The NWS investigation later concluded by the damage in Carroll County that this was indeed a multi-vortex tornado. He also noted there was little warning before the touchdown, but he heard over the radio Tornado Warnings were in effect for Carroll County, and then Switzerland County. He noted that the tornado crossed the Ohio River just after 5:00 p.m. and seemed to slow down as it moved through the County. Switzerland County Sheriff Deputies noted that it crossed the Ohio River a second time near the Ohio-Switzerland County border into Boone County.

Bary Lusby, Director of Emergency Services of Owen County, was interviewed over the phone regarding damage in southern Owen County. He noted none of the people in the field ever saw the second tornado in southern Owen County. "We were all looking at the huge tornado over Carroll County. It was absolutely textbook--rotating wall cloud on the southwest side of the storm, no rain near the tornado, and wind rushing into the tornado from our backs." He received the call about the second tornado around 6:00 p.m. and also about the damage on the Owen-Henry County line. County Sheriffs proceeded to both sites and found only very light damage in southern Owen County. There was no evidence of a tornado near Gratz Kentucky. "I was hoping we didn't get what we kept hearing out of Carroll County on the police radio." He also mentioned that he appreciated the effort the NWS put forth during the event.

North Carolina

The Orange County Emergency Manager was happy with the warning. He believed the NWS did all it could. He commented that the NWS has been more proactive since 1984.

The HAM radio coordinator was very pleased with NWS cooperation.

As a part of the survey, two DST members visited the North Carolina Division of Emergency Management in Raleigh. Interviewed were Joe Myers, Director of State Division of Emergency Management and Chip Patterson, Chief of Operations. Both individuals were happy with the NWS support. They had been in contact with the WSFO early in the day and were prepared for the event.

Two DST members also visited the EOC in Johnson County, North Carolina where they met with Dewayne West. He knew about the Tornado Watch from the NWWS. He had been called at 4:30 a.m. after a tornado had touched down near his sister's home, and he was already preparing to respond.

Media

Weather reporters and news directors were generally complimentary of the information received from NWS offices.

Broadcasters generally lauded NWR. They recommended that NWS conduct a national public awareness campaign to encourage people to own NWRs, especially residents of trailer parks. Several volunteered to help NWS with such an effort.

An often-reported recommendation by the media was the need for more public education on severe storms. Watches should be emphasized more than they are. People should be taught to start planning their moves as soon as a watch is issued, not wait for a warning. A number volunteered to help with such an effort. This idea was discussed in two states, coupled with promotion of NWR ownership.

One radio news director, Randy Bell of WJDS, Jackson, Mississippi, suggested the need for signing up more radio stations on the NWWS because many of them opted for news wire services, which are much slower than NWWS, as their prime alert. His station serves as the EBS outlet for 14 Counties. He would appreciate interim statements from NWS, between warnings, on the storm's changing positions. He suggests that in the southern states ice storms are, for individuals on the move, next most dangerous to tornadoes in deaths and injuries.

Texas

The news director at KTRH, the CPCS-1 station, was very pleased with the coordination and information received from WSO Houston.

Mississippi

In Mississippi, the media were generally very positive and supportive of NWS performance. David Hampton, the Editorial Director of the Clarion-Ledger in Jackson spent 45 minutes with DST members offering to do a special on the coming WSR-88D. Mr. Burt Case, WBLT TV-3 News Director, offered help in promoting the NWR, while expressing concern for the lack of County HAM and spotter organizations.

Channel 3, in its special report, featured an Emergency Management Official in support of the NWS performance.

Mr. Randy Bell, Director of the Jackson area EBS station WJDS-AM/WJDX-FM, spoke with DST members. They have NWWS (alarm beeps on warnings plus a video scroll arrangement is in place to see the warning text). EBS is also activated on WMSI Radio (three stations total). NWR is in the WJDS newsroom as backup. He heard the NWR alarm tone for the tornado in Copiah County and came in to the office.

Both print and broadcast media in Mississippi, including the Associated Press whose release was carried nationally, reported that Jackson suffered with a 35-year-old radar, but that a new Doppler radar is about to be erected there.

Georgia

At WSFO Atlanta, the DST conducted a news briefing which was well attended by television, radio, newspaper and wire services reporters. Most papers reported a job well done by the NWS, albeit under difficult circumstances with obsolete equipment.

Kentucky

The media seemed very pleased with changes made in the past 2 years. The MIC has been on station about 2 years and has apparently established an excellent rapport with the media. Several media contacted indicated they had noticed a marked improvement in services since the MIC's arrival.

North Carolina

Of the three local television stations in the Raleigh-Durham area, only the weathercaster at WTVD stayed on the air through the night. He felt there was good information flow and the products were timely and concise. They broke into programming with statements and warnings. He believed the watches brought awareness to the area. The feedback he received was all positive. Many people remembered the 1988 event, i.e., it "felt" like it did prior to the tornado event in the Raleigh area in 1988. He received one telephone call where the caller stated he believed the warnings saved his family's lives. Unfortunately, the other TV

stations in the Raleigh area were not on the air. They terminated their normal broadcast before the Orange County tornado occurred.

Public Response

Texas

Several citizens in the Channelview section of Houston, Texas where an F4 tornado had devastated a multi-block area were interviewed. Most had been aware of the possibility of tornadoes from their own knowledge of local weather or from the radio and TV forecasts. Those who were listening to radio or television heard the Tornado Warnings. Those who were busy with outside activities or shopping did not hear the warnings. However, those in the vicinity of the tornado all described its intense blackness, the roaring sounds of freight trains and the debris funnel. The tornado was clearly visible. Many Houston citizens have been trained since third grade on the correct actions to take during tornadoes, and, in all cases, they saved their own lives. The most dramatic story was from a mother who went shopping 30 minutes before the tornado hit leaving her five children in the house. The oldest upon realizing the tornado was headed their way sent three youngsters under the bed, and two hid in the closet. Although the house was badly damaged they escaped unscathed.

