Natural Disaster Survey Report

Southeastern United States Palm Sunday Tornado Outbreak of March 27, 1994

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

Cover: Left: (Picture of tornado that struck the Goshen United Methodist Church)
Right: (Aerial view of damaged church)

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Ronald H. Brown, Secretary

National Oceanic and Atmospheric Administration
Dr. D. James Baker, Administrator

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

PREFACE

We normally think of "tornado alley," particularly the Great Plains, as the area where tornadoes unleash their most destructive forces. But, as evidenced by many tornado outbreaks, including the "Huntsville, Alabama, Tornado" of 1989 where 21 people lost their lives, the "Southeastern United States Palm Sunday Tornado Outbreak" of March 27, 1994, again tragically emphasized that some of the most deadly tornadoes occur in the Gulf States and adjacent areas of the southern Appalachian Mountains.

As occurs after major weather-related disasters, a National Oceanic and Atmospheric Administration (NOAA) Disaster Survey Team (DST) was dispatched with very short notice to the devastated areas. I sincerely appreciate their efforts in assessing the entire warning process, including actions of the National Weather Service (NWS) affected offices and our emergency management, law enforcement, and media partners in the hazards community. Through this cooperative effort, the DST has developed valuable recommendations to further strengthen the warning process. But, most tellingly, the team members have brought back such haunting images of wholesale destruction and suffering as to remain an indelible part of our collective experiences. It is at these times that our mission to protect the public from natural hazards becomes most starkly defined in human terms.

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

August 1994

FOREWORD

This report on the "Southeast United States Palm Sunday Tornado Outbreak" of March 27, 1994, was prepared by a NOAA DST. The DST conducted the field survey over a 4-day period beginning Tuesday, March 29.

In carrying out NOAA's charge of expediting this report, the DST has departed from the longer format of earlier disaster survey reports. This document focuses on north-central Alabama and northern Georgia, the areas that sustained the most deadly and damaging tornadoes. Chapter 1 is an overview, providing condensed information on the entire warning process for the two-state outbreak. Chapter 2 provides a meteorological analysis of the outbreak while Chapters 3 and 4 conclude the report with case studies that present more detailed information on the warning process for the two most deadly tornadic events. Continuing the theme of brevity, findings and recommendations are incorporated within the chapters and, wherever possible, tell the story with consequent reduction in narrative text.

The DST visited the National Severe Storms Forecast Center (NSSFC) in Kansas City, Missouri; Weather Service Forecast Offices (WSFO) Birmingham, Alabama, and Atlanta, Georgia; and Weather Service Office (WSO) Athens, Georgia. Management and staff were very helpful in supplying the appropriate information and arranging itineraries and a survey aircraft. The DST divided into two groups. A service group toured the damage areas and interviewed municipal law enforcement officials, county emergency managers, representatives of various local media outlets, and members of the general public, including survivors. A science group conducted ground and aerial surveys to assess tornado track lengths, widths, intensities, and associated damage.

The resultant information in this report provides an assessment of the performance and effectiveness of the involved NWS offices, and their critical relationships with local and county governments and the media in protecting the public from natural hazards. A number of findings and recommendations are presented with the belief that their adoption should further strengthen warning procedures.

Thanks go to all of NWS' partners in the hazards community who took time to provide their views and lend evaluation, from their unique perspective, of the warning process—our shared mission.

The DST is especially grateful to the survivors who quietly volunteered their stories amidst the crumbled remains of their homes. Their graciousness and courage were profoundly moving and represented the defining moments of the survey.

The Disaster Survey Team

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EXECUTIVE SUMMARY

Sunday, March 27, 1994, numerous killer tornadoes, leaving trails of devastation, raced northeastward across the southeastern United States, mainly from north-central Alabama and northern Georgia to the Carolinas. A total of 42 deaths and over 320 injuries (including those in the Carolinas) have been attributed directly to the storms, and damage to property has been estimated at $107 million. Alabama, with 22 fatalities, and Georgia, with 18, sustained the brunt of the storms' effects while 2 deaths occurred in North Carolina.

This report, while providing general information on the total tornado outbreak, focuses on Alabama and Georgia, and, in particular, on the two most deadly events: the tornado that struck the Goshen United Methodist Church (UMC) in extreme southern Cherokee County of Alabama and the tornado that wreaked havoc in Pickens County, Georgia.

Twenty people died and 90 were injured in the Goshen UMC when a tornado (hereafter called the "Cherokee County Tornado") collapsed the roof on the congregation during the Palm Sunday service. The center of the one-half-mile wide tornado with maximum wind speeds of F3[1] strength (158 to 206 mph) passed about 200 yards north of the church, resulting in damage correlating with F1 wind speeds (about 100 mph) toward the tornado's southern periphery.

The tornado struck the rural church at 11:39 a.m. CST, as determined by a radio time check of a Piedmont, Alabama, police officer's call to police headquarters as he spotted the tornado about to strike the church. He had no time to warn the church. WSFO Birmingham, Alabama, issued a tornado warning for southern Cherokee County about 12 minutes before the tornado struck the Goshen UMC. The congregation did not have NOAA Weather Radio (NWR) or any other means of receiving the warning. WSFO Birmingham was proactive in anticipating the severity of the situation and issued, well before the tornadoes, late night and early morning zone forecasts that mentioned severe thunderstorms and a special weather statement that morning at 5:45 a.m. CST that heightened the public's awareness to the potential risks.

The most fatalities in Georgia occurred in Pickens County where nine people died in two tornado events. Of the fourteen family members attending a reunion, 6 of 7 died in a mobile home that was destroyed at 3:24 p.m. EST, near the small community of Jerusalem in the Henderson Mountain area. The other seven survived without serious injury even though their mobile home next door was also destroyed. The F3 tornado was estimated at about one mile wide. The tornado continued moving northeast and killed two more people at 3:34 p.m. EST, less than a mile northwest of the town of Jasper. WSFO Atlanta issued a tornado warning for Pickens County about 4 minutes before the mobile homes were struck and 14 minutes before the Jasper area fatalities occurred. The emergency manager in

[1] On the Fujita Tornado Intensity Scale (see Appendix A), which ranges from F0 (weak) to F5 (violent).

Pickens County said that the family was not aware of the NWS warning of the tornado and did not have NWR. The other death occurred earlier at 2:03 p.m. EST, in nearly the same area, 3 miles south of Jasper. In total, of the 18 people killed in Georgia, 15 (about 83 percent) occurred in mobile homes.

According to the NSSFC, the synoptic (larger scale) atmospheric forces were not as evident for the southeast United States Palm Sunday tornadoes as many of the significant outbreak events of the past. Yet, as early as Saturday, March 26, and increasingly as new data became available overnight, NSSFC recognized the smaller scale ingredients of air mass structure, moisture instability, and wind fields as potentially explosive triggers for severe thunderstorms and tornadoes. NSSFC provided excellent guidance before and during the outbreak, including timely and accurate convective outlooks, a public severe weather outlook, and tornado and severe thunderstorm watches.

About a dozen supercells (i.e., long-lived, violent thunderstorms with tornadic potential) traversed a narrow area typically less than two counties wide, spawning tornadoes in parallel tracks, some of which were nearly overlapping. Timely aerial and ground surveys were critical in resolving these tracks. The supercell that produced the Cherokee County tornado was documented to track at least 200 miles from near Ragland in east-central Alabama northeastward through northern Georgia into South Carolina. Some evidence suggests it continued to the Atlantic coast. An article in the *Atlanta Journal* of April 3, 1994, asked:

> "Just how ferocious were last week's tornadoes? An employee at the state's Burton Trout Hatchery in Rabun County (Georgia) found a bank check from Piedmont, Alabama (near the Goshen UMC). The 1989 canceled check belonging to a Piedmont resident had to travel about 130 miles to reach the hatchery. While the (Piedmont area resident's) mobile home was destroyed...he apparently escaped injury."

Along this supercell path, two separate tornado tracks of just over 50 miles each were observed. The tornado tracks varied in width and destructive intensity. Overall, the width of the tornado tracks averaged about one-half mile but ranged upward to over a mile in a few places. Intensities derived from damage along the tracks ranged up to F3 with a few areas to F4.

The severe storms started early Sunday morning (March 27), complicating the process of mobilizing storm spotters. The resultant lack of ground truth demonstrated WSFO Birmingham and Atlanta forecasters' strong reliance on, and confidence in, Weather Surveillance Radar-1988 Doppler (WSR-88D) as the key warning tool. The East Alabama WSR-88D (Maxwell AFB Department of Defense [DoD] radar) was the main source of warning information for WSFO Birmingham; WSFO Atlanta had dial-up capability for DoD's Robins AFB WSR-88D and the East Alabama WSR-88D and also had use of their Weather Surveillance Radar-1974 (C-band) (WSR-74C) local warning radar. Despite the fact the tornadic storms, for part of their evolution, were observed near the 124 nm velocity display limit of both WSR-88Ds, the radars continued to provide invaluable data. WSO Athens, Georgia, used its network radar and was ably assisted by a local amateur radio

group, which set up operations at the office and remained in contact with spotters in north Georgia throughout the day.

The warning process was also somewhat compromised by the limited resources many rural county emergency managers and law enforcement officials had at their disposal for receiving the emergency messages and enacting their preparedness response plans. Few had NOAA Weather Wire Service (NWWS), the most effective warning delivery system. Most emergency managers relied on their Law Enforcement Telecommunications System (LETS), despite the fact messages can be delayed on these systems. Some only had NWR as the sole source of NWS warnings and related information and praised the system's usefulness.

The 16 television and radio stations surveyed in Alabama and Georgia gave NWS personnel high marks for providing early and timely warnings throughout this outbreak. There were some indications, however, that the process for activating the Emergency Broadcast System (EBS) was faulty. None of the ten radio stations surveyed had NWWS, the most efficient way of activating the EBS. Instead, they relied on manual receipt of NWR broadcasts, a phone call from their county emergency management agency, or a bulletin received through the Associated Press (AP) news wire. Stations surveyed had widely varying methods for activating EBS, and some did not keep logs of when the EBS was activated. This further emphasizes the urgent requirement for the EBS to be upgraded into an automated system, as the Federal Communications Commission (FCC) is planning.

Overall, considering the frenetic activity and tension associated with wave after wave of supercells in a day-long severe weather episode, NWS personnel at WSFOs Birmingham and Atlanta and WSO Athens issued timely warnings for most of the affected counties in their areas of responsibility. They issued a combined total of 75 tornado warnings and 62 severe thunderstorm warnings. Many emergency managers, law enforcement officials, the media, and several survivors interviewed by the DST stated that, through the efforts of these NWS offices, many lives were saved.

DISASTER SURVEY TEAM MEMBERS

Members of the DST for the March 27, 1994, Palm Sunday tornado outbreak are listed below. With substantial help from the local affected NWS offices, Buddy McIntyre and Tim Marshall conducted aerial and ground surveys to determine tornado intensities and associated damage. The rest of the DST was primarily concerned with the effectiveness of the warning process from NWS services to the critical public/private partnerships in the hazards community.

William (Josh) Korotky, WSO Tallahassee Science and Operations Officer, deserves special recognition for his contribution of the meteorological analysis found in Chapter 2.

Linda Kremkau, Program Assistant in the Warning and Forecast Branch at Weather Service Headquarters (WSH), edited and formatted this report into a camera-ready document for publication.

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AP	Associated Press
CAPE	Convective Available Potential Energy
CST	Central Standard Time
CTA	Call to Action
CWA	County Warning Area
DoD	Department of Defense
DST	Disaster Survey Team
EBS	Emergency Broadcast System
EDD	Equipment Delivery Date
EHI	Energy Helicity Index
EOC	Emergency Operations Center
EST	Eastern Standard Time
FCC	Federal Communications Commission
FTS	Federal Telephone System
GEMA	Georgia Emergency Management Agency
LETS	Law Enforcement Telecommunications System
LI	Lifted Index
NAWAS	National Warning System
NGM	Nested Grid Model
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center
NWR	NOAA Weather Radio
NWS	National Weather Service
NWWS	NOAA Weather Wire Service
PUP	Principal User Processor
PWO	Public Severe Weather Outlook
SFD	State Forecast Discussion
SPS	Special Weather Statement
SRH	Storm Relative Helicity
SRWARN	Southern Region WARNing program
SVS	Severe Weather Statement
UMC	United Methodist Church
UTC	Universal Coordinated Time
VDUC	VAS Data Utilization Center
VIL	Vertically Integrated Liquid
WSFO	Weather Service Forecast Office
WSH	Weather Service Headquarters
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

The following findings and recommendations are grouped by subject matter and are found within their appropriate chapters, as indicated. The recommendations are further identified by chapter, section and chronological order within that section. For example, Recommendation 1A1 is found in chapter 1, Section A, and is the first listed recommendation.

Impact of Outbreak

Finding 1: An interior hallway that remained intact in the Goshen UMC during the tornado could have provided adequate shelter for all 150 occupants. (Chapter 3)

Finding 2: Of the 18 people killed in Georgia, 15 (about 83 percent) occurred in mobile homes. (Chapter 1)

Finding 3: As previous disaster survey reports have also documented, permanent homes and manufactured homes without floor/ foundation anchorage, and single and double-wide mobile homes, particularly those that are not anchored or have minimal frame ties, do not provide safe shelter from tornadoes and other high wind events. (Chapter 1)

Recommendation 3: Residents of mobile homes should be instructed on where to find safe shelter in times of emergency. Mobile home parks should provide safe communal shelter with easy access. (Chapter 1)

Finding 4: Many of those people whose homes were severely damaged or destroyed survived without serious injury because they sought shelter in crawlspaces or center hallways/bathrooms. (Chapter 1)

Recommendation 4: NWS should continue to emphasize that people seek shelter in basements or small interior rooms and hallways during threatening weather, and avoid rooms and buildings with large roof spans. (Chapter 1)

Radar Availability and Analysis

Finding 5: The East Alabama DoD WSR-88D (at Maxwell AFB) was the main source of warning information for WSFO Birmingham, an associated user to the radar. The WSFO had the full range of available WSR-88D products. (Chapter 3)

Finding 6: WSFO Atlanta had dial-up capability to DoD's Robins AFB WSR-88D and the East Alabama WSR-88D and direct use of their WSR-74C local warning radar. As a dial-up user, the office had access to a more limited set of WSR-88D products as compared with an associated user. Forecasters used mostly the storm relative velocity and VIL (vertically integrated liquid) products and looping capabilities of the radar for effective radar analyses. (Chapter 4)

Finding 7: Even when tornadic storms approached the 124 nm periphery of the effective range for WSR-88D velocity products, data continued to show significant gate-to-gate shears indicating mesocyclones. (Chapter 1)

Finding 8: WSFOs Birmingham and Atlanta forecasters stated that the WSR-88Ds performed well with no significant problems. Despite the lack of ground truth spotter reports, and the fact that many of the tornadic storms were near the periphery of the velocity data, forecasters issued and maintained tornado warnings based primarily on WSR-88D information. (Chapter 1)

Finding 9: WSO Athens used their Weather Surveillance Radar-1957 (WSR-57) network radar. An invaluable supplement for radar verification, storm tracking and warning issuance was the local amateur radio group that set up operations at the WSO and remained in contact with spotters throughout northeast Georgia. (Chapter 1)

Finding 10: Both WSFOs Birmingham and Atlanta had "Archive IV" capability with the WSR-88D that allowed available products to be stored on optical disks. (Chapter 1)

Meteorological Analysis

Finding 11: According to the NSSFC, the synoptic (larger scale) atmospheric forces were not as evident for the "Southeast United States Palm Sunday Tornado Outbreak" as many of the significant outbreak events of the past. (Chapter 2)

Finding 12: Nevertheless, large-scale advective processes contributed strong low-level vertical wind shear and large thermodynamic instability, creating a prestorm environment capable of supporting the development of tornadic supercells. Mesoscale processes acting within this favorable environment enhanced the large-scale potential and triggered the tornadic storms. (Chapter 2)

Finding 13: NSSFC recognized from the March 27, 1200 Universal Coordinated Time (UTC) (7 a.m. EST), data that the hodographs (polar coordinated plots of winds derived from an atmospheric sounding) and storm relative helicity (SRH) (tendency for storm rotation) calculations were classic indicators for the development of rotating supercells. (Chapter 2)

Finding 14: The entire warm sector extending from Mississippi eastward through all of Georgia had developed an explosive potential, waiting for a "trigger" (a mechanism to initiate the strong convection). (Chapter 2)

Guidance, Forecasts, and Warning Actions

Finding 15: NSSFC provided excellent guidance to field offices before and throughout the event, including Convective Outlook products, the first of which indicated the risk of severe weather more than 24 hours in advance of the outbreak. (Chapter 1)

Finding 16: WSFOs Birmingham and Atlanta and WSO Athens issued a combined total of 75 tornado warnings and 62 severe thunderstorm warnings. Most warnings were timely and saved lives based on DST interviews with survivors, many newspaper reports, and comments from emergency management and radio and television staff. (Chapter 1)

Finding 17: Based on the timely and accurate guidance from NSSFC, WSFO Birmingham began mentioning the possibility of severe weather in State Forecast Discussions (SFD) 24 hours in advance of the event and in their zone forecasts beginning about 19 hours ahead of the event. (Chapter 3)

Finding 18: WSFO Birmingham issued a special weather statement (SPS) at 5:45 a.m. CST, about 5 hours before the first tornado warning was issued, emphasizing the potential for severe weather in parts of Alabama. (Chapter 3)

Finding 19: NSSFC issued Tornado Watch No. 41 at 9:18 a.m. CST that covered a large part of the WSFO Birmingham county warning area (CWA) (including Cherokee County and the Goshen UMC). Shortly after, WSFO Birmingham updated the zone forecasts to include the tornado watch and continued to mention "some thunderstorms may be severe..." in the text of the forecast. (Chapter 3)

Finding 20: NSSFC issued a Public Severe Weather Outlook (PWO) at 10 a.m. CST (11 a.m. EST) that included much of Alabama and Georgia. Reserved for the most potentially dangerous situations, the PWO called for "...widespread severe thunderstorms and tornadoes..." and "...tornadoes that could be particularly intense." (Chapter 1)

Finding 21: WSFO Birmingham issued a tornado warning for northern Calhoun, southern Cherokee, and southeast Etowah Counties at 11:27 a.m. CST, about 12 minutes before the tornado struck the Goshen UMC and killed 20 people and injured 90. (Chapter 3)

Finding 22: NSSFC upgraded northern Georgia to a "Moderate Risk" valid at 10 a.m. EST. Along with the PWO issued at 11 a.m. EST, these actions further emphasized the likelihood of widespread severe thunderstorms with particularly intense tornadoes in a large part of northern Georgia. (Chapter 4)

Finding 23: While northern Georgia was in a "Slight Risk" for severe storms through the early morning hours, WSFO Atlanta focused on flash flooding as the risk of the day. WSFO Atlanta did not issue pre-event statements for severe thunderstorms or tornadoes after NSSFC substantially raised the level of risk for northern Georgia. (Chapter 4)

Recommendation 23: WSFOs identified by NSSFC in their Convective Outlook products as falling within a severe local storms outlook area should issue a morning State Severe Weather Outlook and timely update statements, mentioning the likelihood for severe weather over their area of responsibility. State Severe Weather Outlooks should not be considered optional for "Moderate" or "High Risk" situations. Also, zone forecasts should be worded to further heighten the risk. (Chapter 4)

Finding 24: NSSFC issued Tornado Watch No. 42, valid at 12 Noon EST, that covered a large part of northern Georgia (including Pickens County). Shortly after, WSFO Atlanta updated the zone forecast to include the tornado watch in the headline but because of an incorrect AFOS procedure being run, the zones were labeled 5:10 p.m. EST instead of 1:20 p.m. EST. (Chapter 4)

Finding 25: WSFO Atlanta's forecast wording in their updated zone forecasts did not reflect the magnitude of the event, both in the increased likelihood or severity of the storms. Forecast wording included "...windy with scattered showers and a few thunderstorms." (Chapter 4)

Recommendation 25: When NSSFC guidance indicates an increased probability of severe thunderstorms and tornadoes for an office's area of responsibility, forecasters are encouraged to highlight that potential in the text of the forecast period, using such words as "Thunderstorms likely, some severe and could produce tornadoes" or "Thunderstorms, some with damaging winds and large hail." (Chapter 4)

Finding 26: WSFO Atlanta issued a tornado warning at 3:20 p.m. EST for the counties of eastern Bartow, northwest Cherokee, eastern Gordon, and all of Pickens County about 4 minutes before the tornado struck the mobile homes that killed 6 of 14 people at a family reunion. This same warning provided a 14-minute lead time before the tornado killed two other people near Jasper in Pickens County at 3:34 p.m. EST. (Chapter 4)

Finding 27: Because of the fast movement (up to 65 mph) of the storms, a few warnings for downstream counties had only very short lead times. (Chapter 1)

Recommendation 27: Particularly for fast-moving, severe storms, forecasters should factor in normal delays in the dissemination process when issuing warnings for downstream counties. (Chapter 1)

Finding 28: Few warnings and statements included specific communities near the projected path of the severe storms and tornadoes. (Chapter 1)

Recommendation 28: It is important that warnings include downstream communities in the path of severe storms to heighten public awareness. (Chapter 1)

Finding 29: WSFO Birmingham, using the East Alabama WSR-88D, coordinated several times by telephone with WSFO Atlanta on storms crossing the Alabama/Georgia state line. Some of those times the line was busy. (Chapter 1)

Recommendation 29: One of the more important responsibilities a warning office has is to coordinate with affected offices during ongoing severe weather, particularly when the hazard approaches the adjacent downstream office's area of responsibility. This is important to the adjacent office's ability to issue accurate and timely warnings. The Federal Telephone System (FTS2000) should be implemented as planned in all NWS offices to provide dedicated, point-to-multipoint internal coordination to ensure immediate access. (Chapter 1)

Finding 30: WSFO Atlanta inadvertently issued a series of incorrectly coded warnings due to incorrect date/time entry in Southern Region WARNing program (SRWARN). This led to warnings that were not automatically accessed and further disseminated by several users, such as The Weather Channel and First Alert. (Chapter 4)

Recommendation 30: SRWARN should be modified to make it fail-safe with respect to current date and time. In the interim, operators must check the date/time when booting up SRWARN and, as necessary, enter the correct date/time in UTC on the initialization screen. (Chapter 4)

Finding 31: Documentation of severe weather product dissemination was incomplete or inadequate for many of the warnings. (Chapter 1)

Recommendation 31: It is important that offices take the few moments required to document each severe weather product and time of issuance through the various dissemination mediums. This provides an internal check of product flow to users and accountability of NWS actions. (Chapter 1)

Communications and Dissemination/Emergency Management

Finding 32: Partly because the storms began Sunday morning, WSFOs Birmingham and Atlanta received few if any ground-truth reports from spotters or emergency managers (WSO Athens, ably assisted by a local amateur radio group, received spotter reports). Some ground truth reports that were received by emergency management and law enforcement officials were not relayed to NWS offices. (Chapter 1)

Recommendation 32: The NWS should continue to recruit and train spotter groups and work closely with law enforcement and emergency management to ensure the prompt relay of ground truth reports to NWS offices. The Federal Emergency Management Agency's National Warning System (NAWAS) should be improved and made available to the appropriate emergency management groups in every county. County dispatchers, as a group, should be made aware of the necessity of calling the NWS, especially with early reports. (Chapter 1)

Finding 33: The Goshen UMC did not receive the NWS tornado warning. They were not aware of any television or radio reports and did not have NWR. No siren systems existed near the church. NWR capability could have provided storm victims with precious minutes to seek shelter. (Chapter 3)

Recommendation 33a: Places of public gathering should be equipped with a tone-alert NWR that should be monitored closely during severe weather situations. NWS must continue to emphasize that places of public gathering should have tested preparedness plans to protect people when severe weather threatens. (Chapter 3)

Recommendation 33b: It is important that NWR expansion and proposed enhancements be accelerated to minimize the risk for future loss of life, resulting from natural and manmade hazards. (Chapter 3)

Finding 34: The family having a reunion in Pickens County did not receive the NWS tornado warning. They were not aware of any television or radio reports and did not have NWR. No siren systems existed in their area. (Chapter 4)

Recommendation 34: See Recommendations 33a and 33b. (Chapter 3)

Finding 35: Most emergency managers relied on their state LETS for primary warning notification, despite the fact that delays in receipt of warnings frequently occur on LETS. (Chapter 1)

Finding 36: A number of emergency managers and other local officials in rural counties relied on NWR for receipt of severe weather information. They had high praise for the system and were able to remain somewhat proactive in implementing their community preparedness plans. (Chapter 1)

Finding 37: Those few emergency managers and law enforcement officials who had use of NWWS were the most informed of the developing severe weather. A hard copy of relevant warnings, forecasts, and statements facilitated implementation of their community preparedness plans. (Chapter 1)

Recommendation 37: The NWS should continue to work aggressively with emergency managers and others in law enforcement to encourage their use of NWWS and NWR for timely receipt of severe weather information. (Chapter 1)

Communications and Dissemination/Media Outlets

Finding 38: Media outlets broadcasting to areas affected by the tornado outbreak said they received warnings in a timely manner. Of the 16 radio and television station representatives interviewed by the DST, all expressed appreciation and satisfaction for the speed that warnings were issued. (Chapter 1)

Finding 39: WEIS-AM in Cherokee County was able to broadcast the warning from WSFO Birmingham for the tornado that struck the Goshen UMC about 5 minutes after receiving it, still providing about a 7-minute lead time. (Chapter 3)

Finding 40: Most people interviewed who were aware of NWS warnings received them via commercial radio and television, with only a few via NWR. (Chapter 1)

Finding 41: None of the EBS participating radio stations surveyed in the affected areas were equipped with NWWS. They relied upon other, less effective means (AP news wire, cable television, phone calls from an emergency management agency, or manual receipt of NWR broadcasts) to receive EBS activation instructions. Weather messages on AP news wire can be delayed as priority often is given to "hard" news. (Chapter 1)

Recommendation 41a: NWS should continue its efforts to encourage media outlets to use the NWWS for its speed and hard-copy advantage over other communication methods. (Chapter 1)

Recommendation 41b: NWS should continue to emphasize to the FCC the need for an automated upgrade to the EBS to substantially reduce or eliminate errors in the activation process. (Chapter 1)

Finding 42: Radio and television stations, particularly in rural areas, operate with severely reduced staffs on Sundays. These radio stations typically employ part-time disc jockeys who get varying amounts of refresher training on what to do in a severe weather emergency. (Chapter 1)

Finding 43: Nine of the ten radio stations surveyed said they broadcast NWS warnings, some through formal EBS activation. Several radio stations, however, did not keep logs showing the times they received EBS activation requests. One radio station did not activate its EBS because its transmitter was incorrectly tuned. (Chapter 1)

CHAPTER 1

OVERVIEW
Alabama and Georgia

A. Description and Impact of Outbreak

On Palm Sunday, March 27, 1994, numerous tornadoes killed 42 people, injured over 320 people, and caused nearly $107 million in damage to homes, businesses, public facilities, and the agricultural community. The devastation occurred in a remarkably narrow (less than two-county wide) path, oriented southwest-northeast from central Alabama through northern Georgia to the Carolinas. Several of the tornado tracks were nearly overlapping.

Alabama, with 22 fatalities, and Georgia, with 18, sustained the brunt of the tornadoes while 2 people died in North Carolina.

Of the estimated total dollar damage of 106.8 million, Georgia sustained $67.5 million; North Carolina, $27.2 million; Alabama, $7.6 million; and South Carolina, $4.5 million.

While the severe weather outbreak extended from eastern Mississippi to the Carolinas, the focus of this report is on the deadly tornadoes in Alabama and Georgia. This chapter provides an overview of the two-state outbreak. Separate case studies in Chapters 3 and 4 provide details on the two most deadly events: the Goshen UMC in southern Cherokee County, Alabama, where 20 lost their lives and 90 were injured when a tornado struck at 11:39 a.m. CST; and the family reunion in Pickens County, Georgia, where a tornado destroyed two adjacent mobile homes at 3:24 p.m. EST, killing 6 of the 14 family members present; the same tornado killed two more people at 3:34 p.m. EST in Pickens County.

***Finding*:** **Of the 18 people killed in Georgia, 15 (about 83 percent) occurred in mobile homes.**

***Finding*:** **As previous disaster survey reports also have documented, permanent homes and manufactured homes without floor/foundation anchorage, and single and double-wide mobile homes, particularly those that are not anchored or have minimal frame ties, do not provide safe shelter from tornadoes and other high wind events.**

***Recommendation 1A1*:** **Residents of mobile homes should be instructed on where to seek safe shelter in times of emergency. Mobile home parks should provide safe communal shelter with easy access.**

***Finding*:** **Many of those people whose homes were severely damaged or destroyed survived without serious injury because they sought shelter in crawlspaces or center hallways/bathrooms.**

***Recommendation 1A2*:** **NWS should continue to emphasize that people seek shelter in basements or small interior rooms and hallways during threatening weather, and avoid rooms and buildings with large roof spans.**

This outbreak of tornadoes across Alabama and Georgia will be remembered not only for the tragic loss of life but, from the meteorological perspective, for the unusual way in which waves of supercells (tornado-producing thunderstorms) assaulted such a narrow band of the southeast United States. Two separate supercells with tornadoes moved across several counties during the outbreak while one county endured tornadoes from four supercells. The tornado-producing supercells raced northeastward at speeds up to 65 mph. In total, 6 tornadoes were observed in Alabama and 12 in Georgia.

It should be noted that aerial as well as ground surveys of the damage paths were instrumental in mapping the extent, widths, and intensities of the numerous tornadoes. These surveys should be conducted as soon after the event as possible. Recent coordination plans among various government agencies worked extremely well in scheduling on short notice a NOAA airplane for performing these aerial surveys.

It is also important to understand that the damage level of unanchored homes struck by a tornado may fit the F5 criteria on the Fujita scale but can actually be caused by winds of no more than F3 intensity. When conducting surveys for damage/storm intensity assessments, NWS personnel must take into account that the Fujita scale is composed of separate intensity and damage components. These do not necessarily correlate one for one, particularly for intense tornadoes.

The following information is found at the end of this section: Fig. 1 — Tornado tracks in Alabama and Georgia; Table 1 — Summary of Fatalities, Injuries, and Damage by County; Table 2 — Tornado Fatalities (by age, gender, and location); Table 3 — Total Period of Events and Associated Non-routine Products; Table 4 — Times of Fatalities and Associated Warnings; and Table 5 — Summary of NSSFC Actions (before and during the onset of the outbreak).

Two Supercells and Their Deadly Tornadoes

Many of the tornadoes and most of the fatalities in Alabama and Georgia were the result of two supercells. These are discussed below.

Supercell 1: The "Cherokee County Storm," Tornado 1

During the mid-morning of Sunday, March 27, a severe thunderstorm developed in eastern Jefferson County, Alabama. The storm strengthened into a supercell as it moved eastward into St. Clair County. At 10:55 a.m. CST on the southeast side of the community of

Ragland, a tornado developed from the supercell. From Ragland, it tracked 52 miles across Calhoun County, the Goshen UMC in extreme southern Cherokee County, and over the Alabama state line into western Georgia. Through Calhoun and Cherokee Counties, the tornado's strength ranged up to F3 intensity with the width of the tornado averaging 1/2 mile.

After developing in Ragland, the tornado moved across extreme eastern St. Clair County to the H. Neely Henry Lake. One person was killed at 11:05 a.m. CST in the Ten Islands Historic Park on the lake as several boaters reacted to the approaching storm and headed for the boat ramp at the park. The tornado went across the boat ramp flipping a boat which crushed one person and seriously injured another.

After crossing the H. Neely Henry Lake, the tornado moved across rural sections of Calhoun County. One person was killed as a vehicle was struck by the tornado on U.S. Highway 278, northwest of Piedmont.

The tornado slammed into the Goshen UMC in southern Cherokee County at 11:39 a.m. CST. Twenty people were killed and ninety (90) injured at the church. The tornado continued northeast from the church through rural portions of Cherokee County, dissipating in northwestern Polk County, Georgia.

Supercell 1: The "Cherokee County Storm," Tornado 2

As is typical with many supercells, the storm produced a second tornado a short time later at 1:14 p.m. EST, near Wax Lake, Georgia, in southeast Floyd County. This tornado traveled about 53 miles across Bartow County, the northwest corner of Cherokee County (Georgia), and through Pickens County to east of Jasper near the Pickens-Dawson County border.

Near White in Bartow County the tornado strengthened to F4 intensity and widened to 1 mile. Through Pickens County, the strength of the tornado ranged up to F2 intensity with the width between 1/2 and 3/4 mile.

The tornado killed two people at about 1:47 p.m. EST in a mobile home 6.5 miles northeast of White near State Highway 140 in northeast Bartow County. After crossing the northwest corner of Cherokee County, the tornado moved into Pickens County. One person was killed at 2:03 p.m. EST, 3 miles south of Jasper.

Supercell 1: The "Cherokee County Storm," Tornado 3

At about 2:17 p.m. EST, a third tornado developed from the supercell near the Dawson/ Lumpkin County line about 10 miles west-southwest of Dahlonega. This tornado traveled about 45 miles across Lumpkin, White, and Habersham Counties to just northwest of Tallulah Falls.

The strength of the tornado ranged up to F2 intensity in Lumpkin County and up to F3 in White County. As it entered White County, the tornado expanded in width to between 1 and 1.5 miles.

Two people were killed in mobile homes at 2:36 p.m. EST in the Cavendar Creek area, about 3.5 miles northeast of Dahlonega in Lumpkin County. Another fatality occurred from the tornado in a mobile home about 6 miles north-northwest of Clarkesville in Habersham County.

Supercell 1: The "Cherokee County Storm," Tornado 4

A fourth tornado track from this same supercell, about 30 miles in length, occurred from near Tallulah Falls in Georgia into South Carolina northeast of Walhalla and south of Tamassee. No fatalities occurred from this tornado.

Damage reports in the NSSFC log indicate that this same supercell continued to produce damage across northwestern South Carolina and into North Carolina.

Supercell 2: The "Pickens County Storm," Tornado 1

A second supercell moved into Floyd County, Georgia, from Cherokee County, Alabama, shortly before 2:30 p.m. EST. This supercell tracked across Georgia a little north of the track of the first supercell. It produced its first tornado at 2:30 p.m. in northwest Floyd County near Coosa. This tornado had a track of only several miles. No fatalities resulted from the tornado.