Mississippi

In a visit to Duncan Mobile Home Park near Brandon, DST members talked with Mrs. Maxine Roberts. Her son's tied-down mobile home was destroyed. It was so hot that she and others realized bad weather was coming. Her son, his wife, and their child were not at home. He has an NWR which she gave them. Mrs. Roberts was listening to radio (WMSI 103 FM) and never heard a Tornado Warning for Rankin County. She felt that if there had been a warning people could have taken some lifesaving action. She stated they could hear the Whitfield, Mississippi, siren when it is tested the 1st day of each month.

There was one house destroyed at the Duncan Trailer Park. The 22-year-old woman who lived there had a storm cellar less than 50 ft from her bedroom, but she never got to the cellar. She was thrown by the storm to a lake about 1/4 mile away.

The next location visited was the Easthaven area in northeast Brandon north of I-20 where four people died in a two-story brick home. DST members spoke with Mr. Nick Nickalson the next door neighbor. His microwave clock stopped at 11:52 p.m. He had an NWR receiver but it was turned off. He was unaware of the bad weather, but he knew it was abnormally hot for this time of the year. He had to hold on to the rug to keep from being blown away. He heard Ann his next door neighbor screaming for help. She lost her husband, son, and two of his young friends who were spending the night (all Cub Scouts .. a campout had been

cancelled due to the weather). They were all upstairs coming downstairs. Mr. Nickalson said the sirens in Brandon can be heard "if the wind is blowing right."

Georgia

Damage was surveyed along River Oaks Drive near Eatonton. In one area where there was extensive damage, some of the residents were interviewed. Mr. and Mrs. Joe Faulk were buried under the rubble of their "tied-down" mobile home. There was not much rubble left of the "not-tied-down" mobile home next to their's. They heard of the tornado sighting in Putnam County on WDEN - AM radio in Macon. They did not see the tornado which lasted about 30 seconds. There are no shelters in their area.

Mrs. Martha Smith and Mrs. Darlene Roberts (both with the Georgia State Social Services who were talking to the Faulks) also spoke with DST members. Mrs. Smith said she listened to the Macon NWR on a scanner. Mrs. Roberts had gone shopping. Her husband and daughter heard the warning, accompanied by a beep-tone, for Putnam County on TV and went to their hallway for protection. Both ladies acknowledged that if people had been watching the Atlanta media or a station via satellite dish they would not likely have gotten the warning for Putnam County. CATV presents a mixed bag in their view in terms of getting weather data.

Mr. James Gregory, Director, Putnam County Emergency Medical Services (EMS) and Mr. Troy Reynolds, Fire Chief, Putnam County Fire Department spoke with members of the DST. Mr. Gregory said he saw the tornado and heard a never-ending loud roar like thunder. He lives about 1/2 mile from the tornado path near Lake Oconee. Both Mr. Gregory and Mr. Reynolds would like the WSFO Atlanta to contact them about a new/upgraded spotter training session. This request was passed on to the WSFO Atlanta.

The DST then travelled to the Sheriff's Office and spoke with Mrs. Cherry Batchlor and Mrs. Dianne Pharm. Mrs. Pharm said she had just come in from shopping and saw the tornado. She had developed a safety plan and put it into action. She and her daughter left their home (which she did not trust in a major storm) and sought shelter in the ditch by the railroad track. She said she learned about safety rules in school and from watching TV.

In a visit to Cobb County, northwest of Atlanta, DST members spoke to two residents in Kennesaw. One resident indicated the tornado hit about 12:10 p.m. Trees went down around his home. He felt pressure on his house and in his ears but did not actually see the tornado. He heard of the Tornado Warning on radio and television. Also, the sirens sounded 35 to 40 minutes before the tornado hit. He was well prepared and had high praise for warnings.

The other resident did not see the tornado but saw a wall of water. He did not have radio or TV on and did not hear the sirens (his house was well sealed). He

was not aware of warnings, but the weather just didn't feel right. He did not have a NWR but will buy one.

Kentucky

The only fatality in Kentucky was a woman, who despite the urging of five friends and relatives, decided to remain in her mobile home rather than seek shelter. She was killed, but the others survived. They all knew about the Tornado Warning 5 minutes before it struck and had time to find adequate shelter.

Several people were interviewed who live in a cluster of four mobile homes which sustained a direct hit in Posey Township. One of the residents had just finished building an underground shed and tornado shelter this past summer. One woman commented that she was on the phone with her sister when the Tornado Warning was issued. She told us, "I'm gone!" and went to the other mobile homes to get everyone else out. "It was so scary. You could see it coming right for us! We went into the shelter and closed the door. About 4 or 5 minutes later, we heard the freight train sound. It was all over so fast!" When they came out of the shelter, one mobile home was completely destroyed, and another was heavily damaged.

North Carolina

In the Hillsborough area of Orange County, where two fatalities occurred, a resident, Mr. Bob Rabil, heard the Severe Thunderstorm Warning on NWR about 2:00 a.m. He awakened his wife, and they rushed to a crawl space beneath his home for shelter. Later they heard the roar of the tornado as it passed by. Mr. Rabil is an avid NWR listener and an amateur weather forecaster. He was extremely complementary of the job that WSFO Raleigh did during the event. He commented that the NOVA program (about tornadoes) which aired several weeks prior to the event help him recognize the "signs" of possible severe weather.