Supercell 2: The "Pickens County Storm," Tornado 2

The storm produced a second tornado at 3:01 p.m. EST, about 4.5 miles south of Adairsville in Bartow County. This tornado traveled about 38 miles across northern Bartow County and Pickens County to the Pickens/Dawson County line northeast of Jasper.

The tornado strengthened as it moved across Bartow County and was up to F3 intensity and 1.5 miles in width in Pickens County. The tornado killed one person at 3:04 p.m. EST in an automobile about 3 miles southeast of Adairsville in Bartow County. The tornado then crossed into western Pickens County in the Henderson Mountain area at 3:24 p.m. EST, destroying two adjacent mobile homes and killing 6 of 14 family members attending a reunion. Shortly afterwards, two more people were killed at 3:34 p.m. EST, when their mobile homes were destroyed about a mile northwest of Jasper in Pickens County.

Supercell 2: The "Pickens County Storm," Tornado 3

A third, short-lived tornado occurred from the storm just north of Juno in Dawson County. No fatalities or injuries occurred with this tornado.

Supercell 2: The "Pickens County Storm," Tornado 4

A fourth tornado developed about seven miles northwest of Dahlonega. This tornado traveled just a short distance in Lumpkin County and produced no fatalities or injuries.

B. Radar Availability and Analysis

(See Chapters 3 and 4 for further details on radar analysis relating to the two case studies.)

WSFO Birmingham is an associated user to the DoD East Alabama WSR-88D at Maxwell AFB located near Carrville, Alabama. The radar was delivered in November 1992 with system acceptance by the U.S. Government on February 18, 1993. The WSFO Birmingham Principal User Processor (PUP) was delivered in December 1992. The equipment delivery date (EDD) for the Birmingham WSR-88D, located at the Shelby County Airport, was March 29, 1994.

WSFO Atlanta had access to the DoD Robins AFB WSR-88D through the non-associated PUP at the Southeast River Forecast Center, which is colocated with the WSFO. The radar was delivered to Robins AFB in October 1993 with system acceptance by the U.S. Government on January 10, 1994. The EDD for the Atlanta WSR-88D, located in Peachtree City, Georgia, was May 10, 1994.

Finding: **Even when tornadic storms approached the 124 nm periphery of the effective range for WSR-88D velocity products, data continued to show significant gate-to-gate shears indicating mesocyclones.**

Finding: **WSFOs Birmingham and Atlanta forecasters stated that the WSR-88Ds performed well with no significant problems. Despite the total lack of ground truth spotter reports, and the fact that many of the tornadic storms were near the periphery of the velocity data, forecasters issued and maintained tornado warnings based primarily on WSR-88D information.**

Finding: **WSO Athens used their Weather Surveillance Radar-1957 (WSR-57) network radar. An invaluable supplement for radar verification, storm tracking and warning issuance was the local amateur radio group that set up operations at the WSO and remained in contact with spotters throughout north Georgia.**

Finding: **Both WSFOs Birmingham and Atlanta had "Archive IV" capability with the WSR-88D that allowed available products to be stored on optical disks.**

C. Guidance, Forecasts, and Warning Actions

Finding: **NSSFC provided excellent guidance to field offices before and throughout the event, including Convective Outlook products, the first of which indicated the risk of severe weather more than 24 hours in advance of the outbreak.**

Finding: **NSSFC issued a Public Severe Weather Outlook (PWO) at 10 a.m. CST (11 a.m. EST) that included much of Alabama and Georgia. Reserved for the most potentially dangerous situations, the PWO called for "...widespread severe thunderstorms and tornadoes..." and "...tornadoes that could be particularly intense."**

See Table 5 at the end of this section for a complete summary of NSSFC products and actions for Alabama and Georgia before and during the onset of the outbreak.

The WSFOs' warnings were based primarily on WSR-88D data. The WSO's warnings were based on their WSR-57 network radar and timely ground truth reports.

It is important to note that the NWS offices were also issuing warnings and statements for other storms in their CWA in addition to the Cherokee and Pickens County storms. WSFO Birmingham issued 40 severe thunderstorm warnings and 38 tornado warnings between 9 a.m. CST and 8 p.m. CST. WSFO Atlanta issued 15 severe thunderstorm warnings and 24 tornado warnings between 12:30 p.m. EST and 10:30 p.m. EST. WSO Athens issued 7 severe thunderstorm warnings and 13 tornado warnings between 2 p.m. EST and 10 p.m. EST.

Finding: **WSFOs Birmingham and Atlanta and WSO Athens issued a combined total of 75 tornado warnings and 62 severe thunderstorm warnings. Most warnings were timely and saved lives, based on DST interviews with survivors, many newspaper reports, and comments from emergency management and radio and television staff.**

Finding: **Because of the fast movement (up to 65 mph) of the storms, a few warnings for downstream counties had only very short lead times.**

Recommendation 1C1: **Particularly for fast-moving, severe storms, forecasters should factor in normal delays in the dissemination process when issuing warnings for downstream counties.**

Finding: **Few warnings and statements included specific communities near the projected path of the severe storms and tornadoes.**

Recommendation 1C2: **It is important that warnings include downstream communities in the path of severe storms to heighten public awareness.**

Finding: **WSFO Birmingham, using the East Alabama WSR-88D, coordinated several times by telephone with WSFO Atlanta on storms crossing the Alabama/ Georgia state line. Some of those times the line was busy.**

Recommendation 1C3: **One of the more important responsibilities a warning office has is to coordinate with affected offices during ongoing severe weather, particularly when the hazard approaches the adjacent downstream office's area of responsibility. This is important to the adjacent office's ability to issue accurate and timely warnings. The Federal Telephone System (FTS2000) should be implemented as planned in all NWS offices to provide dedicated, point-to-multipoint internal coordination to ensure immediate access.**

Finding: **WSFO Atlanta inadvertently issued a series of incorrectly coded warnings due to incorrect date/time entry in the Southern Region WARNing (SRWARN) applications program. This led to warnings that were not automatically accessed and further disseminated by several users, such as The Weather Channel and First Alert.**

Recommendation 1C4: **SRWARN should be modified to make it fail-safe with respect to current date and time. In the interim, operators must check the date/time when booting up SRWARN and, as necessary, enter the correct date/time in UTC on the initialization screen.**

Finding: **Documentation of severe weather product dissemination was incomplete or inadequate for many of the warnings.**

Recommendation 1C5: **It is important that offices take the few moments required to document each severe weather product and time of issuance through the various dissemination mediums. This provides an internal check of product flow to users and accountability of NWS actions.**

D. Communications and Dissemination/Emergency Management

Many of the hardest hit areas of northern Alabama and Georgia were in small, rural counties with limited resources for emergency management. The following findings and recommendations summarize emergency management actions and relationships with the NWS and others in the hazards community.

Finding: **Partly because the storms began Sunday morning, WSFOs Birmingham and Atlanta received few if any ground-truth reports from spotters or emergency managers (WSO Athens, ably assisted by a local amateur radio group, received spotter reports). Some ground truth reports that were received by emergency management and law enforcement officials were not relayed to NWS offices.**

Recommendation 1D1: **The NWS should continue to recruit and train spotter groups and work closely with law enforcement and emergency management to ensure the prompt relay of ground truth reports to NWS offices. The Federal**

Emergency Management Agency's National Warning System (NAWAS) should be improved and made available to the appropriate emergency management groups in every county. County dispatchers, as a group, should be made aware of the necessity of calling the NWS, especially with early reports.

Finding: **Most emergency managers relied on state LETS for primary warning notification, despite the fact delays in receipt of warnings frequently occur on LETS.**

Finding: **A number of emergency managers and other local officials in rural counties relied on NWR for receipt of severe weather information. They had high praise for the system and were able to remain somewhat proactive in implementing their community preparedness plans.**

Finding: **Those few emergency managers and law enforcement officials who had use of NWWS were the most informed of the developing severe weather. A hard copy of relevant warnings, forecasts, and statements facilitated implementation of their community preparedness plans.**

Recommendation 1D2: **The NWS should continue to work aggressively with emergency managers and others in law enforcement to encourage their use of NWWS and NWR for timely receipt of severe weather information.**

E. Communications and Dissemination/Media Outlets

Following are findings and recommendations that summarize actions and relationships of local media outlets with the NWS and others in the hazards community.

Finding: **Media outlets broadcasting to areas affected by the tornado outbreak said they received warnings in a timely manner. Of the 16 radio and television station representatives interviewed by the DST, all expressed appreciation and satisfaction for the speed that warnings were issued.**

Finding: **Most people interviewed who were aware of NWS warnings received them via commercial radio and television, with only a few via NWR.**

Finding: **None of the EBS participating radio stations surveyed in the affected areas were equipped with NWWS. They relied on other, less effective means (AP news wire, cable television, phone calls from an emergency management agency, or manual receipt of NWR broadcasts) to receive EBS activation instructions. Weather messages on AP news wire can be delayed as priority often is given to "hard" news.**

Recommendation 1D3: **NWS should continue its efforts to encourage media outlets to use the NWWS for its speed and hard-copy advantage over other communication methods.**

***Recommendation 1D4*:** **NWS should continue to emphasize to the FCC the need for an automated upgrade to the EBS to substantially reduce or eliminate manual errors in the activation process.**

***Finding*:** **Radio and television stations, particularly in rural areas, operate with severely reduced staffs on Sundays. These radio stations typically employ part-time disc jockeys who get varying amounts of refresher training on what to do in a severe weather emergency.**

***Finding*:** **Nine of ten radio stations surveyed said they broadcast NWS warnings, some through formal EBS activation. Several radio stations, however, did not keep logs showing the times they received EBS activation requests. One radio station did not activate its EBS because its transmitter was incorrectly tuned.**

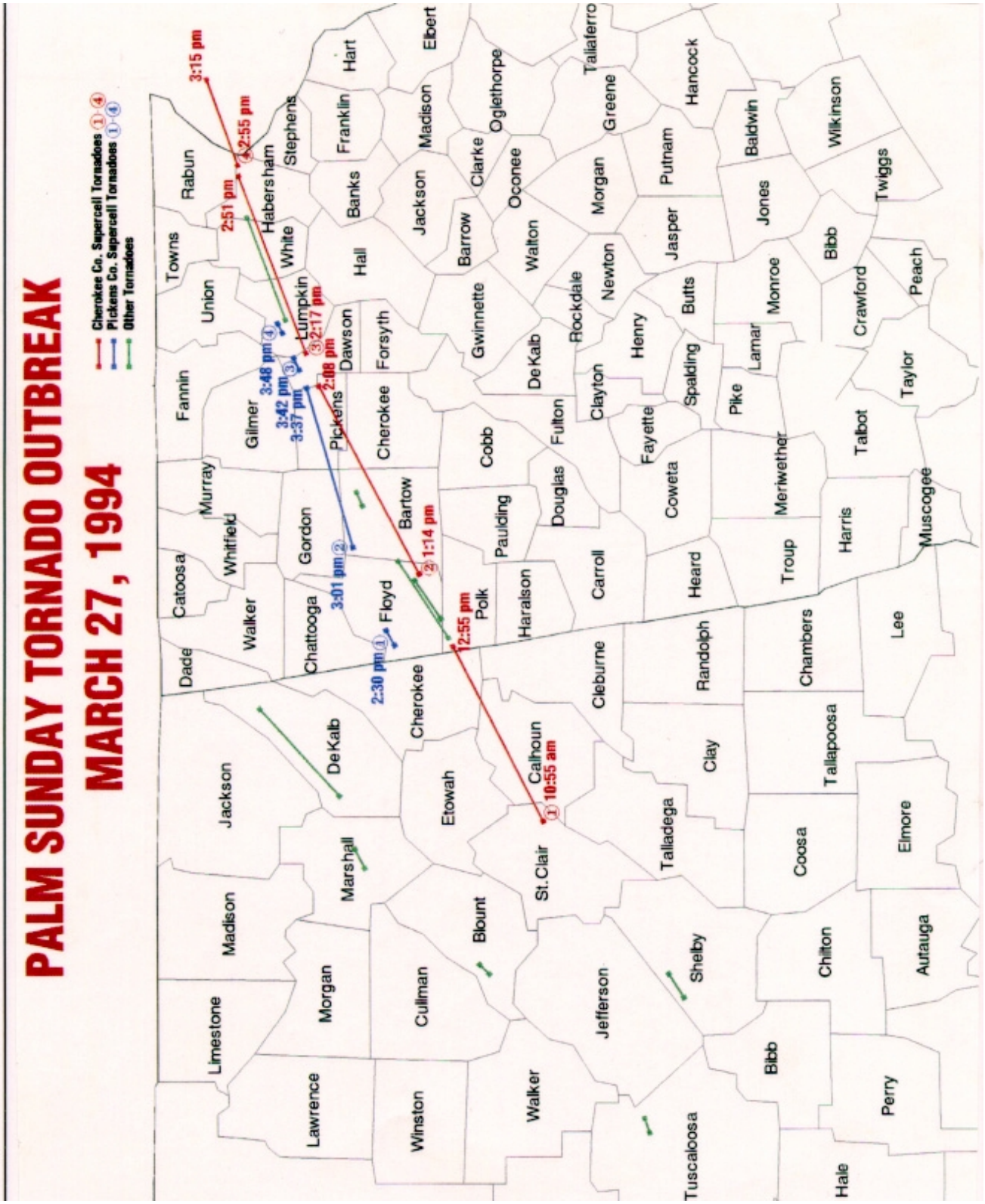

Fig. 1. Total number of tornado tracks in Alabama and Georgia. The four Cherokee County supercell tornadoes (in red) and the four Pickens County supercell tornadoes (in blue) include beginning and end times for each tornado track.

Table 1

SUMMARY OF FATALITIES, INJURIES, AND DAMAGE BY COUNTY ALABAMA AND GEORGIA

County	Fatalities	Injuries	Residences Destroyed	Residences Damaged
ALABAMA				
Calhoun	1	20	45	28
Cherokee	20	92	53	74
St. Clair	1	8	25	28
Subtotal	22	120	123	130
GEORGIA				
Bartow	3	unknown	unknown	unknown
Cherokee	0	1	2	14
Floyd	0	22	100	300
Gordon	0	0	1	3
Habersham	1	6	10	25
Haralson	0	0	1	3
Lumpkin	5	40	32	59
Pickens	9	64	45	174
Polk	0	0	0	3
Rabun	0	2	10	8
White	0	28	30	130
Subtotal	18	163	231	719
TOTAL	**40***	**283****	**354**	**849**

* 40 deaths occurred in Alabama and Georgia; 2 other deaths occurred in North Carolina for a total of 42.
** 283 injuries occurred in Alabama and Georgia; injuries in the Carolinas brought the total to over 320.

Table 2
TORNADO FATALITIES ALABAMA AND GEORGIA

Age	Gender	Location	County
54	F	Outside	St. Clair, AL
49	M	Automobile	Calhoun, AL
54	M	Church	Cherokee, AL
5	M	Church	Cherokee, AL
Approx. 42	M	Church	Cherokee, AL
54	F	Church	Cherokee, AL
4	F	Church	Cherokee, AL
30s	M	Church	Cherokee, AL
34	F	Church	Cherokee, AL
39	M	Church	Cherokee, AL
3	M	Church	Cherokee, AL
50	F	Church	Cherokee, AL
64	M	Church	Cherokee, AL
72	F	Church	Cherokee, AL
12	M	Church	Cherokee, AL
25	M	Church	Cherokee, AL
24	F	Church	Cherokee, AL
2	F	Church	Cherokee, AL
38	M	Church	Cherokee, AL
10	F	Church	Cherokee, AL
Late 70s	M	Church	Cherokee, AL
37	M	Church	Cherokee, AL
72	M	Mobile Home	Bartow, GA
72	F	Mobile Home	Bartow, GA
34	M	Automobile	Bartow, GA
52	M	Mobile Home	Pickens, GA
52	F	Mobile Home	Pickens, GA
28	M	Mobile Home	Pickens, GA
25	F	Mobile Home	Pickens, GA
1	M	Mobile Home	Pickens, GA
16	M	Mobile Home	Pickens, GA
88	F	Mobile Home	Pickens, GA
84	F	Mobile Home	Pickens, GA
46	F	Permanent Home	Pickens, GA
74	F	Mobile Home	Lumpkin, GA
62	M	Mobile Home	Lumpkin, GA
80	F	Mobile Home	Lumpkin, GA
70	M	Mobile Home	Lumpkin, GA
63	F	Permanent Home	Lumpkin, GA
87	F	Mobile Home	Habersham, GA

Table 3

TOTAL PERIOD OF EVENTS AND ASSOCIATED NON-ROUTINE PRODUCTS ALABAMA AND GEORGIA

	Event Start/End	Products
ALABAMA (CST)		
WSFO Birmingham	9:16 a.m./10 p.m.	TOR - 38
		SVR - 40
		SVS/SPS - 29
		Total - 107
GEORGIA (EST)		
WSFO Atlanta	12:42 p.m./10:30 p.m.	TOR - 24
		SVR - 15
		SVS/SPS - 3
		Total - 42
WSO Athens	2:20 p.m./1:53 a.m. (3/28/94)	TOR - 13 SVR - 7
		SVS/SPS - 13
		Total - 33

Legend
TOR (tornado warnings)
SVR (severe thunderstorm warnings)
SVS (severe weather statements)
SPS (special weather statements)

Table 4

TIMES OF FATALITIES AND ASSOCIATED WARNINGS ALABAMA AND GEORGIA

Supercell 1 — Cherokee County Storm

County	Fatalities	Time of Fatalities	Warning
St.Clair, AL	1	11:05 a.m. CST	TOR 10:53 - 11:45 a.m.
Calhoun, AL	1	11:35 a.m. CST	TOR 10:49 a.m. - Noon
Cherokee, AL	20	11:39 a.m. CST	TOR 11:27 - Noon
Bartow, GA	2	1:47 p.m. EST	TOR 1:16 - 2 p.m.
Pickens, GA	1	2:03 p.m. EST	TOR 1:41 - 2:15 p.m.
Lumpkin, GA	2	2:36 p.m. EST	TOR 2:20 - 3:30 p.m.
Habersham, GA	1	3:15 p.m. EST	TOR 2:37 - 3:30 p.m.

Supercell 2 — Pickens County Storm

County	Fatalities	Time of Fatalities	Warning
Bartow, GA	1	3:04 p.m. EST	SVR 3:01 - 3:30 p.m.
Pickens, GA	6	3:24 p.m. EST	TOR 3:20 - 3:45 p.m.
Pickens, GA	2	3:34 p.m. EST	TOR 3:20 - 3:45 p.m.

Additional Fatalities

County	Fatalities	Time of Fatalities	Warning
Lumpkin, GA	3	3:25 p.m. EST	TOR 2:20 - 3:30 p.m.

Table 5

SUMMARY OF NSSFC ACTIONS
ALABAMA AND GEORGIA

Date	Time (CST)	Product
3/26	2 a.m.	Day Two Outlook "possibility of isolated supercells with threat of tornadoes"
3/26	Noon	Day Two Outlook "some supercell tornadoes possible"
3/27	1 a.m.	Day One Outlook ("Moderate Risk"—Alabama/"Slight Risk"—most of Georgia) "primary threat of damaging winds...however tornadoes are also possible"
3/27	9 a.m.	Day One Outlook ("Moderate Risk"—extended to central and northern Georgia) "high wind damage potential...tornado potential will increase rapidly"
3/27	9:05 a.m.	Mesoscale Discussion for Alabama and Georgia (statement focusing on severe thunderstorm potential and possibility of tornado watch issuance)
3/27	9:18 a.m.	Tornado Watch No. 41 valid until 4 p.m. (includes a large part of northern and central Alabama) "supercells and tornadoes likely"
3/27	10 a.m.	Public Severe Weather Outlook (includes much of Alabama and Georgia—reserved for highest risk of severe weather) "potential for tornadoes, some that could be particularly intense"
3/27	11 a.m.	Mesoscale Discussion for Georgia "very favorable wind structure for supercell/tornadic thunderstorms"
3/27	11 a.m.	Tornado Watch No. 42 valid until 7 p.m. EST (6 p.m. CST) (includes a large part of northern Georgia) "possibility of very damaging tornadoes"
3/27	1:30 p.m.	Day One Outlook ("High Risk" for a large part of Alabama and the northern half of Georgia) "numerous tornadic storms"

CHAPTER 2

METEOROLOGICAL ANALYSIS

Finding: **According to the NSSFC, the synoptic (larger scale) atmospheric forces were not as evident for the "Southeast United States Palm Sunday Tornado Outbreak" as many of the significant outbreak events of the past.**

No prominent mid-level short wave moved through the area. The upper-level jet did not move across the warm sector. There was no major cyclogenesis.

Finding: **Nevertheless, large-scale advective processes contributed strong low-level vertical wind shear and large thermodynamic instability, creating a prestorm environment capable of supporting the development of tornadic supercells. Mesoscale processes acting within this favorable environment enhanced the large-scale potential and triggered the tornadic storms.**

Features at 1200 UTC (7 a.m. EST), March 27

Surface features presented a complex pattern at 1200 UTC (Fig. 2). From a weak low over extreme northern Kentucky, a cold front extended southwest across the Cumberland Plateau of Tennessee to the lower Mississippi Valley. A warm front meandered eastward from the low and a weak surface trough extended from northern Alabama to the western Carolinas. The axis of the cold front was parallel to the mean upper flow at 1200 UTC. With no important change expected in the flow during the next 12 hours, there was no impetus for the front to either advance or recede.

The 300 mb initial field of the Nested Grid Model (NGM) depicted a deep, positively tilted long wave trough over the central United States (Fig. 3). East of the trough axis, the polar jet stream spanned the Southern Plains, the mid-Mississippi Valley, and the Ohio Valley, with a 140 knot jet core centered over east-central Missouri. Although the jet core was far removed from the area where tornadoes later occurred, the right entrance region of the upper jet would soon be over northern Alabama. Observational and numerical studies have shown that the right entrance region of an upper jet can generate an ascent region capable of initiating deep, moist convection.

A strong vorticity maximum was rounding the base of the 500 mb trough near the Baha Peninsula (Fig. 4). There were no significant short waves approaching the pre-convective environment over the Southeast, and vorticity advection was minimal over the region. Consequently, the large-scale forcing did not favor cyclogenesis along the frontal zone.

Two distinct wind maxima were indicated at 850 mb (Fig. 5). A 60-knot jet was centered over western Virginia, moving northeast. A second wind maximum exceeding 50 knots was approaching the Gulf Coast south of Louisiana. The jet approaching the Gulf Coast at 1200 UTC produced and maintained significant low-level vertical wind shear over the prestorm environment.

The warm sector airmass was weakly to moderately unstable, with lifted index (LI) values between -2 and -5 (Fig. 5). Fig. 6 contains the field of equivalent potential temperature (theta-e) on the 295 K potential temperature (theta) surface, considered to be the bottom of the isentropic boundary layer. The figure shows a large moisture source over the Gulf of Mexico and a broad theta-e ridge over the Deep South. Flux vectors (Fig. 6) indicate that the Gulf moisture is being driven northward and along the frontal zone. Tropical characteristics of the warm sector airmass are substantiated by theta-e values exceeding 340° K.

Upper air soundings at 1200 UTC (not shown) did not reveal any major obstacles to convective development over the southeast United States. The thermodynamic cap was weak and low-level moisture was plentiful. The soundings also indicated significant vertical wind shear over much of the Southeast. This is important because the strength and pattern of the vertical wind shear strongly influences the type of convection that forms. For example, significant vertical wind shear increases the potential for long-lived, strongly rotating storms (i.e., supercells), especially if the pattern of the shear (i.e., hodograph) indicates substantial curvature through the lowest 2-3 km. These important characteristics of the vertical wind shear can be quantified from the storm's reference frame, by calculating the storm relative helicity (SRH). Observational studies and numerical model simulations have shown that SRH values greater than 150-225 m^2s^2 are associated with the development of supercell storms especially if the environment contains moderate or strong instability. At 1200 UTC, values of 0-2 km SRH ranged from 360 m^2s^2 at Jackson, Mississippi (JAN), to 430 m^2s^2 at Centreville, Alabama (CKL).

Finding: **NSSFC recognized from the March 27, 1200 Universal Coordinated Time (UTC) (7 a.m. EST), data that the hodographs (polar coordinated plots of winds derived from an atmospheric sounding) and storm relative helicity (SRH) calculations were classic indicators for the development of rotating supercells.**

The interactive capabilities of the VDUC (VAS Data Utilization Center) work station were invaluable to NSSFC in fully using the data sources that were available. By modifying the observed 7 a.m. EST, March 27, sounding with the subjectively determined surface temperatures and dew points, NSSFC fully appreciated the severe weather potential of this airmass.

Finding: **The entire warm sector extending from Mississippi eastward through all of Georgia had developed an explosive potential, waiting for a "trigger" (a mechanism to initiate the strong convection).**

Mesoscale Features at 1800 UTC (1 p.m. EST), March 27

The surface low which was centered over northern Kentucky at 1200 UTC was located over west-central Pennsylvania at 1800 UTC (Fig. 7). However, the frontal zone had become nearly stationary from Alabama to the lower Mississippi Valley. The surface trough which extended from northern Alabama to the western Carolinas at 1200 UTC (Fig. 2) developed an impressive temperature gradient by 1800 UTC (Fig. 8), suggesting low-level frontogenesis. In fact, the magnitude of the horizontal temperature gradient normal to the frontal zone increased dramatically from the western Carolinas to the lower Mississippi Valley between 1200 UTC and 1800 UTC. This was important because frontogenesis is associated with increasing low-level convergence, enhanced lift, and strengthening low-level vertical wind shear.

Subjective surface analysis (Fig. 7) indicated a series of mesoscale frontal waves; one over north-central Alabama, another over southwest Mississippi, and a third over west-central Louisiana. Mesoscale circulations are important because they help to focus and trigger convective storms. The mesolow over north-central Alabama was associated with the tornadic supercells that devastated parts of Alabama and Georgia between 1600 UTC and 1900 UTC.

Special upper air soundings were taken at 1800 UTC by JAN (Fig. 9) and CKL (Fig. 10). These soundings indicated 0-2 km SRH values near 440 m^2s^2 at both sites, based on an observed storm motion of 245º/45 knots. The field of SRH at 1800 UTC (Fig. 11) demonstrates that the vertical wind shear had become stronger and more widespread since 1200 UTC especially from eastern Louisiana to western Georgia. This area coincides with the 850 mb jet max diagnosed over the Gulf at 1200 UTC and situated over southern Alabama at 1800 UTC. The soundings also substantiate that the atmosphere had become more unstable across the South since 1200 UTC, with Convective Available Potential Energy (CAPE) values of 2348 J kg^{-1} at JAN and 2665 J kg^{-1} at CKL. A study by Johns, et al. (1991), demonstrated that for any particular value of CAPE, there appears to be a range of SRH values compatible with the development of tornadic supercell storms. The Energy Helicity Index (EHI) was designed to represent the empirical relationship suggested by that study. Values greater than one have been associated with increasing supercell potential; values of five or greater have been associated with an enhanced potential for supercell storms to produce strong or violent tornadoes. EHI values of 6.44 at JAN and 7.28 at CKL suggested a very dangerous environment at 1800 UTC.

Conclusion

This was not a "synoptically evident" event. However, the thermodynamic cap was weak over much of the Southeast, and the advection of tropical low-level moisture yielded CAPE values around 2500 J kg^{-1}. Once convection began, there was a high likelihood that supercell storms would develop because the environment contained significant low-level vertical wind shear and associated high values of SRH. Finally, low-level frontogenesis combined with the circulations and convergence-divergence patterns associated with a series of mesolows to focus and trigger the storms.

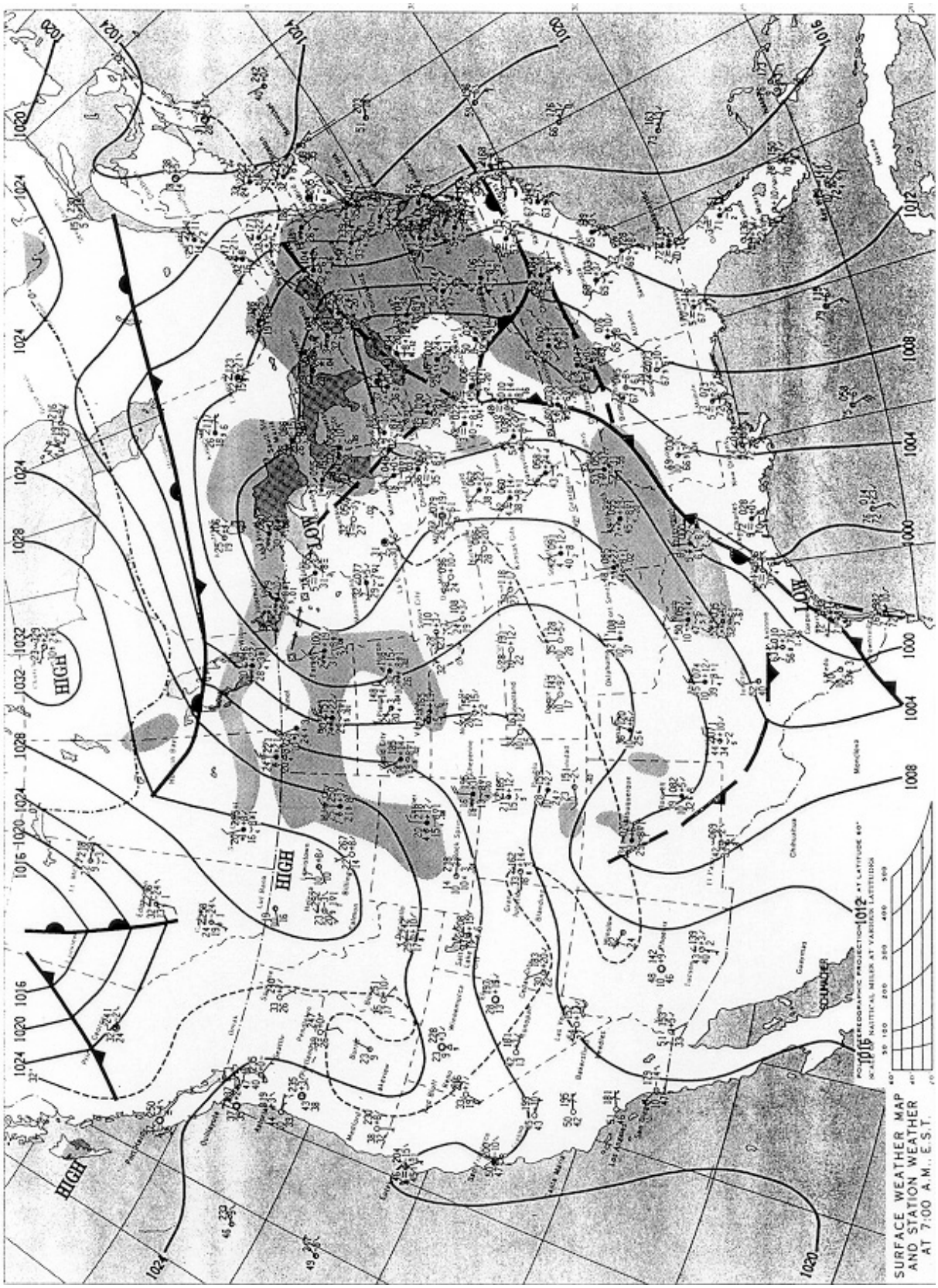

Fig. 2. Surface plots and subjective surface analysis for 1200 UTC (7 a.m. EST), March 27, 1994. Plots are in standard format with conventional symbols.

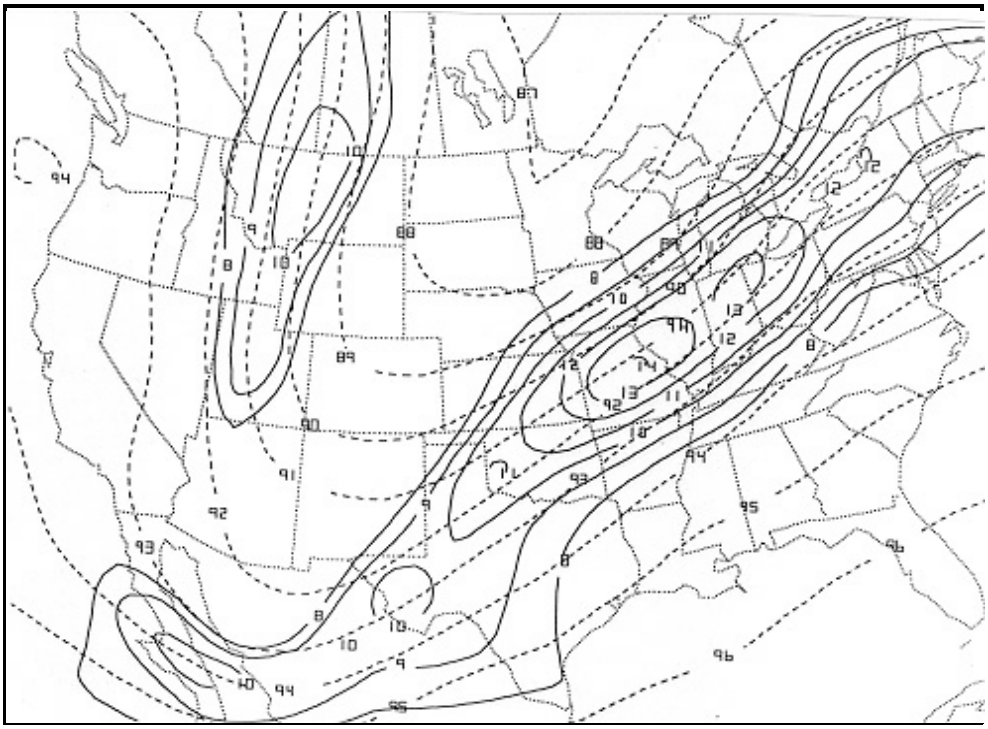

Fig. 3. NGM 300 mb initial field of geopotential height (dashed) and isotachs (solid), valid 1200 UTC (7 a.m. EST), March 27, 1994. Isotachs are contoured every 10 kts for wind speeds ≥ 80 kts.