There were several others interviewed at the Hillsborough damage site. The general response was that they did not know a tornado was coming. They knew there was a watch in effect and there was the potential for tornadoes, but they had also heard the Tornado Watch was due to expire at 1:00 a.m. So, they went to bed. The watch was extended at 12:19 a.m. and expanded eastward. The event occurred about 2:20 a.m.

FINDINGS AND RECOMMENDATIONS

Finding 7.1: In general, people were aware of and responded properly to the threat of inclement weather in their area. Most first utilized the media to obtain weather information. Then, personal, visual confirmation verified the absence or presence of actual danger before safety measures were taken. These factors worked less effectively where there were no warnings, people were asleep, or were

primarily in mobile homes. In those areas where an actual warning may not have been in effect, forecasts, watches, and warnings for nearby areas usually indicated the threat of severe weather.

Finding 7.2: In Houston, the users felt that the short format (several lines) severe weather and special weather statements were extremely helpful to update the situation.

Recommendation 7.2: Continue using these types of statements to update the event and encourage other NWS offices to act similarly.

Finding 7.3: Some users felt that more emphasis should be given to warning messages for situations that are particularly certain and dangerous (e.g. confirmed tornado in highly populated area).

Recommendation 7.3: The NWS should explore ways to more effectively convey the urgency and serious nature of the warning message during especially high threat situations.

APPENDIX A

FUJITA TORNADO INTENSITY SCALE

Category	Definition--Effect
(F0)	Gale tornado (40-72 mph): Light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards.
(F1)	Moderate tornado (73-112 mph): Moderate damage. The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads.
(F2)	Significant tornado (113-157 mph): Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
(F3)	Severe tornado (158-206 mph): Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
(F4)	Devastating tornado (207-260 mph): Devastating damage. Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
(F5)	Incredible tornado (261-318 mph): Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile sized missiles fly through the air in excess of 100 yards; trees debarked; incredible phenomena will occur.

APPENDIX B

OVERALL PERFORMANCE STATISTICS

The statistical analysis is based on the standard procedures of the NWS. The national warning verification program uses a "generic concept" to verify warnings. In the case of severe local storms, this means tornado or severe thunderstorm warnings are verified by either tornado or severe thunderstorm events. Likewise, tornado or severe thunderstorm events are covered by either tornado or severe thunderstorm warnings. In addition, separate tornado and severe thunderstorm statistics are presented to further delineate the NWS's ability to distinguish between the two types of warnings.

The basic unit of warning for tornadoes and severe thunderstorms is the County. In the statistical analysis, a warning that covers three Counties is counted as three "warned areas." At least one severe event occurring during the valid period of a warning in a warned County produces a "verified warning."

The statistical measures applied to severe local storm warnings are warning accuracy, false alarm rate, and lead time. Warning accuracy is the percent of Counties that had a severe local storm while a warning was in effect. The false alarm rate is the percent of Counties warned that did not have severe weather. The lead time is the time from the issuance of a warning until the beginning time of a severe weather event. A tornado or severe thunderstorm that occurred without warning is assigned a lead time of zero.

The outbreak produced 254 severe weather events: 151 tornado, 27 hail, and 76 thunderstorm wind. There were 12 killer events, 65 that produced injuries, and 58 that caused at least $500,000 in damage, virtually all the result of tornadoes. In fact only three of the 103 severe thunderstorm (hail and wind) events resulted in injuries and none in deaths or significant damage. The data are summarized in Table B1.

Table B1. Shows the number of events covered by either a tornado or severe thunderstorm warning. The percentage of total events in a warning is in parentheses.

Events	*Tornado*	*Severe Thunderstorm*	*Total*
All Events	113 (75)	85 (83)	198 (78)
Killer Events	9 (75)	-- (--)	9 (75)
Injury Events	49 (82)	5 (80)	54 (83)
Damage Events	49 (84)	-- (--)	49 (84)

Of the 254 severe weather events, 198 were in a severe weather warning, for a warning accuracy of 78 percent. The average lead time for these events was 20 minutes. For those events that caused deaths, injuries, and significant damage, the warning accuracy was 75, 83, and 84 percent, respectively. Table B2 shows results when the two types of warnings are separated.

Table B2. Shows the number of events covered by the proper warning (i.e., tornado event covered by a tornado warning and severe thunderstorm event covered by a severe thunderstorm warning). The percentage of total events are in parentheses.

Events	*Tornado*	*Severe Thunderstorm*	*Total*
All Events	74 (49)	60 (58)	134 (53)
Killer Events	4 (33)	-- (--)	4 (33)
Injury Events	30 (50)	3 (60)	33 (51)
Damage Events	31 (53)	-- (--)	31 (53)

Overall, the results shown in Tables B1 and B2 were better than the average based on severe weather statistical data from the three previous years.

The outbreak provided a chance to compare performance at a weather office equipped with a NEXRAD radar with stations using conventional radar data. WSO Houston, Texas, had its WSR-88D operating at the time of outbreak. The performance statistics for Houston were the best among all those office involved in the outbreak. The numbers are more dramatic considering the performance of the other offices was already better than average and Houston did not have the advantage of being downstream from where the activity began. The numbers are summarized in Table B3. In addition, average lead time for warned events improved to 25 minutes.

Table B3. Same as Table B2, except for WSO Houston only.

Events	*Tornado*	*Severe Thunderstorm*	*Total*
All Events	15 (88)	1 (100)	16 (89)
Killer Events	-- (--)	-- (--)	---(--)
Injury Events	6 (100)	-- (--)	6 (100)
Damage Events	7 (100)	-- (--)	7 (100)

Statistics on watches separated by type of event are given in Table B4.