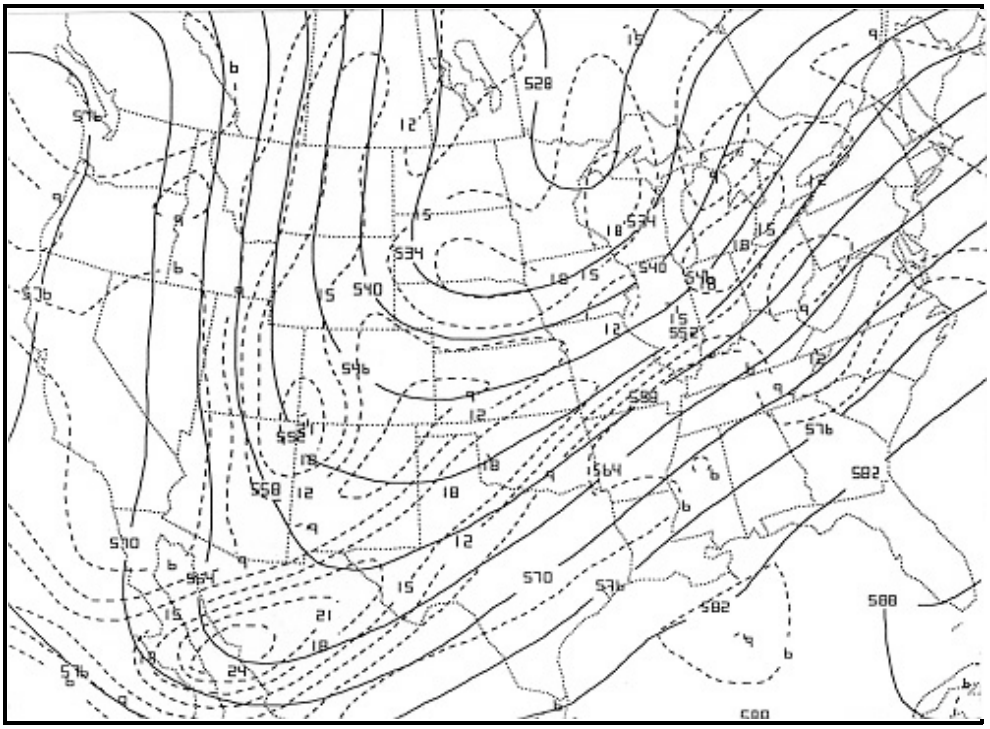

Fig. 4. NGM 500 mb initial field of geopotential height (solid) and vorticity (dashed), valid 1200 UTC (7 a.m. EST), March 27, 1994.

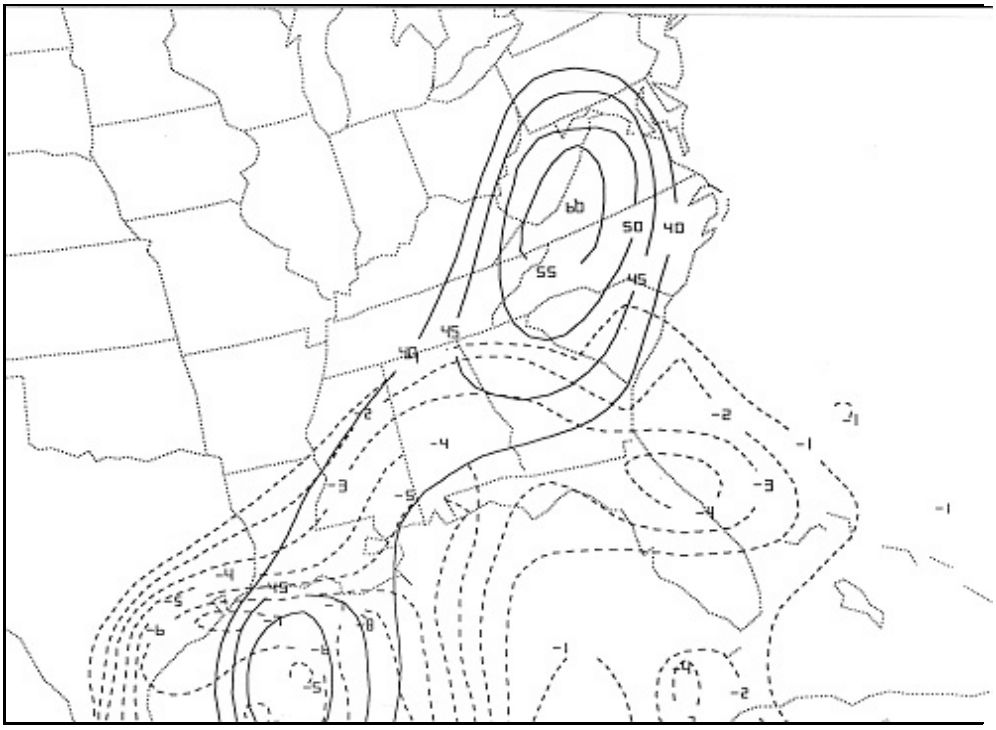

Fig. 5. NGM 850 mb initial field of isotachs (solid) and Lifted Index (dashed), valid 1200 UTC (7 a.m. EST), March 27, 1994. Isotachs are in 5 kt intervals for wind speeds ≥ 40 kts. Lifted Index values are contoured every 1° C for values ≤ -1° C.

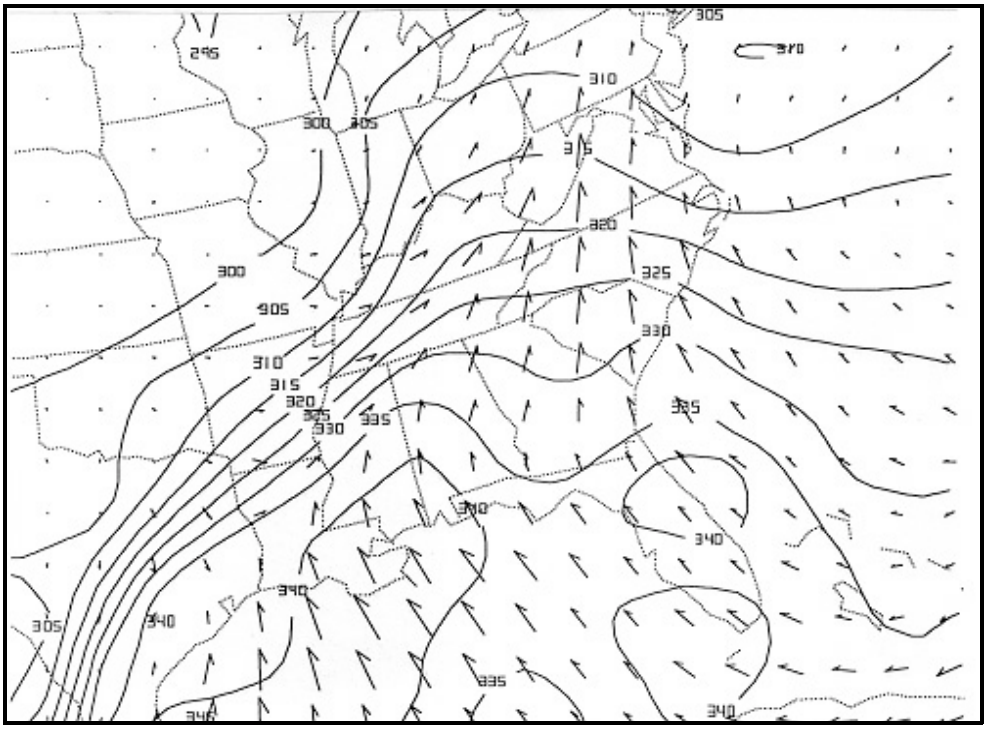

Fig. 6. NGM initial field of equivalent potential temperature (theta-e) and moisture transport vectors on the 295 K isentropic surface, valid 1200 UTC (7 a.m. EST), March 27, 1994. Theta-e contoured every 5 K.

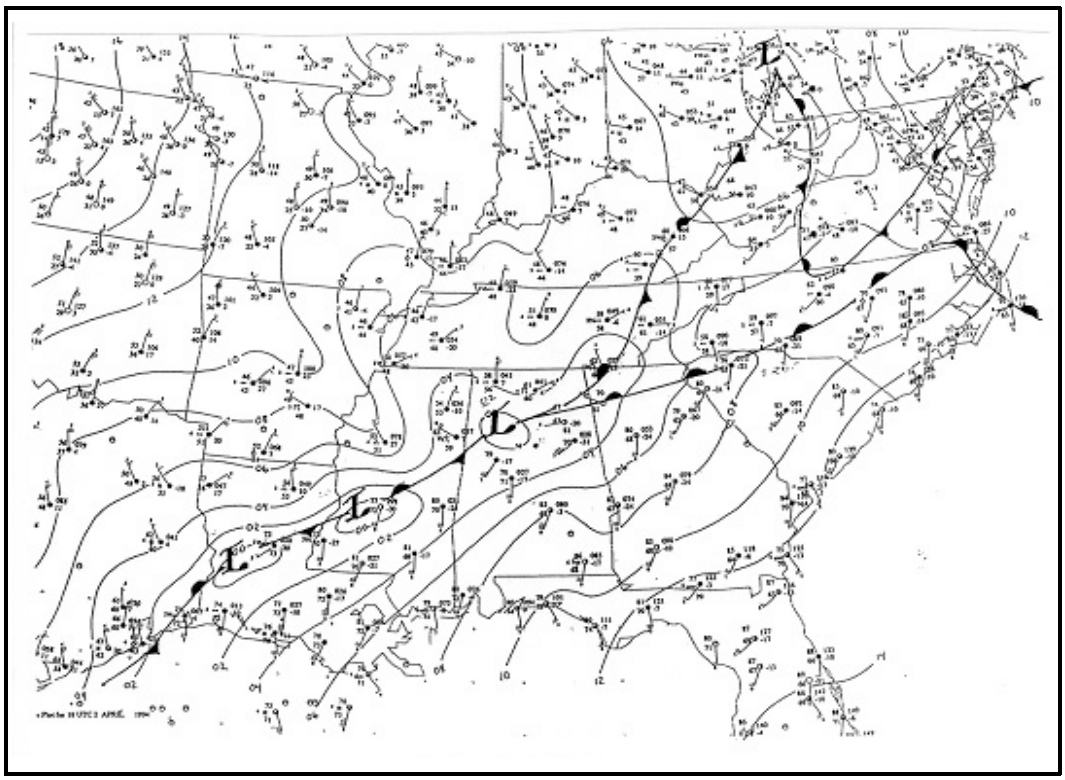

Fig. 7. Surface plots and subjective surface analysis for 1800 UTC (1 p.m. EST), March 27, 1994. Plots are in standard format with conventional symbols.

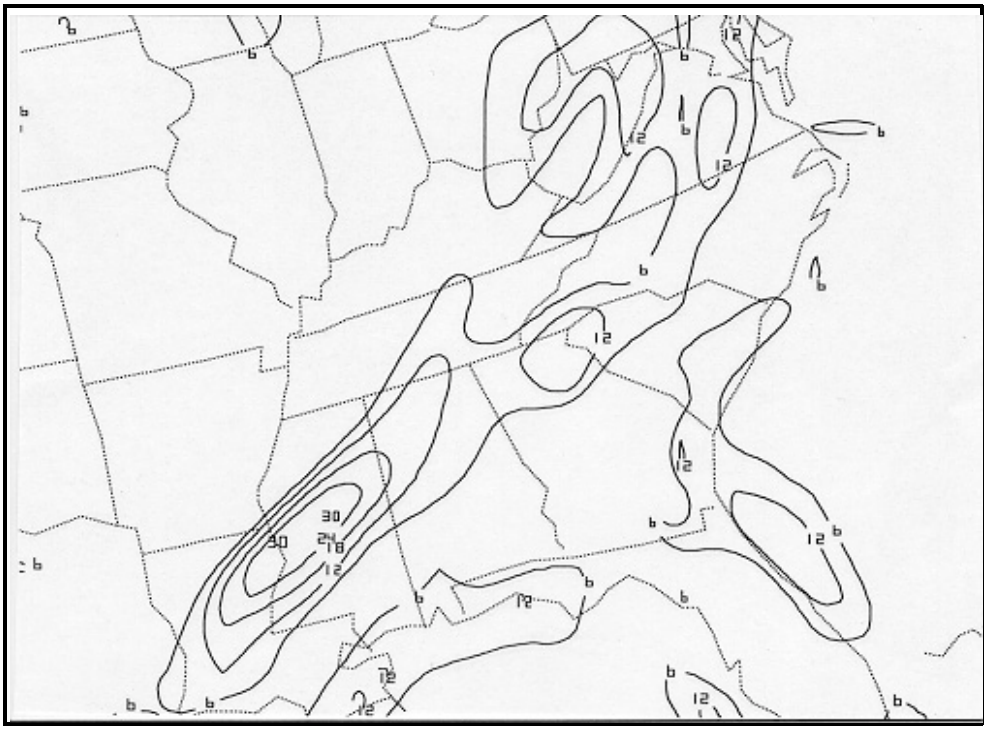

Fig. 8. Change in the magnitude of the temperature gradient between 1200 UTC and 1800 UTC (1 p.m. EST), March 27, 1994. Values are contoured for positive changes.

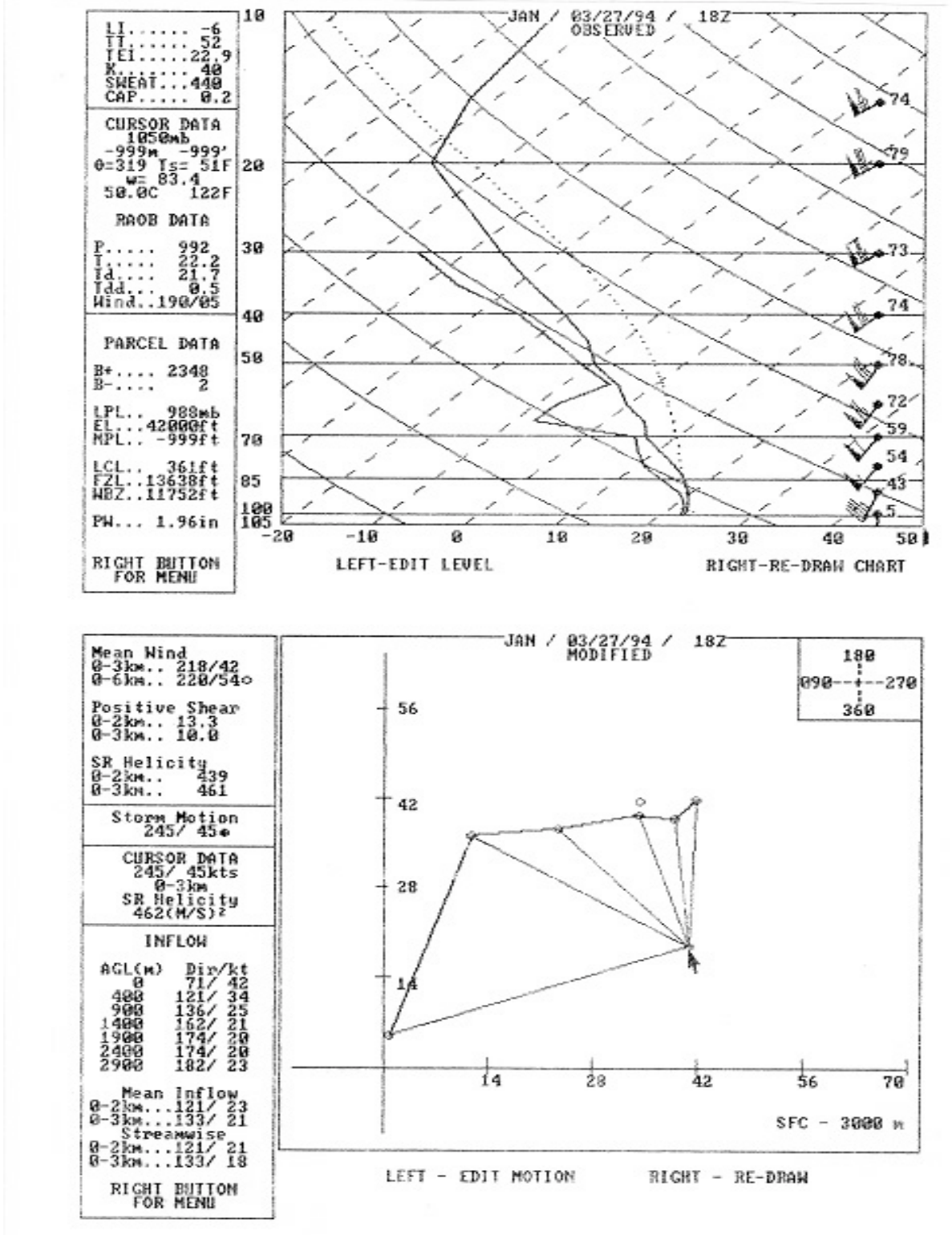

Fig. 9. Special upper-air sounding for Jackson, Mississippi (JAN), valid 1800 UTC (1 p.m. EST), March 27, 1994. The Skew-T (top) depicts a CAPE value of 2348 J kg^{-1}. The hodograph (bottom) indicates 0-3 km SRH of 463 m^2 s^2, based on an observed storm motion of 245/45.

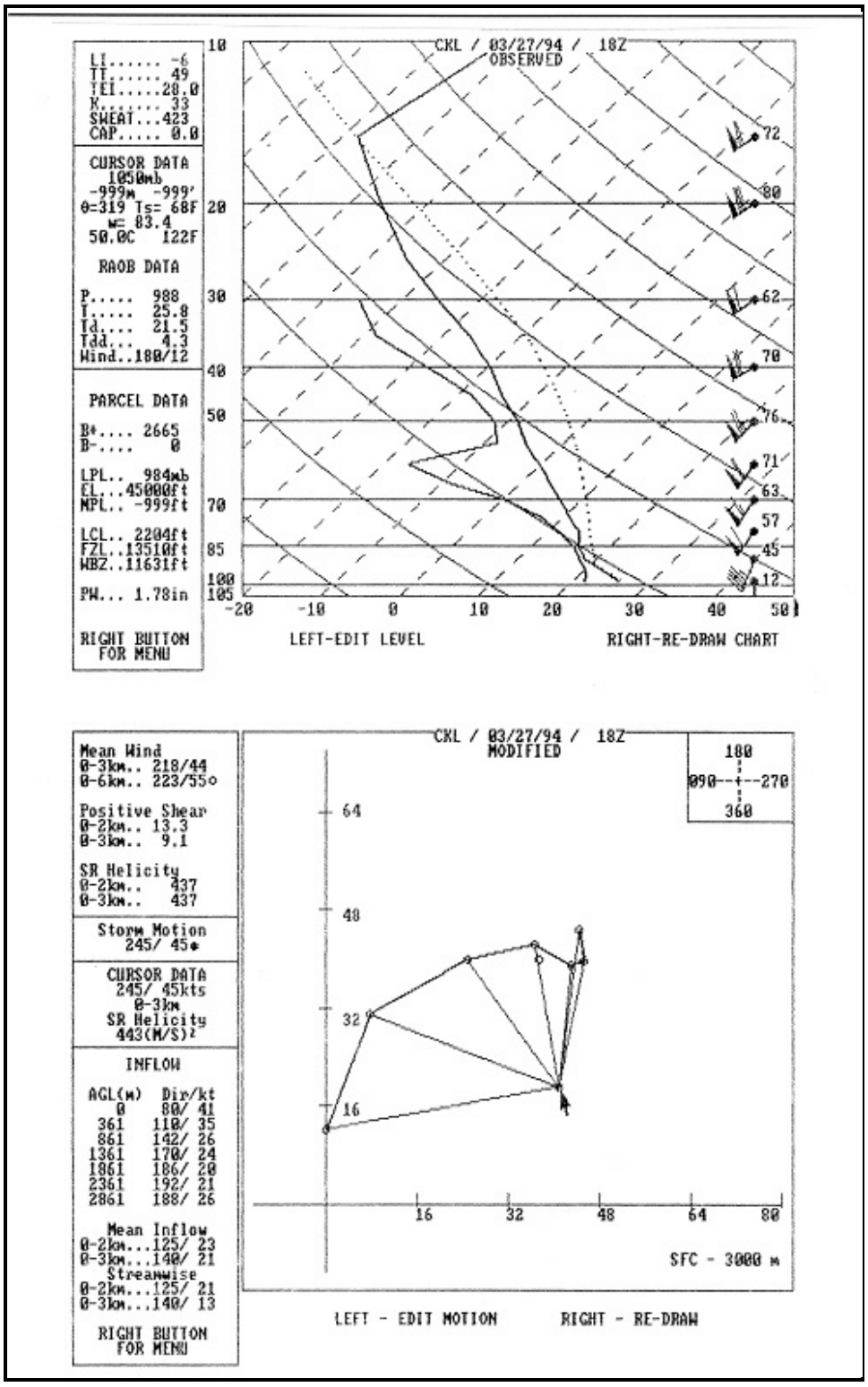

Fig. 10. Special upper-air sounding for Centreville, Alabama (CKL), valid 1800 UTC (1 p.m. EST), March 27, 1994. The Skew-T (top) depicts a CAPE value of 2665 J kg^{-1}. The hodograph (bottom) indicates 0-3 km SRH of 443 m^2 s^2, based on an observed storm motion of 245/45.

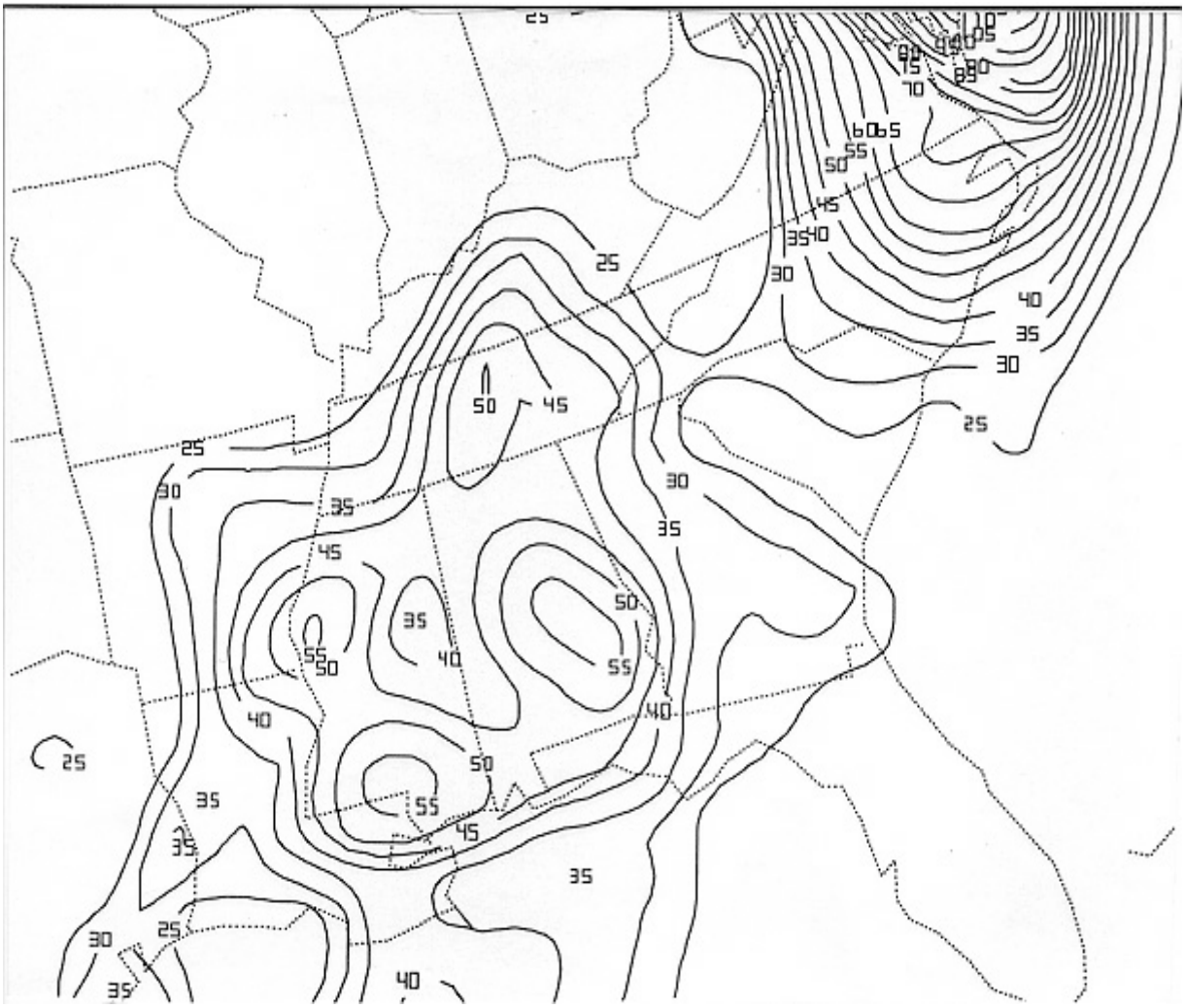

Fig. 11. Rapid Update Cycle analysis of storm-relative environmental helicity, valid 1800 UTC (1 p.m. EST), March 27, 1994. SRH values are contoured every 50 m^2 s^2 for values ≥ 250 m^2 s^2.

CHAPTER 3

TORNADO CASE STUDY NO. 1
Southern Cherokee County, Alabama/
Goshen United Methodist Church

NWS Warnings Save Lives...

A DST member and the Warning Coordination Meteorologist from WSFO Birmingham were assessing the damage to several homes about one-half mile west ("upstream") of the Goshen UMC in extreme southern Cherokee County on Wednesday morning, March 30. A woman across and about a hundred yards down County Road 31 noticed the two men walking through the rubble of one of the houses that was totally demolished by the Cherokee County Tornado. She separated herself from a swarm of workers fixing her house that had surprisingly sustained only "moderate" damage and walked over. After learning who the two individuals were, she quietly described her harrowing experience.

She, her husband and child, and her brother's child were at home that Sunday morning. Her brother, who was working in extreme northern Calhoun County (a few miles away), heard the NWS tornado warning for Calhoun County and telephoned his sister to take cover in his house since it had a basement and hers didn't. This was about 20 minutes before the tornado struck. By the time she could gather her family, the tornado was rapidly bearing down on them. They fled across the road to her brother's house and all but the husband managed to slip into the basement. The husband was thrown free and sustained some injuries; none very serious. The rest of the family clung together miraculously unscathed in an interior doorjamb of the basement while her brother's house collapsed around them.

A. Description and Impact of Event

On Sunday, March 27, at 11:39 a.m. CST, a tornado struck the Goshen UMC in southern Cherokee County, Alabama, killing 20 people and injuring 90. The time was determined by a police officer's radio time-check as he spotted the tornado just before it hit the church and radioed the report into police headquarters in Piedmont. He did not have time to warn the church.

This was the first of four tornadoes produced by the "Cherokee County" supercell (see Chapter 1). At the time of occurrence, the tornado had a forward speed of about 55 mph and had been on the ground for about 35 miles, beginning in Ragland. The center of the one-half-mile wide tornado and its maximum F3 wind speeds passed about 200 yards north of the church, resulting in damage toward the tornado's southern periphery, correlating with wind speeds rated F1 on the Fujita scale. This was consistent with surrounding damage to residences, where wind speeds were estimated at about 100 mph.

The most severely damaged area of the Goshen UMC was the sanctuary (near the middle of the building) when the southern periphery of the tornado broadsided the south roof and wall.

The sanctuary was rectangular in plan with the long dimension oriented east-west, 60-feet long by 38-feet wide. Winds that toppled the sanctuary came from the south direction and preceded the tornado centerline. The tornado center was positioned northwest of the church when failure of the sanctuary occurred. As the tornado center passed north of the church, winds at the church shifted to west and resulted in the removal of the roof section above the classrooms. The high pitch of the roof and tall height of the walls acted like a sail to catch the wind. Failure of the sanctuary roof and walls occurred as they rotated to the north. Injuries and deaths were attributed to falling debris.

Finding: **An interior hallway that remained intact in the Goshen UMC during the tornado could have provided adequate shelter for all 150 occupants.**

As mentioned in Recommendation 4, people should seek shelter in basements or small interior rooms and hallways during threatening weather, and avoid rooms and buildings with large roof spans.

B. Radar Evaluation

Finding: **The East Alabama DoD WSR-88D (at Maxwell AFB) was the main source of warning information for WSFO Birmingham, an associated user to the radar. The WSFO had the full range of available WSR-88D products.**

As mentioned in Finding 8, WSFO Birmingham forecasters stated that the radar performed well with no significant problems. Despite the total lack of spotter reports confirming the existence of the tornado, they maintained and extended tornado warnings based mainly on WSR-88D information.

As the Cherokee County storm moved through St. Clair County, WSFO Birmingham forecasters recognized features in the reflectivity data associated with tornado or severe thunderstorm occurrence, including weak echo channels (suggesting strong, straight-line winds), V-notches, hook echoes, and bounded weak echo regions (suggesting storm rotation).

WSR-88D velocity data showed a pronounced couplet—strong inbound velocity next to strong outbound velocity. The couplet suggested a mesocyclone—an area of intense

rotation within the storm, characteristic of a supercell that could produce strong and violent tornadoes. When all radar data was examined, the WSFO Birmingham staff concluded that a powerful supercell was threatening the area and issued tornado warnings for St. Clair, Calhoun, and Etowah Counties between 10:49 a.m. and 10:53 a.m. CST.

The Cherokee County Storm maintained these radar characteristics as it moved through Calhoun County, resulting in the 11:27 a.m. CST tornado warning for Cherokee County. At 11:37 a.m. CST, just 2 minutes prior to the tornado striking the Goshen UMC, WSR-88D reflectivity data (Fig. 12a) indicated a well defined hook echo. Storm-Relative Mean Radial Velocity data (Fig. 12b-d) indicated a deep mesocyclone from the lowest elevation of the volume scan from 0.5° elevation through the 2.4° elevation.

C. Guidance, Forecasts, and Warning Actions

Although the situation was not as synoptically evident as many other outbreak cases, NWS forecasters at NSSFC recognized the possibility for severe weather well in advance of the event and provided excellent guidance products (see Chapter 1, Table 5, for a complete list of NSSFC products and actions before and during the onset of the outbreak). The NSSFC began calling attention to the affected area in the initial Day Two Convective Outlook, issued at 2 a.m. CST, March 26, and indicated Alabama was in a risk for severe thunderstorms. By Saturday afternoon, March 26, NSSFC forecasters addressed the possibility of supercells and tornadoes across portions of the southeast United States, including Alabama.

The early morning NSSFC Day One Convective Outlook, issued at 1 a.m. CST, March 27, again emphasized that supercells were favorable and included Alabama in a "Moderate Risk."

***Finding*: Based on the timely and accurate guidance from NSSFC, WSFO Birmingham began mentioning the possibility of severe weather in State Forecast Discussions (SFD) 24 hours in advance of the event and in their zone forecasts beginning about 19 hours ahead of the event.**

The WSFO Birmingham SFD, issued at 3:37 a.m. CST, Saturday, March 26, mentioned, "...a favorable area for possible severe weather on Sunday...." By late afternoon Saturday, WSFO Birmingham forecasters were even more confident of severe weather on Sunday. The 3:07 p.m. CST SFD mentioned "...severe weather across most of the state Sunday into Sunday night...."

In an aggressive move by WSFO Birmingham forecasters, the wording "thunderstorms may be severe" was added to the second period ("tomorrow") of the zone forecasts issued at 4:05 p.m. CST, Saturday, March 26. Thus, for over 19 hours before tornado touchdown, the zone forecast for Cherokee County called for the possibility of severe weather.

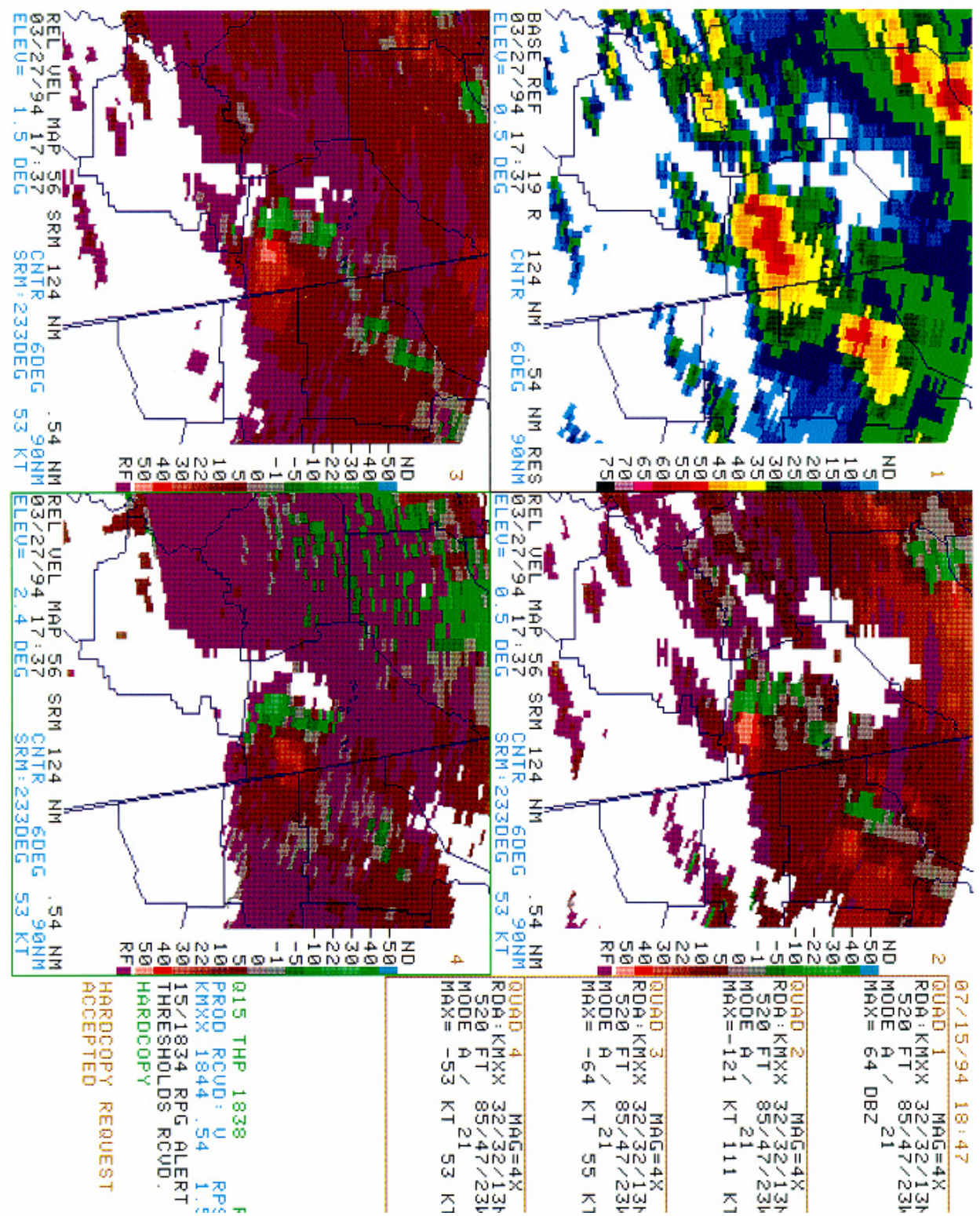

Fig. 12. From East Alabama WSR-88D, March 27, 1994, 1737 UTC (11:37 a.m. CST): (a) Base Reflectivity, 0.5° elevation; (b-d) Storm-Relative Mean Radial Velocity, elevations 0.5°, 1.5°, 2.4°, respectively.