Table B4. Shows the number of events covered by watches. The percentage of total events is in parentheses.

Events	*Tornado*	*Severe Thunderstorm*	*Total*
All Events	146 (97)	97 (94)	243 (96)
Killer Events	11 (92)	-- (--)	11 (92)
Injury Events	56 (93)	5 (100)	61 (94)
Damage Events	56 (97)	-- (--)	56 (97)

APPENDIX C

Chronology of Selected Products

I. WATCHES

NNNN>##<A
<ZCZC MKCSEL4
E:292.0913 341.0911 341.0881 292.083:WWUS9 KMKC 220225
MKC WW 220225
LAZ000-MSZ000-ARZ000-220900-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 914
NATIONAL WEATHER SERVICE KANSAS CITY MO
825 PM CST SAT NOV 21 1992

A..THE NATIONAL SEVERE STORMS FORECAST CENTER HAS ISSUED A TORNADO WATCH FOR

PORTIONS OF SOUTHEAST LOUSIANA
A LARGE PART OF MISSISSIPPI AND
PORTIONS OF SOUTHEAST ARKANSAS
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS SATURDAY NIGHT AND SUNDAY MORNING UNTIL 300 AM CST.

THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES. ALSO..LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING THUNDERSTORM WINDS CAN BE EXPECTED.

THE TORNADO WATCH AREA IS ALONG AND 85 STATUTE MILES EAST AND WEST OF A LINE FROM 40 MILES EAST SOUTHEAST OF HOUMA LOUISIANA TO 55 MILES NORTH NORTHEAST OF GREENWOOD MISSISSIPPI.

REMEMBER...A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE WARNINGS.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 2 IN. EXTRM TURBC AND SFC WND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO 560. MEAN WIND VECTOR 23035.

D... STG/SVR TSTMS TO CONT TO DVLP AND MOVE RPDLY NEWD AHD OF CDFNT AND ASSOCD VIGOROUS UPR TROF. 85KT PROGD MID LVL WND FIELD COUPLED WITH 40/50 KT SELY LOWER LVL WND FIELD WL PROVD FVRBL SPD/DIR SHEAR TO SUPPORT ISOLD TORNADIC ACTVTY OVER NIGHT. STG SFC PRESSURE FALL/RISE COUPLET TRKG ENEWD TWD CNTRL MS. NEW ERL PROGS SUG ACTVTY WL CONT SVR MOST OF NIGHT.

E...OTR TSTMS... CONT WW 913.

...ANTHONY

NNNN>##<A
<ZCZC MKCSEL6
E:305,0862 363,0854 363,0830 305,0834:WWUS9 KMKC 221229
MKC WW 221229
TNZ000-ALZ000-NCZ000-GAZ000-221900-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 916
NATIONAL WEATHER SERVICE KANSAS CITY MO
729 AM EST SUN NOV 22 1992

.A..THE NATIONAL SEVERE STORMS FORECAST CENTER HAS ISSUED A
TORNADO WATCH FOR

PORTIONS OF EASTERN ALABAMA
A LARGE PART OF WESTERN AND NORTHERN GEORGIA
PORTIONS OF MIDDLE AND EASTERN TENNESSEE
AND A SMALL PART OF WESTERN NORTH CAROLINA

FROM 830 AM UNTIL 200 PM EST EST THIS SUNDAY MORNING AND
AFTERNOON.

THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY
DAMAGING TORNADOES. ALSO..LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING
THUNDERSTORM WINDS CAN BE EXPECTED.

THE TORNADO WATCH AREA IS ALONG AND 75 STATUTE MILES EAST AND WEST
OF A LINE FROM 35 MILES SOUTHEAST OF DOTHAN ALABAMA TO 55 MILES
NORTH NORTHWEST OF KNOXVILLE TENNESSEE.

REMEMBER...A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR TORNADOES
AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE
AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND
LISTEN FOR LATER STATEMENTS AND POSSIBLE WARNINGS.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 1 IN. EXTRM TURBC
AND SFC WND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO 450. MEAN WIND
VECTOR 23035.

D... BAND OVR SVR TSTMS PRODUCING DMG WINDS AND TORNADOES IS EXPCD
TO CONT INTENSE AS IT MOVS EWD AND BUILDS NWD. WRM FNT IS MOVG N
OF ATL AND AHN AND IS LKLY TO MOV NWD INTO TN AND NC WITH TIME.
WIND FIELDS ON 12Z RAOBS ARE EXTRMLY STG...ENHANCING THE SHEAR NECESSARY FOR
SUPERCELL DVLPMT. CHC OF DMGG TORNADOES WITH STGR CELLS.

E...OTR TSTMS... CONT VALID PTN OF WW NR 915.

...JOHNS

II. COUNTY REDEFINING STATEMENTS

A. Mississippi

-- KJAN 220237

AREAL OUTLINE FOR TORNADO WATCH NUMBER 914
NATIONAL WEATHER SERVICE JACKSON MS
832 PM CST SAT NOV 21 1992

IN MISSISSIPPI
THIS WATCH INCLUDES 72 COUNTIES...

MSC011-013-015-017-019-025-027-043-057-071-081-083-087-095-097-
105-107-115-119-133-135-151-155-161-220900-
IN NORTH MISSISSIPPI 24 COUNTIES...

BOLIVAR	CALHOUN	CARROLL	CHICKASAW
CHOCTAW	CLAY	COAHOMA	GRENADA
ITAWAMBA	LAFAYETTE	LEE	LEFLORE
LOWNDES	MONROE	MONTGOMERY	OKTIBBEHA
PANOLA	PONTOTOC	QUITMAN	SUNFLOWER
TALLAHATCHIE	WASHINGTON	WEBSTER	YALOBUSHA

$$

MSC007-021-023-029-049-051-053-055-061-063-069-075-079-089-099-
101-103-121-123-125-127-129-149-159-163-220900-
IN CENTRAL MISSISSIPPI 25 COUNTIES...

ATTALA	CLAIBORNE	CLARKE	COPIAH
HINDS	HOLMES	HUMPHREYS	ISSAQUENA
JASPER	JEFFERSON	KEMPER	LAUDERDALE
LEAKE	MADISON	NESHOBA	NEWTON
NOXUBEE	RANKIN	SCOTT	SHARKEY
SIMPSON	SMITH	WARREN	WINSTON
YAZOO			

$$

MSC001-005-031-035-037-039-041-045-047-059-065-067-073-077-085-
091-109-111-113-131-147-153-157-220900-
IN SOUTH MISSISSIPPI 23 COUNTIES...

ADAMS	AMITE	COVINGTON	FORREST
FRANKLIN	GEORGE	GREENE	HANCOCK
HARRISON	JACKSON	JEFFERSON DAVIS	JONES
LAMAR	LAWRENCE	LINCOLN	MARION
PEARL RIVER	PERRY	PIKE	STONE
WALTHALL	WAYNE	WILKINSON	

...AND ADJOINING COASTAL WATERS OF THE FOLLOWING COUNTIES:-
HANCOCK HARRISON JACKSON

$$

B. Georgia

ETTAA00 KATL 221251

AREAL OUTLINE FOR TORNADO WATCH NUMBER 916
NATIONAL WEATHER SERVICE ATLANTA GA
830 AM EST SUN NOV 22 1992

IN GEORGIA
THIS WATCH INCLUDES 99 COUNTIES...

GAC015-045-047-055-057-063-067-077-083-085-089-097-111>117-121-
123-129-135-143-149-151-213-223-227-233-247-255-295-313-221900-
IN NORTHWEST GEORGIA 31 COUNTIES...

BARTOW	CARROLL	CATOOSA	CHATTOOGA
CHEROKEE	CLAYTON	COBB	COWETA
DADE	DAWSON	DEKALB	DOUGLAS
FANNIN	FAYETTE	FLOYD	FORSYTH
FULTON	GILMER	GORDON	GWINNETT
HARALSON	HEARD	HENRY	MURRAY
PAULDING	PICKENS	POLK	ROCKDALE
SPALDING	WALKER	WHITFIELD	

$$

GAC053-145-171-193-197-199-215-231-249-259>263-269-285-293-307-
221900-
IN WEST CENTRAL GEORGIA 16 COUNTIES...

CHATTAHOOCHEE	HARRIS	LAMAR	MACON
MARION	MERIWETHER	MUSCOGEE	PIKE
SCHLEY	STEWART	SUMTER	TALBOT
TAYLOR	TROUP	UPSON	WEBSTER

$$

GAC007-037-061-087-095-099-131-177-201-205-239-243-253-273-221900-
IN SOUTHWEST GEORGIA 14 COUNTIES...

BAKER	CALHOUN	CLAY	DOUGHERTY
DECATUR	EARLY	GRADY	LEE
MILLER	MITCHELL	QUITMAN	RANDOLPH
SEMINOLE	TERRELL		

$$

GAC027-071-275-277-287-321-221900-
IN SOUTH CENTRAL GEORGIA 6 COUNTIES..

BROOKS	COLQUITT	THOMAS	TIFT
TURNER	WORTH		

$$

GAC021-079-081-093-153-169-207-225-235-289-315-221900-
IN CENTRAL GEORGIA 11 COUNTIES...

BIBB	CRAWFORD	CRISP	DOOLY
HOUSTON	JONES	MONROE	PEACH
PULASKI	TWIGGS	WILCOX	

$$

GAC011-013-035-059-119-137-139-157-159-187-195-211-217-219-237-
241-257-281-291-297-311-221900-

IN NORTHEAST GEORGIA		21 COUNTIES...	
BANKS	BARROW	BUTTS	CLARKE
FRANKLIN	HABERSHAM	HALL	JACKSON
JASPER	LUMPKIN	MADISON	MORGAN
NEWTON	OCONEE	PUTNAM	RABUN
STEPHENS	TOWNS	UNION	WALTON
WHITE			

$$

THIS WATCH INCLUDES THE FOLLOWING CITIES AND SURROUNDING AREAS...
ATLANTA...ROME...COLUMBUS...ATHENS...MACON...AND ALBANY

AMATEUR RADIO AND OTHER SPOTTERS ARE REQUESTED TO MONITOR
THIS WEATHER SITUATION AND RELAY REPORTS PROMPTLY TO THE
NEAREST NATIONAL WEATHER SERVICE OFFICE.

$$

III. STATEMENTS AND WARNINGS

A. Houston, TX

NNNNZCZC SATSPSHOU
ETTAA00 KHOU 211613
TXZ032-037-045>047-049-211800

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE HOUSTON TX
1013 AM CST SAT NOV 21 1992

...STRONG DAMAGING WINDS...HAIL AND TORNADOES ARE POSSIBLE LATER THIS AFTERNOON OVER SOUTHEAST TEXAS...

AT 10 AM...A FAST MOVING COLD FRONT WAS MOVING INTO CENTRAL TEXAS AND WAS PRODUCING A LINE OF SHOWERS AND THUNDERSTORMS STRETCHING FROM WACO TO AUSTIN. AS THIS LINE OF SHOWERS AND THUNDERSTORMS MOVES INTO SOUTHEAST TEXAS LATER TODAY SOME OF THESE THUNDERSTORMS COULD BECOME SEVERE PRODUCING STRONG DAMAGING WINDS...HAIL AND POSSIBLE TORNADOES.