The early morning WSFO Birmingham SFD, issued at 2:33 a.m. CST Sunday, March 27, called for the "...possibility of severe weather...." This SFD contained a discussion of synoptic-scale features, forecast models, and zone forecast parameters. There was little mention, however, of the meteorological environment that might have focused on a significant tornado event.

Both the early morning (4:45 a.m. CST, March 27) and mid morning (9:39 a.m. CST, March 27) Alabama zone forecasts stated that "...thunderstorms may be severe..." There was the mention of heavy rain but no specific mention of the possibility of tornadoes.

Early Sunday morning, WSFO Birmingham issued two additional products to help prepare the public for the possibility of severe weather.

Finding: **WSFO Birmingham issued a special weather statement (SPS) at 5:45 a.m. CST, about 5 hours before the first tornado warning was issued, emphasizing the potential for severe weather in parts of Alabama.**

This gave advance notice to the population of the impending threat. Much of the special weather statement, however, contained synoptic detail, with a relatively small part directly conveying specific information about the threat. Tornadoes were not specifically mentioned, however. At 9:40 a.m. CST, March 27, a public information statement was issued that contained tornado safety rules. No other SPSs or other hazard awareness statements were issued before the first warnings. While tornadoes were recognized as a possibility, the clear, specific tornado outbreak threat, as opposed to severe thunderstorms, most likely was not recognized until mid-morning Sunday.

Recognition of the magnitude of the outbreak became most apparent after analysis of the 6 a.m. CST, March 27, data. Based on this information, NSSFC issued a PWO, reserved for the most dangerous situations, at 10 a.m. CST, March 27, with an emphasis on widespread severe thunderstorms and tornadoes across the central Gulf Coast into the western Carolinas. The possibility of particularly intense tornadoes was mentioned.

Finding: **NSSFC issued Tornado Watch No. 41 at 9:18 a.m. CST that covered a large part of the WSFO Birmingham county warning area (CWA) (including Cherokee County and the Goshen UMC). Shortly after, WSFO Birmingham updated their zone forecasts to include the Tornado Watch in the headline and continued to mention "some thunderstorms may be severe..." in the text of the forecast.**

Before WSFO Birmingham forecasters issued the Cherokee County tornado warning, they issued four severe thunderstorm warnings between 9:16 a.m. and 10:45 a.m. CST. They also issued the following two tornado warnings and follow-up severe weather statements (SVS) that provided updates on the location of the tornadoes. Again, information used in these statements was provided by the WSR-88D and not real-time reports. Thereafter, numerous tornado warnings were issued.

10:45 a.m. CST — SVS
10:49 a.m. CST — tornado warning for Etowah and Calhoun Counties
10:53 a.m. CST — tornado warning for St. Clair County
11:20 a.m. CST — SVS

During the time the tornado was traversing Calhoun County, the Calhoun County Emergency Operations/911 Center (EOC) received 89 reports of the tornado sighting or tornado damage. None of these reports were relayed to WSFO Birmingham.

***Finding*:** **WSFO Birmingham issued a tornado warning for northern Calhoun, southern Cherokee, and southeast Etowah Counties at 11:27 a.m. CST, about 12 minutes before the tornado struck the Goshen UMC and killed 20 people and injured 90.**

The 11:27 a.m. CST tornado warning contained the following information:

> "At 11:30 a.m...Weather Service radar indicated a tornado on the ground just east of the Ohatchee Area in Calhoun County, moving northeast at 35 to 40 mph. This storm is expected to travel along the Calhoun/Etowah border into Cherokee County during the next half hour."

The warning also contained two call to action statements (CTA).

Positive Aspects of NWS Warning:

- Timely and accurate warning for Cherokee County.
- Correct coding.
- "Tornado on the ground" reinforces threat.
- Mentions where the tornado will go.
- Contains a CTA.

Possible Areas of Improvement:

- Mention specific communities/public places in the path of the tornado.
- Include a reference to a large, well known city if possible.
- Use only one CTA.
- Use specific times. Instead of "next half hour," use, for example, "between 11:30 a.m. and 12 Noon."

D. Communications and Dissemination/Emergency Management

Based upon discussions with emergency managers, it appears that the majority of the emergency management community was not completely aware of the significant threat before the development of the first tornadoes. In almost all cases, EOCs were not adequately staffed before the event. Most of these difficulties were attributed to the event occurring on a Sunday. Some emergency managers did not tune into television or radio. Others were at church and were not aware of the impending severe weather.

After the WSFO Birmingham staff issued the tornado warning for southern Cherokee County at 11:27 a.m. CST, March 27, it was disseminated to law enforcement, emergency management, and the public.

NWS Dissemination Times:

11:27 a.m. CST Tornado Warning

AFOS — 11:28 a.m. CST
NAWAS — 11:28 a.m. CST
NWWS — 11:29 a.m. CST
NWR — 11:26 a.m. CST (short statement)
11:29 a.m. CST (full statement)

Hard copy of the warning was distributed to the Alabama counties via the Alabama LETS. Entry into this system from the NWWS is manual and takes several minutes. Thus, it would be expected that warning dissemination via LETS would be 2 to 4 minutes later (about 11:32 a.m. CST).

While most emergency managers relied on LETS for primary warning notification, a number of emergency managers and other local officials in rural counties relied on NWR for receipt of severe weather information. They had high praise for NWR and were able to remain somewhat proactive in implementing their community preparedness plans. Those few emergency managers and law enforcement officials who had use of NWWS were the most informed of the developing severe weather. Hard copy of relevant warnings, forecasts, and statements facilitated implementation of their community preparedness plans.

Following are emergency management/law enforcement actions and comments the DST received in interviews with personnel from Cherokee and Calhoun Counties to provide a more complete picture of the total warning process in the affected areas in northern Alabama.

Ronnie Strawbridge, emergency manager in Cherokee County, said he did receive notice of the warning. Before the warning, he was attempting to deploy spotters. Because it was a Sunday morning, however, he was unable to reach all spotters, and full spotter coverage was not in place at the time of the tornado warning.

Delois Champ, Public Information Officer for Calhoun County Emergency Management Agency, and other staff members provided information on their operations in warning situations and gave the DST a tour of their secured, underground facility. In response to the nearby Anniston Army Depot, which is one of several around the country that harbors an aging chemical stockpile that is slated for elimination, the county requires a highly sophisticated emergency center and preparedness plan. As a result, all warning actions in the county benefit from this advanced technology.

E. Communications and Dissemination/Media Outlets

As described above, WSFO Birmingham disseminated the Cherokee County tornado warning via NWR, NWWS, and NAWAS. Local television and radio outlets received the warning and broadcast it to the public.

Finding: **WEIS-AM in Cherokee County was able to broadcast the warning from WSFO Birmingham for the tornado that struck the Goshen UMC about 5 minutes after receiving it, still providing about a 7-minute lead time.**

Finding: **The Goshen UMC did not receive the NWS tornado warning. They were not aware of any television or radio reports and did not have NWR. No siren systems existed near the church. NWR capability could have provided storm victims with precious minutes to seek shelter.**

Recommendation 3E1: **Places of public gathering should be equipped with a tone-alert NWR that should be monitored closely during severe weather situations. NWS must continue to emphasize that places of public gathering should have tested preparedness plans to protect people when severe weather threatens.**

Recommendation 3E2: **It is important that NWR expansion and proposed enhancements be accelerated to minimize the risk for future loss of life, resulting from natural and manmade hazards.**

Following are comments and actions the DST received in interviews with members of several media outlets involved with the Palm Sunday warnings in Alabama.

Tom Williams, General Manager of WHMA-FM in Anniston (Calhoun County, south of the Cherokee County tornado track), stated that power failed at his facility at 10:55 a.m. CST. The only available source of weather information was NWR. Mr. Williams relied on NWR to obtain the required severe weather information to be broadcast to the community. He stated that "NOAA Weather Radio was it!" He was "very satisfied" with WSFO Birmingham's services and stated that they did "a four-star job." "At 11 o'clock in the morning," he continued, "the churches are full—this is the Bible Belt. How do you get the word out to everybody? It's impossible. Mass communication only works with people who are listening. I think the Weather Service did a hell of a job. I give them four stars."

Dr. Ted Klimasewski of WJSU-TV (CBS) in Anniston said the delivery of information from WSFO Birmingham was "exceptionally good." "I think TV stations need to be more prepared for an event of this sort on the weekends. Things really get down to a skeleton crew especially in the morning hours." He also stated that he would like to see specific cities mentioned within the warnings and statements. (See Finding and Recommendation 28.)

Jerry Baker, owner of the 1,000-watt WEIS-AM station in Centre (Cherokee County, north of the tornado track), said the station's computer is linked into the WSO Huntsville Enterprise radar. The station was in constant communication with the Huntsville WSO (in the northern part of Alabama). As a public service, this small AM station provides regular weather updates and interrupts/pre-empts regular programming to broadcast detailed weather reports/warnings. According to Mr. Baker, "We're here to serve. My FCC license says we are a public trustee, and we take that literally. We don't take it lightly...we're not here just to broadcast music, news, and entertainment."

James Spann, meteorologist for WBRC-TV Channel 6 (ABC) in Birmingham, said NWS warnings "were excellent in this case." He also said "The WSR-88D at Maxwell AFB (East Alabama) performed like a champ. The problem was a lot of people didn't hear the warnings. A lot of the problem is public apathy." The station subscribes to a service that automatically generates a crawl across the screen based on NWWS transmissions.

Jerry Tracy, meteorologist for WVTM-TV Channel 13 in Birmingham, uses a station Doppler radar and monitors Centreville's WSR-57 radar. He was aware that WSFO Birmingham was using the new radar (East Alabama) and said "...it performed flawlessly. It was probably the best handling of a severe weather event I've seen in terms of lead times and issuances of warnings." This station also subscribes to a service that provides a crawl of NWWS transmissions. The warnings come up almost instantaneously, but the station does not keep records that would show the time the warnings were broadcast.

Joe Madison, Program Director for WMJJ-FM in Birmingham (the primary EBS station in the city), said "The Associated Press wire service is normally our first line of warning. We rely heavily on that." He also said that NWR warnings seem to come in about the same time as AP bulletins. In severe weather, the station also uses services of local TV meteorologist, James Spann, or his associate.

Mark Bass, General Manager of the 100,000-watt WQEN-FM station in Gadsden (Etowah County, north of the Cherokee County tornado track), said "We take weather information around here very seriously. On the day of the storm, we had the whole station crew down here all day." His station serves Etowah County and reaches into about 14 of the surrounding counties. In the control room, the station has NWR, a TV monitor tuned to cable broadcast of Doppler radar, AP wire, and maintains direct contact with emergency management.

Fred Gray, disk jockey for the religious format WJBY-AM in Gadsden, said he activated EBS three times that day, once before 11 a.m., once between 11 a.m. and noon, and once around 1 p.m. After the Meadowbrook Baptist Church heard the outdoor sirens, the pastor canceled the station's weekly live broadcast of their 11 a.m. service. Gray carried a solid hour of weather information and warnings until noon.

Following are some of the preparedness/awareness activities conducted by WSFO Birmingham in northeastern Alabama at the beginning of the 1994 severe weather season as part of its ongoing role in educating users and the public to hazardous weather situations.

2/22/94	Visits to WEIS-AM, WAGC-AM, and WRHY-FM radio stations (all in Cherokee County).
2/22/94	Spotter training session for Cherokee County Emergency Management in Centre. About 35 people attended composed mostly of law enforcement, rescue squad, and volunteer fire personnel.

2/24/94	Spotter training session for St. Clair County Emergency Management in Pell City. The crowd included amateur radio operators, emergency management staff, general public, law enforcement, and rescue squad and fire department staff.
2/28-3/4/94	Severe Weather Awareness Week in Alabama, a statewide public awareness campaign.
3/3/94	Safety awareness talks at two elementary schools in Calhoun County.
3/3/94	Appeared on WJSU-TV (Anniston) noon talk show discussing Severe Weather Awareness Week and tornado safety.
3/3/94	Spotter training session for Calhoun County Emergency Management Agency in Anniston with about 20 people attending.

Two close-up views of the damaged inner sanctuary of the Goshen UMC. The collapsed roof is visible in both pictures. (Note, for orientation, see the cover photograph of the entire damaged church.) Photographs courtesy of Barry Reichenbaugh.

Unanchored home shifted off its foundation. Most of the home, including the garage, moved to the north (Calhoun County, Alabama). Photograph courtesy of _____.

F4 to F5 damage occurred in F3 intensity winds as house was not anchored to its foundation. Photograph courtesy of _____.

CHAPTER 4

TORNADO CASE STUDY NO. 2
Pickens County, Georgia

<u>NWS Warnings Save Lives</u>...An Atlanta Journal article in the "News For Kids" section reported a story on two young girls who had a very close call. The article stated:

> ***"...Hundreds of others saw the twisters or heard their roar—including Brandy Wood, 11, and Kelly Meadows, 12, of Jasper. The girls, both sixth-graders at Pickens Elementary, were playing together at Brandy's house when they <u>heard an alert on the radio</u>. As the killer winds approached, they say the weather got very weird. 'The sky was like green or greenish-blue,' Brandy said. 'It started hailing real bad, about the size of golf balls. The hail and rain were cold, but the air was hot. The wind was getting higher and faster. It sounded like a train was going through.' About the time the hail hit, the girls went to the basement where they sat whispering and listening. ...After about 15 minutes, Brandy and Kelly went outside. 'You could see pieces of people's houses up in the trees,' Brandy said. 'It just barely missed our house. I've never been in anything like that...'."***

A. Description and Impact of Event

On Sunday afternoon, March 27, two tornadoes over an hour apart, but in close, parallel tracks, moved rapidly northeast at about 50 mph across Pickens County, Georgia, killing 9 people and injuring 64. Damage estimates in the county, including damage to personal residences and commercial property, exceeded $23 million.

The first killer tornado came into Pickens County just before 2 p.m. EST from the Salacoa Valley in the southwest corner of the county and moved rapidly northeast. A person at home was killed at 2:03 p.m., 3 miles south of Jasper. (This was the second tornado produced by the Cherokee County storm that caused the deaths at the Goshen UMC [Chapter 3, Case Study No. 1].)

The second killer tornado, hereafter called the "Pickens County storm," the primary subject of this case study, entered Pickens County from Gordon County in the Jerusalem Church area around 3:19 p.m. EST. Of the 14 family members attending a reunion, 6 of 7 died when their mobile home was destroyed at 3:24 pm EST, near the small community of Jerusalem in the Henderson Mountain area. The other seven survived without serious

injury even though their mobile home next door was also destroyed. The tornado then killed two more people in separate mobile home incidents at 3:34 p.m. EST, about a mile northwest of Jasper.

B. Radar Evaluation

Finding: **WSFO Atlanta had dial-up capability to DoD's Robins AFB WSR-88D and the East Alabama WSR-88D and direct use of their WSR-74C local warning radar. As a dial-up user, the office had access to a more limited set of WSR-88D products as compared with an associated user. Forecasters used mostly storm relative velocity and VIL (vertically integrated liquid) products and looping capabilities of the radar for effective radar analyses.**

Forecasters indicated no significant problems were encountered with either of the radars and were always able to dial in successfully during the active severe weather period. As with WSFO Birmingham, the forecasters in WSFO Atlanta stated the WSR-88D performed very well and provided confidence in issuing and maintaining tornado warnings despite the lack of ground truth, the limited product set at their office, velocity range folding, and the distance from the radars to the storms.

Pickens County is just beyond the 124 nm range for velocity products from the East Alabama WSR-88D. Before it moved out of velocity data range, the Pickens County supercell exhibited a pronounced couplet of strong inbound velocity adjacent to strong outbound velocity, indicative of a mesocyclone, as it moved through northern Bartow County (Fig. 13a). Reflectivity data from the East Alabama WSR-88D (effective out to 248 nm) continued to exhibit characteristics suggesting storm rotation as the storm moved out of Bartow and Gordon Counties and into Pickens County (Fig. 13b).

As the storm moved into Pickens County, it moved into the periphery of the velocity data range of the Robins AFB WSR-88D, still exhibiting strong characteristics of a mesocyclone. Based on this information from both WSR-88Ds and the reflectivity data from their own WSR-74C, WSFO Atlanta staff concluded that a powerful supercell was threatening Pickens County and issued a tornado warning for the counties of eastern Bartow, northwest Cherokee, eastern Gordon, and all of Pickens at 3:20 p.m. EST. As the storm continued across Pickens County (Fig. 13c), velocity data continued to exhibit a pronounced couplet of strong inbound velocity adjacent to strong outbound velocity (Fig. 13d) (Fig. 13a-d, 0.5° elevation).

C. Guidance, Forecasts, and Warning Actions

The meteorological situation was even less synoptically evident for Georgia as it was for Alabama. Nevertheless, NSSFC forecasters began calling attention to the effected area in the initial Day Two Convective Outlook, issued at 3 a.m. EST, March 26 (see Chapter 1, Table 5, for a complete list of NSSFC products and actions before and during the onset of the outbreak). NSSFC forecasters addressed the possibility of supercells and tornadoes across portions of the southeast United States, including the northern half of Georgia.

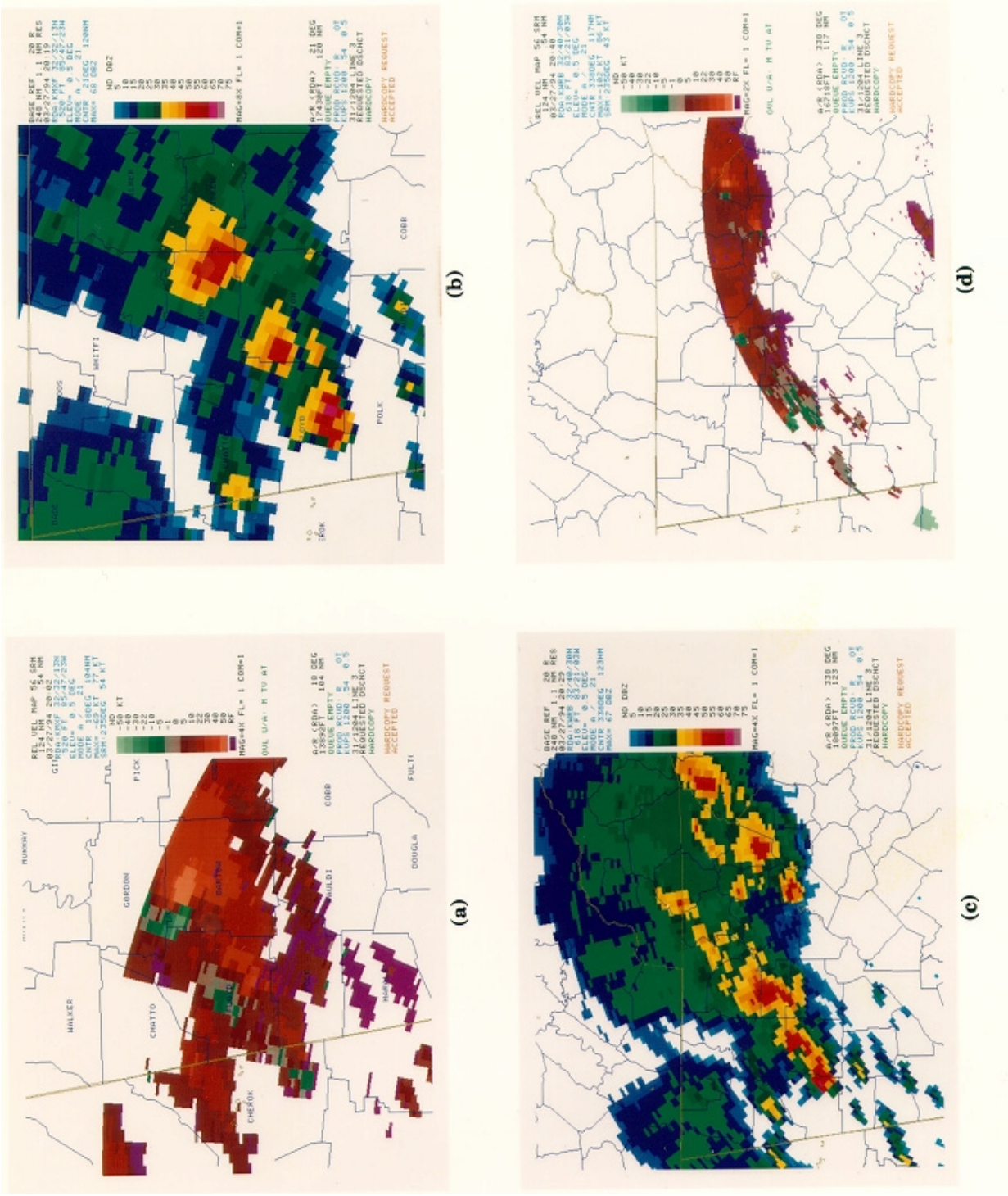

Fig. 13. For March 27, 1994, (a-d) 0.5° elevation: (a) Storm-Relative Mean Radial Velocity, East Alabama WSR-88D, 2002 UTC (3:02 p.m. EST); (b) Base Reflectivity, East Alabama WSR-88D, 2019 UTC (3:19 p.m. EST); (c) Base Reflectivity, Robins AFB WSR-88D, 2029 UTC (3:29 p.m. EST); and (d) Storm-Relative Mean Radial Velocity, Robins AFB WSR-88D, 2040 UTC (3:40 p.m. EST).

The early morning Day One Convective Outlook issued at 2 a.m. EST, March 27, again mentioned that supercells were favorable and included most of Georgia in a "Slight Risk" area. Recognition of the magnitude of the outbreak, however, became most apparent after analysis of the 7 a.m. EST, March 27, NMC computer generated model guidance.

Finding: **NSSFC upgraded northern Georgia to a "Moderate Risk" valid at 10 a.m. EST. Along with the PWO issued at 11 a.m. EST, these actions further emphasized the likelihood of widespread severe thunderstorms with particularly intense tornadoes in a large part of northern Georgia.**

Finding: **While northern Georgia was in a "Slight Risk" for severe storms through the early morning hours, WSFO Atlanta focused on flash flooding as the risk of the day. WSFO Atlanta did not issue pre-event statements for severe thunderstorms or tornadoes after NSSFC substantially raised the level of risk for northern Georgia.**

Recommendation 4C1: **WSFOs identified by NSSFC in their Convective Outlook products as falling within a severe local storms outlook area should issue a morning State Severe Weather Outlook and timely update statements, mentioning the likelihood for severe weather over their area of responsibility. State Severe Weather Outlooks should not be considered optional for "Moderate" or "High Risk" situations. Also, zone forecasts should be worded to further heighten the risk.**

Finding: **NSSFC issued Tornado Watch No. 42 valid at 12 Noon EST, that covered a large part of northern Georgia (including Pickens County). Shortly after, WSFO Atlanta updated their zone forecasts to include the Tornado Watch in the headline, but because of an incorrect AFOS procedure being run, the zones were labeled 5:10 p.m. EST instead of 1:20 p.m. EST.**

Finding: **WSFO Atlanta's forecast wording in the updated zone forecasts did not reflect the magnitude of the event, both in the increased likelihood or severity of the storms. Forecast wording included "...windy with scattered showers and a few thunderstorms."**

Recommendation 4C2: **When NSSFC guidance indicates an increased probability of severe thunderstorms and tornadoes for an office's area of responsibility, forecasters are encouraged to highlight that potential in the text of the forecast period, using such words as "Thunderstorms likely, some severe and could produce tornadoes," or "Thunderstorms, some with damaging winds and large hail."**

Finding: **WSFO Atlanta issued a tornado warning at 3:20 p.m. EST for the counties of eastern Bartow, northwest Cherokee, eastern Gordon, and all of Pickens County about 4 minutes before the tornado struck the mobile homes that killed 6 of 14 people at a family reunion. This same warning provided a**

14-minute lead time before the tornado killed two other people near Jasper in Pickens County at 3:34 p.m. EST.

The 3:20 p.m. EST tornado warning contained the following information.

> "Radar indicated a severe thunderstorm from southeast Gordon County across northern Bartow County. This storm was moving northeast at 50 mph. A tornado was reported with this storm near White in central Bartow County around 3:15 p.m. EST."

Positive Aspects of NWS Warning:

- — Timely and accurate warning for Pickens County.
- — Correct coding.
- — Contains a CTA.
- — Contained actual tornado report (however, this report turned out to be inaccurate; actually this was the second tornado from the Cherokee County [Alabama] storm that struck White at about 1:45 p.m. EST).

Possible Areas of Improvement:

- — Mention specific communities/public places in path of the tornado.
- — Include a reference to a large, well known city if possible.

During the time the tornadoes were occurring, WSFO Atlanta forecasters did not issue any follow-up statements to inform the public on the progress of the tornadoes.

As mentioned in Finding and Recommendation 28, it is critical that warnings include specific communities/public places in the path of severe storms.

D. Communications and Dissemination/Emergency Management

The tornado warning for Pickens County at 3:20 p.m. EST was disseminated to law enforcement, emergency management, and the public.

NWS Dissemination Times:

3:20 p.m. EST Tornado Warning
AFOS — 3:21 p.m. EST
NWWS — 3:20 p.m. EST
NAWAS — 3:23 p.m. EST
NWR — 3:22 p.m. EST

Hard copy of the warning was distributed via NWWS to the Georgia Emergency Management Agency (GEMA). Further distribution to state, county and local officials, and the state LETS was done through GEMA. Entry into the LETS from the NWWS is manual and takes several minutes. As in Alabama, it would be expected that warning

dissemination via LETS would be 2 to 4 minutes later. The law enforcement community also receives warnings and other messages via NAWAS.

Following are emergency management/law enforcement actions and comments not only from Pickens County, but, to provide a more complete picture of the total warning process, also from other affected areas in northern Georgia.

C. R. (Bud) Aiken, Director of the Pickens County Emergency Management Agency, stated that they received early notification of NWS warnings from GEMA. Once emergency management was alerted to the severe weather, they tuned to NWR for all subsequent information, per GEMA instructions. Mr. Aiken said "The NWS did an excellent job in keeping he and his staff up to date." He learned of the severity of the situation through broadcasts of NWS information on Atlanta TV and went directly to the emergency management facility before 2 p.m. EST. To his surprise, his full staff, having been alerted to the severe weather, was already mobilized and at work.

He also provided information in the following finding based on post-event interviews his staff conducted.

***Finding*: The family having a reunion in Pickens County did not receive the NWS tornado warning. They were not aware of any television or radio reports and did not have NWR. No siren systems existed in their area.**

***Recommendation 4D1*: See Recommendations 33a and 33b.**

(Interestingly, Mr. Aiken said that GEMA has arranged to have NWS warnings and other pertinent weather information broadcast to schools through the Public Broadcast System's existing TV-education-to-the-schools program. This action was expected to begin for the school term in the fall of 1994.)

Charlie Herrington, Chief of the six-man police force in Cleveland (White County), nestled in the mountains of extreme northeast Georgia, stated that NWR was the only way police headquarters received NWS warnings. Given their limited resources and that the community lacked sirens, the few minutes advance warning of the impending tornado was not enough time for them to help alert the affected citizenry.

Jerry Ely, Rome Sheriff Department's Warrant Division Captain, heard tornado warnings for Floyd County via radio scanner 15 to 20 minutes before the Lindale area was struck by a tornado during the evening hours. He stated, "Early warnings no doubt saved many lives and allowed police, fire, and emergency response teams to be dispatched to the disaster scenes prior to and during the tornado touchdowns."

(Two Lindale/Silver Creek area residents, who were at a day care center, said they heard the tornado warnings for Floyd County on television 5 to 10 minutes before touchdown in their neighborhood. They thanked one of the WSFO Atlanta forecasters, who was on a local office preliminary survey, for NWS's early warnings.)

Barry Church, Director of the Emergency Management Agency of Habersham County in extreme northeast Georgia, stated that they use and further disseminate NWWS information over their state LETS. Importantly, because the EOC combines the Emergency Management Agency with Central Communications (911), spotter reports were relayed in a timely manner to WSO Athens for effective warnings issuances. This EOC is a highly sophisticated underground facility, fully self-contained with auxiliary power on automatic transfer.

Other contacts that provided general information found in this report are:

Jimmy Berry, Sheriff, Dahlonega (Lumpkin County)

Don Eaabolt, Director of the Emergency Management Agency in Dahlonega

Officer Larry Haynes, Training Officer for 911 in Habersham County

E. Communications and Dissemination/Media Outlets

Following are comments and actions the DST received in interviews with members of several media outlets involved with the Palm Sunday warnings in Georgia. Pickens County is a small, rural county with a total population of about 14,000 people. No radio or television stations originate from within the county. Most people in the county receive their information from Atlanta media outlets and, for local information, from WCHK-AM/FM in Canton in Cherokee County.

Byron Dobbs, General Manager of WCHK-AM/FM in Canton (Cherokee County, directly south of Pickens County), said he took many calls from listeners unsure of what safety measures to follow while under a tornado warning. WCHK has an NWR in the room adjacent to the control room and receives EBS signals from WSB radio in Atlanta. The station is a radio affiliate of WSB-TV, Atlanta, and that day simulcast all of weathercaster Glenn Burns' updates live.

Glenn Burns, meteorologist with WSB-TV (ABC, Channel 2) in Atlanta, said the station subscribes to WSI's service, which takes NWS warnings and watches and automatically broadcasts them on a crawl across the television screen. The station issued the first tornado warning at about 12:40 p.m. for the city of Rome (and the rest of Floyd County). "I thought the local WSFO had an outstanding performance throughout the storm," Mr. Burns said. The only complaints he received were from some Atlanta viewers who were angry that the alarms on their weather radios didn't go off in the immediate Atlanta area. (Atlanta wasn't in the warning areas and their NWRs rightly should not have been alarmed.)

Bud Veazey, Operations Manager for WAGA-TV, Channel 5 (CBS) in Atlanta, said that the station receives its weather information from NWWS and the AP news wire and automatically directs appropriate messages into their newsroom computer for automatic generation of a TV crawl. WAGA displayed a flash flood watch at 11:15 a.m. EST from WSFO Atlanta for extreme north Georgia. The station also displayed NSSFC's tornado

watch at 12:45 p.m. EST for most of north Georgia, including Pickens County. The first of

WSFO Atlanta's tornado warnings, for Floyd County, was displayed at 12:48 p.m. EST. Also, WAGA had called in the weekend weathercaster, John Doyle, who did live updates about every 15 to 30 minutes from about 1 p.m. EST through much of the afternoon. The station uses an older DoD FPS-77 radar (5 cm) with Doppler add-on and has its own in-house system (Lightning Fast Weather).

Mitch Elliott, disc jockey for the 100,000-watt WFOX-FM station in Atlanta, which reaches into Pickens and Lumpkin Counties, worked from noon to 4 p.m. Sunday, March 27. He received two calls from the Athens WSO to activate the EBS; once at 2:30 p.m. EST and again at 2:44 p.m. EST.

Phil Castleberry, General Manager of WDGR-AM in Dahlonega (Lumpkin County), said they aired the first EBS warning at 2:30 p.m. and the second at 2:44 p.m. (Their EBS transmission comes from WFOX-FM in Atlanta). The station lacks a back-up generator and was off the air for an hour or two after power was knocked out after 2:50 p.m. EST.

Bobby Price, General Manager of WTSH-FM in Rome (Floyd County), said the station's transmitter log indicates the EBS alert was received at 2:45 p.m. EST. However, he said, "We received the warning from the NWS a few minutes before and issued it to the public at that time."

Noelle Stettner, Program Director of WLET-FM in Gainesville (Hall County), said NWR is not kept in the control room but in an adjacent office. They don't get the AP news wire, but they have a partnership with, and get breaking information from, the local newspaper—part of the Gannet chain (including *USA Today*). She said station employees are thoroughly trained in how to react to an EBS activation. The station did not receive the EBS signal because the part-time engineer had been working on the station's equipment and had their receiver tuned to the wrong station!

Following are some preparedness/awareness activities conducted by WSFO Atlanta at the beginning of the 1994 severe weather season as part of its ongoing role in educating users and the public to hazardous weather situations.

2/21-25/94 Annual Georgia Severe Weather Awareness Week Campaign

— Mass statewide mailing to spotters, Emergency Management Agencies, schools, and the media to announce the event and to encourage participation.

— Throughout the week, various severe weather preparedness exercises were broadcast over NWR.

2/25/94 A "mock" tornado warning for the state of Georgia was issued and successfully received by many of the participants, including schools, spotters, and the members of the general public.

The remains of a mobile home in Pickens County where six people in the same family were killed. The Palm Sunday tornadoes resulted in three other deaths in the north Georgia County and 64 people were treated at emergency rooms for storm-related injuries. (Photograph courtesy of Pickens County Progress, Jasper, Georgia)

A common sight in many areas of Pickens County: storm victims picking through the rubble, looking for salvageable personal belongings. Authorities believe as many as six different twisters touched down in the county on Palm Sunday between 1:30 and 8:30 p.m. CST, cutting two broad paths of destruction across the 20-mile-wide county. (Photograph courtesy of Pickens County Progress, Jasper, Georgia)

One of many toppled mobile homes along Hill City Road in Pickens County, Georgia. J. C. Hightower and his son, Scot, who both live nearby, heard about another mobile home in the area that was picked up into the air 25 feet, then smashed to the ground. Witnesses expected to find the occupant they knew was inside crushed in the rubble. But before they could get there to help, a man crawled out on his own without any life-threatening injuries. (Photograph courtesy of Pickens County Progress, Jasper, Georgia)

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.