YOU SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER AND STAY TUNED TO NOAA WEATHER RADIO...TELEVISION AND OTHER NEWS SOURCES FOR THE LATEST UPDATES. LOCAL EMERGENCY MANAGERS AND SKYWARN BE PREPARED FOR ACTIVATION.

ZCZC SATTORHOU ALL 212215
TTAA00 KHOU DDHHMM
TXC201-212215-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE HOUSTON TX
311 PM CST SAT NOV 21 1992

THE NATIONAL WEATHER SERVICE IN HOUSTON HAS EXTENDED THE TORNADO WARNING UNTIL 415 PM CST
FOR PEOPLE IN THE FOLLOWING LOCATION.....

IN SOUTHEAST TEXAS

...HARRIS COUNTY

THE TORNADO WARNING FOR HARRIS COUNTY HAS BEEN EXTENDED UNTIL 415 PM. NUMEROUS TORNADIC THUNDERSTORMS WERE MOVING RAPIDLY NORTHEAST OUT OF FORT BEND COUNTY.

IF YOU ARE IN THE PATH OF A TORNADO...THE SAFEST PLACE IS A BASEMENT. GET UNDER A WORKBENCH OR PIECE OF STURDY FURNITURE. IF NO BASEMENT IS AVAILABLE...SEEK SHELTER IN AN INTERIOR ROOM SUCH AS A CLOSET ON THE LOWEST FLOOR. USE BLANKETS...PILLOWS...OR CUSHIONS TO COVER YOUR BODY. AVOID WINDOWS.

<ZCZC SATSVSHOU
ETTAA00 KHOU 212115
TXZ047-212100-

SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE HOUSTON TX
315 PM CST SAT NOV 21 1992

...TORNADO WARNING FOR HARRIS COUNTY IN EFFECT UNTIL 415PM...
...TORNADO WATCH REMAINS IN EFFECT FOR SOUTHEAST TEXAS UNTIL 8PM...

A TORNADO WAS REPORTED ON THE GROUND NEAR ALMEDA GENOA ROAD AND I-45. THIS TORNADO WAS MOVING NORTHEAST AT 25 TO 30 MPH. PERSONS IN THIS VICINITY SHOULD TAKE COVER IMMEDIATELY.

<ZCZC SATSVSHOU
ETTAA00 KHOU 212142
TXZ047-212100-

SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE HOUSTON TX
340 PM CST SAT NOV 21 1992

...TORNADO WATCH REMAINS IN EFFECT FOR SOUTHEAST TEXAS UNTIL 8PM...
...TORNADO WARNING IN EFFECT UNTIL 415 PM FOR HARRIS COUNTY...

AT 340 PM... THERE WAS A TORNADO ON THE GROUND AT WOOD FOREST AND BELTWAY 8. THIS TORNADO WAS MOVING NORTHEAST AT 25 MPH. PERSONS IN THE COMMUNITIES ALONG HIGHWAY 90 SOUTH OF LAKE HOUSTON TAKE COVER.

<ZCZC SATSVSHOU
ETTAA00 KHOU 212145 COR
TXZ047-212230-

SEVERE WEATHER STATEMENT ...HEADER TIME CORRECTED....
NATIONAL WEATHER SERVICE HOUSTON TX
340 PM CST SAT NOV 21 1992

...TORNADO WATCH REMAINS IN EFFECT FOR SOUTHEAST TEXAS UNTIL 8PM...
...TORNADO WARNING IN EFFECT UNTIL 415 PM FOR HARRIS COUNTY...

AT 340 PM... THERE WAS A TORNADO ON THE GROUND AT WOOD FOREST AND BELTWAY 8. THIS TORNADO WAS MOVING NORTHEAST AT 25 MPH. PERSONS IN THE COMMUNITIES ALONG HIGHWAY 90 SOUTH OF LAKE HOUSTON TAKE COVER.

B. Jackson/Meridian, MS

NNNNJANSPSJAN
TTAA00 KJAN 211931
MSZALL-220000-

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE JACKSON MS
130 PM CST SAT NOV 21 1992

...SEVERE WEATHER POSSIBLE FOR MISSISSIPPI TONIGHT...

THE STAGE IS BEING SET FOR STRONG AND POTENTIALLY SEVERE THUNDERSTORMS TONIGHT. ALTHOUGH THERE IS A THREAT FOR SEVERE THUNDERSTORMS STATEWIDE... THE MAIN FOCUS WILL BE IN THE CENTRAL AND SOUTHERN COUNTIES OF THE STATE.

A DEVELOPING AREA OF LOW PRESSURE LOCATED BETWEEN CORPUS CHRISTI AND VICTORIA TEXAS DURING THE NOON HOUR WILL INTENSIFY AND MOVE NORTHEAST INTO WESTERN LOUISIANA AND ARKANSAS LATER TONIGHT. THUNDERSTORMS WERE ALREADY FIRING UP ALONG A LINE ACROSS EAST TEXAS.

THESE THUNDERSTORMS WILL CONTINUE TO DEVELOP AND MOVE EAST TONIGHT... MOVING INTO WESTERN LOUISIANA LATE THIS AFTERNOON AND TOWARD THE MISSISSIPPI RIVER AROUND 9PM THIS EVENING.

IF YOU LIVE IN THE SOUTHWEST AND WEST CENTRAL COUNTIES OF MISSISSIPPI... THEN YOU MAY WANT TO STAY TUNED TO YOUR FAVORITE COMMERCIAL TELEVISION AND RADIO STATION...AS WELL AS NOAA WEATHER RADIO LATER THIS AFTERNOON.

THUNDERSTORMS COULD LIKELY BECOME SEVERE...ESPECIALLY AFTER 9PM THIS EVENING. STRONG WINDS...DAMAGING HAIL...FREQUENT LIGHTNING AND BRIEF HEAVY RAINFALL ...AS WELL AS THE POSSIBLITY FOR TORNADOES ARE POSSIBLE WITH THE THUNDER STORMS TONIGHT.

THE THUNDERSTORMS WILL LIKELY TRACK TO THE EAST AND NORTHEAST...HOWEVER... BASED ON CURRENT WEATHER DATA AND PROJECTED MOVEMENT OF THE SYSTEM...THE STONGEST STORMS SHOULD MOVE INTO THE EASTERN COUNTIES AFTER MIDNIGHT.

NNNN<<<<<<<<<<<<<<<<<<<<<<<<<JANTORJAN
ETTAA00 KJAN 220546
MSC129-031-220615-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE JACKSON MS
1145 PM CST SAT NOV 21 1992

THE NATIONAL WEATHER SERVICE IN JACKSON HAS ISSUED A
TORNADO WARNING EFFECTIVE UNTIL 1215 AM CST
FOR PEOPLE IN THE FOLLOWING LOCATIONS...S...

IN CENTRAL MISSISSIPPI
...SMITH COUNTY

IN SOUTH CENTRAL MISSISSIPPI

...COVINGTON COUNTY

AT 1144 PM CST JACKSON RADAR STILL INDICATED A POSSIBLE TORNADO ALONG THE JEFFERSON DAVIS/COVINGTON COUNTY LINE MOVING NORTH NORTHEAST AT 35 MILES AN HOUR. THIS MOVEMENT WILL TAKE THE STORM TOWARDS THE TOWNS OF MOUNT OLIVE AND MIZE.

IF YOU ARE IN THE PATH OF A TORNADO...THE SAFEST PLACE IS IN AN INTERIOR ROOM ON THE LOWEST FLOOR. GET UNDER STURDY FURNITURE. USE PILLOWS OR CUSHIONS TO COVER YOUR HEAD.
NNNN

NNNN<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<JANSVRJAN
#TTAA00 KJAN 220613
MSC079-121-123-220645-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE JACKSON MS
1212 AM CST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN JACKSON HAS ISSUED A SEVERE THUNDERSTORM WARNING EFFECTIVE UNTIL 1245 AM CST FOR PEOPLE IN THE FOLLOWING LOCATIONS...S...

IN CENTRAL MISSISSIPPI

...LEAKE COUNTY...NORTHERN RANKIN COUNTY...SCOTT COUNTY

AT 1212 AM CST WEATHER RADAR INDICATED A SEVERE THUNDERSTORM IN NORTHERN RANKIN COUNTY MOVING NORTHEAST AT 40 TO 45 MILES AN HOUR. THIS STORM HAS CAUSED SOME DAMAGE AROUND THE BRANDON AREA.

A TORNADO WATCH IS ALSO IN EFFECT. REMEMBER SEVERE THUNDERSTORMS CAN PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT BE ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS.

JANTORMEI
TTAAOO KMEI 220633
MSC061-220730-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE MERIDIAN MS
1231 AM CST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN MERIDIAN HAS ISSUED A TORNADO WARNING EFFECTIVE UNTIL 130 AM CST FOR PEOPLE IN THE FOLLOWING LOCATION.....

IN EAST CENTRAL MISSISSIPPI
...JASPER COUNTY

AT 1230 AM CDT...MERIDIAN RADAR INDICATED A POSSIBLE TORNADO 7 MILES NORTHWEST OF BAY SPRINGS MISSISSIPPI. MOVEMENT WAS NORTHEAST AT 45 MPH.

IF YOU ARE IN THE PATH OF A TORNADO...THE SAFEST PLACE IS A BASEMENT. GET UNDER A WORKBENCH OR PIECE OF STURDY FURNITURE. IF NO BASEMENT IS AVAILABLE...SEEK SHELTER IN AN INTERIOR ROOM SUCH AS A CLOSET ON THE LOWEST FLOOR. USE BLANKETS...PILLOWS... OR CUSHIONS TO COVER YOUR BODY. AVOID WINDOWS.

C. Atlanta/Macon/Athens, GA

ATLSPSATL
ETTAA00 KATL 221011
GAZALL-221500-

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE ATLANTA GEORGIA
515 AM EST SUN NOV 22 1992

..SEVERE THUNDERSTORMS EXPECTED TODAY AND TONIGHT OVER MUCH OF THE SOUTHEASTERN UNITED STATES..

THE NATIONAL SEVERE STORMS FORECAST CENTER IN KANSAS CITY MISSOURI IS FORECASTING SEVERE THUNDERSTORMS AND POSSIBLE TORNADOES TODAY INTO TONIGHT OVER MUCH OF THE SOUTHEASTERN UNITED STATES.

THE STATES WHICH ARE MOST LIKELY TO EXPERIENCE THE BRUNT OF THE SEVERE THUNDERSTORM ACTIVITY INCLUDE GEORGIA...EXTREME NORTHWEST FLORIDA...CENTRAL AND EASTERN ALABAMA...AND EASTERN TENNESSEE.

A STRONG LOW PRESSURE SYSTEM CONTINUES TO INTENSIFY THIS MORNING OVER THE MIDDLE AND LOWER MISSISSIPPI VALLEY. SEVERE THUNDERSTORMS...OCCASIONALLY PRODUCING TORNADOES...HAVE BEEN ASSOCIATED WITH THIS STORM SYSTEM OVERNIGHT AND THESE STRONG STORMS ARE CONTINUING EARLY THIS MORNING AHEAD OF A COLD FRONT EXTENDING FROM NORTHERN MISSISSIPPI SOUTHWARD INTO THE GULF OF MEXICO.

THE LEADING EDGE OF THE SEVERE THUNDERSTORMS HAD MOVED INTO EXTREME WESTERN ALABAMA AROUND 4 AM...AND A TORNADO WATCH WAS IN EFFECT FOR MUCH OF ALABAMA UNTIL 10 EST. AS THESE STORMS MOVE EASTWARD IT IS LIKELY THAT A TORNADO WATCH WILL BE ISSUED FOR WESTERN SECTIONS OF GEORGIA THIS MORNING...AND EASTERN GEORGIA BY EARLY AFTERNOON.

RESIDENTS ARE URGED TO REVIEW SAFETY RULES...AND LISTEN TO RADIO...TELEVISION...OR NOAA WEATHER RADIO FOR LATER STATEMENTS AND POSSIBLE WATCHES OR WARNINGS. THIS IS A POTENTIALLY DANGEROUS WEATHER SITUATION AND SHOULD BE MONITORED CLOSELY.

#TTAA00 KATL 221646
GAC067-097-223-221730-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE ATLANTA GA
1144 AM EST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN ATLANTA HAS ISSUED A
TORNADO WARNING EFFECTIVE UNTIL 1230 PM EST
FOR PEOPLE IN THE FOLLOWING LOCATIONS...

IN NORTHWEST GEORGIA

...COBB COUNTY...DOUGLAS COUNTY...PAULDING COUNTY

AT 1143 AM EST DOULAS COUNTY SHERIFFS DEPARTMENT REPORTED A TORNADO ON THE GROUND AT POOL ROAD IN WESTERN DOUGLAS COUNTY. THIS TORNADO IS MOVING

NORTHEAST AT 45 MPH. PERSONS IN DOULGASVILLE.. HIRAM AND AUSTELL SHOULD TAKE COVER NOW.

ATLTORATL
#TTAA00 KATL 221714
GAC057-121-221800-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE ATLANTA GA
1211 PM EST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN ATLANTA HAS ISSUED A
TORNADO WARNING EFFECTIVE UNTIL 100 PM EST
FOR PEOPLE IN THE FOLLOWING LOCATIONS...

IN NORTHWEST GEORGIA

...CHEROKEE COUNTY...NORTHWESTERN FULTON COUNTY

AT 1210 PM EST WEATHER SERVICE RADAR INDICATED A POSSIBLE TORNADO IN COBB COUNTY. THE STORM IS MOVING NORTHEAST AT 45 MPH AND SHOULD MOVE INTO CHEROKEE AND NORTH FULTON COUNTIES WITHIN THE NEXT 15 MINUTES. PLEASE TAKE COVER NOW.

THIS IS A DANGEROUS STORM SITUATION. ACT QUICKLY. IF YOU ARE IN THE PATH OF THIS TORNADO MOVE TO A SHELTER BELOW GROUND IF AVAILABLE. OTHERWISE...GO TO A SMALL INTERIOR ROOM ON THE LOWEST FLOOR POSSIBLE. AVOID WINDOWS. ABANDON CARS AND MOBILE HOMES FOR A REINFORCED BUILDING OR GET INTO A DITCH OR CULVERT.

NNNNATLTORATL

ATLTORMCN
#TTAA00 KMCN 222117
GAC237-222215-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE MACON GA
416 PM EST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN MACON GA HAS ISSUED A
TORNADO WARNING EFFECTIVE UNTIL 515 PM EST
FOR PEOPLE IN THE FOLLOWING LOCATIONS...

IN NORTHEAST GEORGIA

...PUTNAM COUNTY

AT 415 PM MACON RADAR INDICATED A POSSIBLE TORNADO NORTH OF GRAY MOVING TOWARD EATONTON. RADIO SPOTTERS REPORTED SEEING A FUNNEL CLOUD WEST OF GRAY DURING THE PAST HALF HOUR. PEOPLE IN THE PATH OF THIS STORM SHOULD GO TO A SAFE PLACE IMMEDIATELY. MOVEMENT OF THIS STORM WAS NORTHEAST AT 45 MILES AN HOUR.

IF YOU LIVE IN A HOME OR APARTMENT...SEEK SHELTER IN THE INNERMOST PORTION OF THE BUILDING ON THE LOWEST FLOOR. GET TO A BASEMENT IF ONE IS AVAILABLE. AVOID WINDOWS AND PROTECT YOUR BODY FROM FLYING DEBRIS WITH CUSHIONS...BLANKETS...OR PILLOWS.

ATLSVRAHN
#TTAA00 KAHN 222124
GAC133-222230-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE ATHENS GA
421 PM EST SUN NOV 22 1992

THE NATIONAL WEATHER SERVICE IN ATHENS HAS ISSUED A SEVERE THUNDERSTORM WARNING EFFECTIVE UNTIL 530 PM EST FOR PEOPLE IN THE FOLLOWING LOCATIONS.....

IN NORTHEAST GEORGIA

...GREENE COUNTY

AT 415 PM RADAR INDICATED A SEVERE THUNDERSTORM NEAR EATONTON GEORGIA MOVING NORTHEAST AT 50 MILES AN HOUR. PERSONS IN GREENE COUNTY SHOULD PREPARE NOW FOR THREATNING WEATHER.

A TORNADO WATCH IS ALSO IN EFFECT FOR THE WARNED AREA. REMEMBER SEVERE THUNDERSTORMS CAN AND OCCASIONALLY DO PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT BE ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS.