Service Assessment

July 5–14, 1996

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, MD

April 1997

Cover photograph: Hurricane Bertha - *http://www.ncdc.noaa.gov/pub/data/images/*.

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Preface

The primary purpose of this Service Assessment is to document the evaluation of the National Weather Service's (NWS) performance in fulfilling its mission of providing timely warnings and accurate forecasts for Hurricane Bertha. The NWS's products and services used by emergency managers are key to preparedness for and the mitigation of a tropical cyclone's impact. More specifically, this was the first time a complete Hurricane Liaison Team (HLT) was used in an operational environment. This team is a joint venture between the Federal Emergency Management Agency (FEMA), the NWS and state and local emergency management officials. The concept is to supplement the National Hurricane Center (NHC) staff with Federal, state and local emergency management personnel to provide information and coordination between the NHC and emergency management decision makers. As this assessment has noted, the warning process is a partnership between the NWS and all organizations charged with responding to natural hazards. We in the NWS will continue to forge and nurture relationships to ensure the best possible warning service for our citizens.

Elbert W. Friday, Jr.
April 1997

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Appendices

Acronyms

AFOS	Automation of Field Operations and Services
AOC	Aircraft Operations Center
ASOS	Automated Surface Observing System
AST	Atlantic Standard Time
AVN	Aviation Model
CWA	County Warning Area
DEMA	Delaware Emergency Management Agency
ECMWF	European Center for Medium Range Weather Forecasting
EDT	Eastern Daylight Time
EMC	Emergency Management Center
EMWIN	Emergency Managers Weather Information Network
ERH	Eastern Region Headquarters
ET	Electronics Technician
Eta	Eta Model
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
ft	feet
GFDL	Geophysical Fluids Dynamical Lab Model
GOES	Geostationary Operational Environmental Satellite
HLS	Hurricane Local Statement
HLT	Hurricane Liaison Team
HPC	Hydrometeorological Prediction Center
in	inch
IR	Infrared
kts	knots
MAR	Modernization and Restructuring
mb	millibar
MIC	Meteorologist in Charge
MPC	Marine Prediction Center
mph	miles per hour
MRF	Medium-range Forecast Model
MRFX	Medium-range Forecast Experimental Model
NAWAS	National Warning System
NCEP	National Centers for Environmental Prediction
NEXRAD	Next Generation Weather Radar
NGM	Nested Grid Model
NHC	National Hurricane Center
nm	nautical miles

NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Naval Operational Global Atmospheric Prediction System
NOW	Short Term Forecast
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
NWWS	NOAA Weather Wire Service
OM	Office of Meteorology
PUP	Principal User Processor
QPF	Quantitative Precipitation Forecast
RDA	Radar Data Acquisition
SOO	Science and Operations Officer
SPC	Storm Prediction Center
SRH	Southern Region Headquarters
SSMI	Special Sensor Microwave Imagery
TPC	Tropical Prediction Center
TWC	The Weather Channel
UTC	Coordinated Universal Time
VIS	Visible
VITEMA	Virgin Islands Territory Emergency Management Agency
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WSH	Weather Service Headquarters
WSR-88D	Weather Surveillance Radar-1988 Doppler
WV	Water vapor

Acknowledgments

This report was produced by having those responsible for each portion of the service provided write their own section. Each NWS field office and NWS Regional Office affected by Bertha conducted its own survey of the services they provided. Additionally, assessments were written by the National Centers that provided products and services related to Bertha. The Service Assessment Team is grateful to all those that provided valuable input into this document. The individuals primarily responsible for the Assessment are as follows:

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Executive Summary

Background

Hurricane Bertha was an early season Category 2 storm when it made landfall on the coast of North Carolina on July 12, 1996. Twelve deaths have been directly attributed to Bertha with United States damages estimated at $270 million. Extensive evacuations of vulnerable areas occurred in advance of Bertha, including 250,000 in North Carolina, 80,000 in South Carolina and 20,000 in Georgia. Revenue losses to the tourist industry approached $40 million.

Bertha closely paralleled the southeast U.S. coast at a distance from 170 to 200 miles. This created multiple state involvement with almost all of the U.S. east coast involved with some watch or warning. The NHC's track forecast was very accurate with average forecast track errors 15 percent lower than the 10-year official track averages. Where the storm came ashore in North Carolina, watches and warnings were posted 65 hours and 47 hours before landfall, respectively, which far exceeds the NHC stated goals of 36 and 24 hours. Nevertheless, the coordination between NHC and emergency managers, regarding the issuances of watches and warnings, was frustrated by efforts to reconcile the meteorology of the event with state and local response requirements. Bertha's anticipated turn from a northwest direction to north-northwest as it approached the southeast coast was agonizingly slow. This put a great deal of pressure on the elected officials and Emergency Management Centers (EMCs) of Florida, South Carolina and North Carolina concerning what actions to take. This was also the first time the HLT had been fully deployed at the NHC. A Service Assessment Team was dispatched to the NHC as well as the impacted states to investigate these issues and to evaluate the HLT.

Issues

Bertha's slow northward turn off the Florida coast caused the state of Florida to urge NHC to issue watches when NHC felt they were unnecessary. The major concern was that if the storm continued to move differently than forecast, sufficient response time would not be available if watches or warnings were issued at short notice. Similarly, South Carolina expressed the need for early release of the official forecast track before NHC had completed the internal NWS coordination process. Several recommendations have been made in this report to help resolve these issues.

A variety of communication/coordination issues were also revealed. NHC/state briefings were complicated by the fact that no single communication system was used to brief state emergency management officials, adding to the workload of the hurricane specialists and confusion between state EMCs and the NHC as to what method of coordination would be employed. Similar coordination problems occurred between NWS field offices and local EMCs as well as between some state and local EMC(s). Internal coordination between NWS offices posed difficulties as not all necessary offices are connected to the Hurricane Hotline. This problem will continue to increase as additional NWS offices spin up to full Weather Forecast Office (WFO) status.

The amount of meteorological information received by state and local EMCs to a large extent depended upon the resources available to each office. Even though it is not considered an operational system, Internet received high praise while the National Oceanic and Atmospheric Administration (NOAA) Weather Wire Service (NWWS) continues to prove too costly for some EMCs. Additionally, NOAA Weather Radio (NWR) coverage is still lacking in some coastal areas. Accordingly, the NWS should seek to expand implementation of the Emergency Management Weather Information Network (EMWIN) as well as NWR.

This was the first time the HLT was used in an operational environment. This team is a joint venture between FEMA, the NWS and state and local emergency management officials. The concept is to supplement the NHC staff with Federal, state and local emergency management personnel to provide information and coordination between the NHC and emergency management decision makers. As this is a new initiative, the HLT is still evolving in response to the needs and desires of both the partners in the HLT and their customers. Questions remain regarding the ultimate mission, function and operations of the HLT. Additionally, a larger resource pool of available people to staff the HLT needs to be identified, and smoother procedures for setting up the team's hardware need to be established.

Some data acquisition problems were also noted. The St. Croix and St. Thomas Automated Surface Observing Systems (ASOS) were both powered down by the Federal Aviation Administration (FAA) when the airport towers were abandoned resulting in the loss of valuable ground truth data. Due to the remoteness of the site, the San Juan Weather Surveillance Radar-1988 Doppler (WSR-88D) remote data acquisition (RDA) unit uses generator power since commercial power is not available. The generator produces irregular frequency fluctuations which puts the system out of service. The FAA electronics technician was able to keep the system operational throughout the storm, and a more permanent fix was employed after the passage of Bertha. NWSFO Miami noted that without data off the southeast Florida coast, no wave information is available south of Melbourne. This forced the staff to estimate waves from their wind forecasts.

Meteorology

Bertha was an early season Cape Verde hurricane which started as a tropical depression in the central tropical Atlantic on July 5. For 3 days, the depression moved west-northwest at 23 to 29 miles per hour (mph) and strengthened to a hurricane on July 8 as the center moved across the

Leeward and Virgin Islands of the northeast Caribbean. Bertha turned northwestward on July 9. Maximum sustained winds reached 115 mph at 2 a.m. Eastern Daylight Time (EDT), when Bertha was centered 138 miles north of Puerto Rico. The last hurricane to reach this strength this early in the season was Alma in 1966. Moving northwest, the center paralleled the Bahama islands. The track became north-northwest on July 10 and 11 as the center moved parallel to the coast of Florida and Georgia. With a forward speed of 17 mph, Bertha made landfall at 4 p.m. EDT on July 12 on the coast of North Carolina, midway between Wrightsville and Topsail Beaches.

Bertha quickly dropped below hurricane strength when it moved inland over eastern North Carolina. Highest wind gusts reported on land were 108 mph at Camp Lejeune and Jacksonville, North Carolina. The lowest observed sea-level pressure at landfall was 977 millibars (mb) at Surf City, North Carolina. A value of 974 mb is assumed to be the minimum landfall pressure. Bertha then moved northeast along the U.S. east coast, producing 45 to 60 mph sustained winds over land from northern North Carolina to New England. Bertha was declared extratropical on July 14 when the center moved from the Maine coast to New Brunswick, Canada.

Coastal storm surge flood heights, from Florida through New England, ranged from 1 to 4 feet, but values to 5 feet were estimated on the North Carolina coast from Cape Fear to Cape Lookout. A storm surge of 6 feet was indicated near Swansboro, North Carolina.

Rainfall associated with Bertha occurred from the eastern Carolinas to Maine with many locations receiving 2- to 4-inch amounts. Isolated reports of over 6 inches were reported from North Carolina to Massachusetts. The maximum was 7.20 inches at Billerica, Massachusetts. Bertha's rapid motion through the Northeast served to limit rainfall duration and amounts.

Six tornadoes have been confirmed with four in Virginia, one in North Carolina and one in Maryland.

Summary of Findings and Recommendations

National Implementation

Finding 1a: Some confusion remains as to the purpose of the HLT.

Finding 1b: The workload for the hurricane specialists, with the HLT in place, was not reduced and in some instances increased.

Recommendation 1: In conjunction with FEMA, the functions and operations of the HLT must be reviewed and refined. The results should be briefed at the National Hurricane Conference and other suitable forums. FEMA representatives are encouraged to take an active role in the Interdepartmental Hurricane Conferences.

Finding 2: There are insufficient HLT members to support speciality functions (electronics, communications) to avoid burnout, turnover and absences due to sickness, annual leave, etc.

Recommendation 2: As part of the NWS/FEMA review, the specific tasks of the HLT members must be outlined and an adequate resource pool identified. The NOAA/NWS Hurricane Conference should be the forum for discussing and validating HLT mission, membership and other requirements.

Finding 3: Hardware required to support the HLT is extensive and requires significant time and effort to set up.

Recommendation 3: FEMA must provide a complete set of instructions that will assist in the set-up process. Additionally, FEMA and NHC should identify electronic specialist(s) who can set up and test the equipment prior to the arrival of the HLT. Given the location of the NHC on the Florida International University campus, NHC could explore the possibility of involving university resources to assist in the process.

Finding 4a: There was no single communication system used to brief state emergency management officials. This led to confusion among the EMCs.

Finding 4b: NHC was required to conduct multiple briefings when more than one state was impacted by Hurricane Bertha. This proved to be extremely time consuming for the hurricane specialists.

Finding 4c: During teleconferences established by the HLT, the local NWS offices were not always involved.

Finding 4d: Several times local emergency managers were tied into state and regional briefings coordinated through the HLT. The locals would then be brought into a local conference call with their state and local NWS offices. This was repetitive and not a good use of the local emergency managers limited time.

Finding 4e: NHC briefing calls to North Carolina state emergency management officials frequently came at times when these individuals were already in the midst of a briefing by the NWSFO or with local emergency management officials along the coast.

Recommendation 4: FEMA and the NWS must ensure that coordination methodologies and protocols are firmly established before the next hurricane season. The local NWS office(s) must be included in all NHC state conference calls to add local expertise and to prepare for their coordination calls with local emergency managers.

Finding 5a: The Modernization and Restructuring (MAR) of the NWS has created a greater need for internal forecast coordination as the number of forecast offices has increased.

Finding 5b: As Hurricane Bertha approached the Delmarva region, confusion arose when the wind forecasts from two NWS offices for adjacent forecast areas were significantly different.

Recommendation 5: The NWS needs to move quickly to establish an internal coordination mechanism.

Finding 6: Some EMCs are having problems receiving weather information. NWR coverage is incomplete and NWWS is too costly for some EMCs. Computer bulletin boards and the Internet received high praise.

<u>Recommendation 6</u>: The NWS should continue to seek partnerships to expand NWR coverage in support of the Gore initiative and target resources to ensure reliable programming and maintenance of the new systems. The NWS must actively support implementation of EMWIN and seek additional partnerships to ensure its availability from multiple sources. EMCs should be reminded of other resources, such as the free redistribution of NWWS from their state distribution point and the use of Packet Radio.

<u>Finding 7a</u>: A number of offices noted a truncation of some of the more lengthy Hurricane Local Statements (HLS) on The Weather Channel (TWC). Moreover, it was also noted that some of the Short Term Forecasts (NOW) were cut off at six, as opposed to eight lines. This premature truncation of the HLS and NOW resulted in critical information not being passed on to the viewer.

<u>Finding 7b</u>: The "segmented" HLS format used by NWSFO San Juan marked an improvement over their HLSs issued during Hurricane Marilyn.

<u>Finding 7c</u>: NWSFO San Juan's NOWs were informative, but some of them tended toward the radar narrative summary style of writing.

<u>Recommendation 7</u>: OM needs to work with TWC to resolve the truncation issue. All offices should be reminded of the NOW's primary function, to serve as a forecast of future conditions and impacts rather than a summary of past events.

<u>Finding 8</u>: Potentially valuable meteorological data was lost when the St. Croix and St. Thomas ASOS units were powered down when the FAA abandoned their towers.

<u>Recommendation 8</u>: NWS and FAA officials should ensure that ASOS units remain in service during the approach of a tropical cyclone.

<u>Finding 9</u>: Rip currents associated with Bertha resulted in 3 deaths and over 100 rescues along the Florida and southeast Georgia coasts. Heavy surf advisories were canceled before two of the deaths occurred. Lack of data off the southeast Florida coast forced forecasters to estimate wave heights from local wind forecasts.

<u>Recommendation 9</u>: NWSFO Miami must redouble their efforts at seeking partnerships with Beach Patrol units and other organizations to secure critical wave height and surf reports.

<u>Finding 10</u>: Hurricane specialists were urged to change the location of watches and warnings. This was exemplified when Bertha's slow northward turn resulted in Florida State officials requesting NHC to post watches on the Florida coast when hurricane specialists felt that this was unnecessary.

<u>Recommendation 10</u>: NHC needs to remain sensitive to unique and special situations that occur which emergency managers must resolve during hurricane threats. State officials have the authority to issue mandatory evacuations for vulnerable coastal areas even when NHC may feel that meteorological conditions do not justify issuing hurricane watches or warnings. The NWS and FEMA need to expand the present hurricane course for emergency managers and should develop a distance learning approach to the present NHC resident course. As a part of this course, a module should be developed for NWS personnel at both the NHC and at local offices to ensure that they fully appreciate emergency manager requirements.

<u>Finding 11</u>: The NHC was requested to release forecast points early.

<u>Recommendation 11</u>: NHC <u>should not</u> release forecast points prior to completion of forecast coordination. If the meteorology changes significantly and unexpectedly between the 6 hourly advisory forecasts, then NHC will issue a special advisory. However, in truly unique circumstances, some coordination on trends and changes from the previous forecast can be discussed with the local NWSO and NWSFO so they can brief state or local EMCs prior to the issuance of the new forecast. There is also a continuing need to educate emergency managers and other customers about hurricane forecasts and products and the uncertainties related to these products.

Finding 12: Hurricane strike probabilities are still not fully understood by state and local EMCs and are being misrepresented by the media. These probabilities are especially confusing when a hurricane is paralleling the coast.

Recommendation 12: The NWS and FEMA should develop new educational materials related to the use of hurricane strike probabilities as well as the use of forecasts and forecast uncertainties in the decision-making process. This should be included in the residence training at NHC as well as in distance learning modules for emergency managers. These materials should also be provided to coastal WCMs for outreach efforts to the local media. Similarly, NHC should investigate better ways of graphically depicting forecasts and forecast uncertainties.

Finding 13: Many NWS offices participate in post-storm local-level evaluations and critiques, usually led by the WCM and/or the MIC.

Recommendation 13: This practice of local self-evaluation should be encouraged at all NWS offices, coastal or otherwise.

NCEP Implementation

(National Centers for Environmental Prediction)

Finding 14: The Internet has become very popular, and the information available over the Internet from NHC received very favorable comments. Naturally, when the hurricane was close to land, access to the NHC Homepage was difficult.

Recommendation 14: NHC should investigate the possibility of increasing their Internet capabilities.

Finding 15: The NHC rarely sought input from the SPC nor made attempts to ensure that the SPC was "on the line" during the hotline coordination. As a result, field offices that were concerned with the tornado threat were never sure that the SPC was on the line although the SPC makes it a practice to monitor the line continuously.

Recommendation 15: The NHC should include the SPC in its roll call list for coordinating advisories when a tropical cyclone threatens the U.S. mainland. In addition, the NHC should make it a point to invite comments from the SPC in such situations.

Regional Implementation

Finding 16a: Due to the remoteness of the location, the San Juan WSR-88D RDA does not utilize commercial power.

Finding 16b: The RDA's emergency generator produces an electric current with irregular frequency fluctuations.

Recommendation 16: Officials from the SRH and Puerto Rico emergency management should encourage the FAA to develop a plan for supplying the WSR-88D with stable commercial power and with stable, reliable emergency generator power.

Finding 17: The lack of reliable redissemination systems caused some delay in the receipt of weather products necessary to the emergency management decision-making process in Delaware. The use of the fax blast was not always reliable.

Recommendation 17: ERH should work with FEMA Region 3 and WSH to resolve this issue.

Chapter 1

Service Assessment Summary

Operations of the Hurricane Liaison Team

Traditionally, local emergency managers from Florida, as well as some FEMA regional personnel, volunteered to work at NHC to field calls from local emergency managers and to keep FEMA national and regional offices apprised of the evolving situation from an emergency management perspective. The 1996 hurricane season was the first real effort to formalize the ad hoc process and make it more of a functioning unit. This resulted from the highly active 1995 hurricane season where it became evident that something had to be done to take some of the external pressure off of the NHC hurricane specialists. Accordingly, the HLT was formed at the request of the State of Florida, FEMA and the NWS. The HLT was first activated during Hurricane Bertha. Since this was the first official activation, some of its purpose and function were not clearly understood by all of the parties involved. It was expected that the HLT could relieve some of the external demands placed on the hurricane specialist. During Bertha, this was not the case. In fact, the workload was even greater due to the number of briefings that required participation of a specialist. The HLT concept is still under development and its functions and operations are being reviewed. A major concern is to ensure that the HLT does not detract from local emergency managers contacts with their local NWS offices and WCMs.

Prior to the start of the 1996 hurricane season, individuals were identified and chosen who had the necessary skills and expertise. After working Hurricane Bertha, the team realized that, given the extended hours that are required and the possibility of a team member(s) being unavailable, a sufficient number of skilled people were not identified to fill these positions.

In addition to staffing, a unique set of hardware is required to meet the operational requirements of the HLT. Since the equipment was not prepositioned and there was no dedicated electronics expert assigned to assemble the hardware, some time was lost setting up the equipment.

The video conferencing between NHC and FEMA Headquarters ensured that FEMA senior management and all organizations supporting the Federal Response Plan had the necessary information to be proactive, making timely response actions. Video conferences were scheduled twice a day for the Director of FEMA and were accomplished with minimal problems.

State and Local Coordination

Florida, South Carolina, North Carolina -- Unlike FEMA Headquarters and NHC, most state EMCs currently do not have video conference capability but expressed a willingness to add this technology. However, due to high costs, video conferencing is not affordable to NWS field offices. Most briefings are done via voice only with each state using differing communication conferencing systems to speak to the NHC. Some use the National Warning System (NAWAS); others, such as Florida, have their own conference systems with a line to NHC. Some of the conference calls were done on NAWAS while others were made through existing Federal and state teleconference systems but established by government operators. The South Carolina EMC missed an NHC briefing since they were not sure whether the call was on NAWAS or some other system.

NHC and the states agreed that a universal conferencing system needs to be established as coordination is too difficult with multiple systems. A single system would also help decrease the workload for the hurricane specialist as all state EMCs could be conferenced together and briefed at once. Local NWS offices stated they were not always tied into conference calls between the state EMCs and the NHC.

During Hurricane Bertha, many of the local EMCs were tied into HLT briefings along with their state EMCs. After this briefing, they would then participate in another conference call, involving EMCs in the local area, the state EMC and the local NWS. In survey team discussions with local emergency managers, they expressed little interest in talking directly with NHC. They would rather be tied into a telephone conference call with their surrounding EMCs and local NWS office. They assume the state and local NWS offices will talk with the NHC and pass information to them during their local conference call.

In interviewing local emergency managers, the survey team was told NWWS continues to prove too expensive for local EMCs with limited funding. The EMWIN was discussed and could prove to be a viable alternative for users who currently have no level of support or can afford very little. North Carolina officials note that the NWR is still not available in some areas along their coastline.

The use of Internet is increasing and South Carolina and North Carolina are using the Internet as one method to access the latest information. However, when Bertha approached the coastline, the Internet connection to the NHC was difficult or impossible to get.

Delaware and Maryland -- NAWAS was used as the primary communication and coordination tool by Mt. Holly NWSFO during events of Hurricane Bertha. Delaware Emergency Management Agency (DEMA) felt the support provided during Hurricane Bertha did not meet the level of support provided prior to the policy change. The use of a single conference call by several NWS offices for coordination among multiple states, as well as the loss of access to the

26 local municipalities on the DEMA bridge, was a major concern. Subsequent work between the OM, ERH and DEMA has found an equitable resolution using the DEMA bridge.

Delaware does not have an effective mechanism in place for the redistribution of both national and local weather information and guidance. This put county and municipal emergency managers at a disadvantage as they had no hard copies of NWS watches, warnings and statements. This forced coordination calls to be longer as they became a dissemination mechanism rather than a coordination tool. Delaware officials also noted several occasions where wind forecasts issued for adjacent areas by different NWSFOs were significantly different which caused confusion and raised the anxiety of many local emergency managers.

NWS Operations

As Hurricane Bertha paralleled the coast, it had the potential to make its initial landfall anywhere from Florida to North Carolina. This put extreme pressure on NHC as well as the state EMCs. Although NHC's forecast tracks for Bertha proved to be quite accurate, state EMCs urged NHC to change the location and timing of watches and warnings and to release the forecast tracks early. This caused tension between NHC and their external users. The state EMCs thought their input and concerns were being ignored while NHC felt that they were being second guessed on their meteorology.

While the states agreed NHC is the technical leader and the recognized expert, the EMCs continue to emphasize that watches and warnings are not purely a meteorological call but must also consider emergency response and public safety. The states agree they have the authority to issue mandatory evacuations for vulnerable coastal areas. They said that despite their efforts to motivate people, the public will often not respond to recommendations or evacuation information unless there is a watch or warning in effect.

Graphical representation of hurricane strike probabilities can be a useful tool, however, it was noticed during Bertha that these graphics were not fully understood by the public or the EMCs. In some cases, it lead to misinformation, and in others the media was incorrectly depicting strike probabilities. While strike probabilities work well with storms that strike the coast perpendicularly, they were confusing when a storm parallels the coast.

Chapter 2

National Perspectives

National Hurricane Center

Synoptic History

Hurricane Bertha originated from a tropical wave which moved from Africa to the Atlantic on July 1, 1996. A weak circulation was first detected on satellite imagery on July 3, centered about 575 miles south of the Cape Verde Islands in the far eastern Atlantic Ocean. The track of the circulation center begins on July 5, when the circulation is believed to have reached the surface and become a tropical depression in the central tropical Atlantic. This track is displayed in Figure 1 and listed in Appendix B, Table 1.

Bertha followed a fairly smooth curved path around the western periphery of the Atlantic subtropical high pressure ridge. This ridge changed little during Bertha's existence, and a weak mid-level trough persisted in the western North Atlantic. For three days, the depression moved toward the west-northwest at the fast forward speed of 23 to 29 mph. It strengthened to a hurricane with 1-minute maximum sustained winds of 86 mph on July 8 as the center moved across the Leeward and Virgin Islands of the northeastern Caribbean. The center moved between Antigua and Barbuda at 2 a.m. Atlantic Standard Time (AST) (0600 Coordinated Universal Time [UTC]) on July 8, across St. Barthelemy, Anguilla and St. Martin, just north of St. Thomas, and over the British Virgin Islands by 2 p.m. AST (1800 UTC).

The track gradually turned northwestward on July 9 as maximum sustained winds reached 115 mph at 2 a.m. AST (0600 UTC). Bertha was centered 138 miles north of Puerto Rico at this time but earlier passed within 35 miles of the island. Since the strongest winds were located in the northeast quadrant of the hurricane, most of Puerto Rico experienced only tropical storm conditions. The exception is the Puerto Rican island of Culebra, where hurricane-force winds are believed to have occurred.

Moving northwestward at a slower forward speed of 17 to 23 mph, the center of Bertha moved parallel to the Bahama Islands, passing 45 to 70 miles northeast of the Turks and Caicos Islands, San Salvador, Eleuthera and the Abacos. Again, the strongest winds were located to the northeast of the center, but 75-mph sustained winds might have reached some of the above mentioned islands.

Continuing on its gradual turn, the track became north-northwestward on July 10 and 11 as the center moved parallel to the coast of Florida and Georgia at a distance of 170 to 200 miles

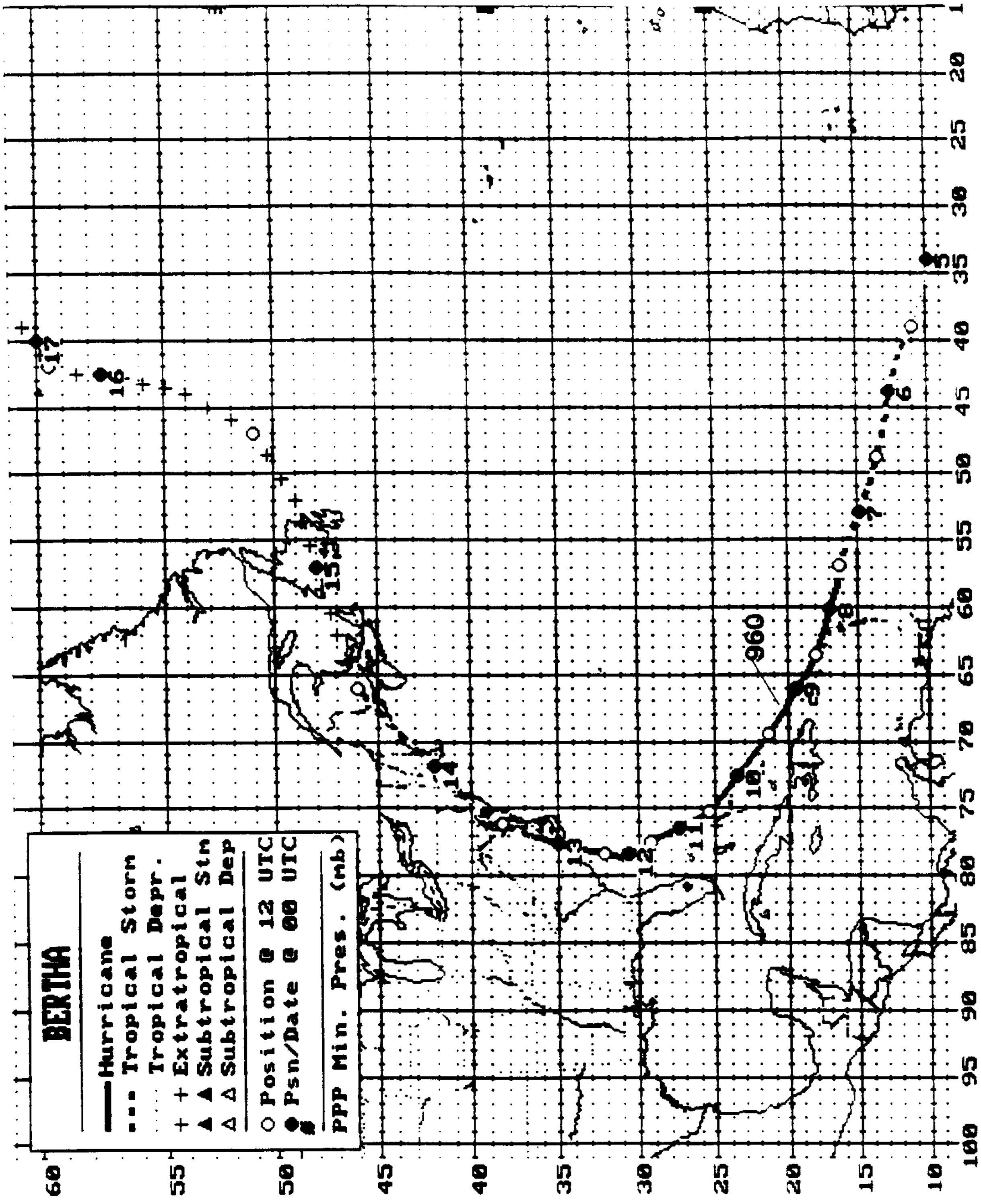


Figure 1: Track of Hurricane Bertha, July 5-14, 1996 (extratropical track July 14-17).

offshore. During this time, the forward speed slowed to about 9 mph. Moving northward and re-accelerating to a forward speed of 17 mph, Bertha made landfall at 4 p.m. EDT (2000 UTC) on July 12 on the coast of North Carolina. At landfall, Bertha was a Category 2 storm on the Saffir-Simpson Hurricane Scale (see Appendix A) as the center crossed the coast midway between Wrightsville and Topsail Beaches. The hurricane had been gradually weakening since its top speed of 115 mph on July 9 to 81 mph on July 11. Then, 12 hours before landfall, the estimated maximum 1-minute winds increased to 104 mph. Bertha quickly dropped below hurricane strength when it moved inland over eastern North Carolina. Bertha then moved northeastward along the U.S. east coast, producing 45 to 60 mph sustained winds over land from northern North Carolina to New England. Over the nearby Atlantic, 70 mph winds were the rule. Bertha was declared extratropical on July 14 when the center moved from the Maine coast to New Brunswick, Canada. The extratropical storm brought 45 to 60 mph winds to the Canadian Maritime Provinces and was tracked to just south of Greenland on July 17.

Meteorological Statistics

Figures 2 and 3 show a plot, versus time, of the various data used to estimate the minimum central sea-level pressure and the maximum 1-minute wind speed 33 feet above ground. Included are data from reconnaissance aircraft and satellite Dvorak-technique wind speed estimates. Appendix B, Table 2, lists selected surface observations of lowest pressure, peak wind, storm surge and rainfall values. Appendix B, Table 3, lists ship reports of 39 mph or greater that were associated with Bertha. The minimum pressure of 960 mb occurred at 2 a.m. EDT (0600 UTC) on July 9 and is based on a dropsonde measurement. The best track maximum sustained wind speed of 115 mph at the same time is based on a 700-mb flight-level wind speed of 140 mph, measured 22 miles east-northeast of the center.

Observations are incomplete from the Leeward and Virgin Islands, but because the circular eyewall was 20 to 35 miles across, it is believed that hurricane conditions with sustained wind speeds to 86 mph could have occurred on Antigua, Barbuda, Nevis, St. Eustatius, St. Barthelemy, Anguilla, St. Martin, and from St. Thomas northward through the U.S. and British Virgin Islands. Experience with Hurricane Marilyn in 1995 suggests that even higher sustained winds can occur over mountainous terrain as is found on many of these islands. Winds 40 to 45 mph were experienced over portions of Puerto Rico as indicated by the San Juan observations in Appendix B, Table 2.

A reconnaissance aircraft flight level wind speed of 127 mph in the northeast quadrant of the circulation several hours before landfall is the basis for estimating sustained surface winds of 104 mph on the coast at landfall. The lowest sea-level pressure observed at landfall was 977 mb at Surf City, North Carolina, and a value of 974 mb is assumed to be the minimum pressure at landfall.

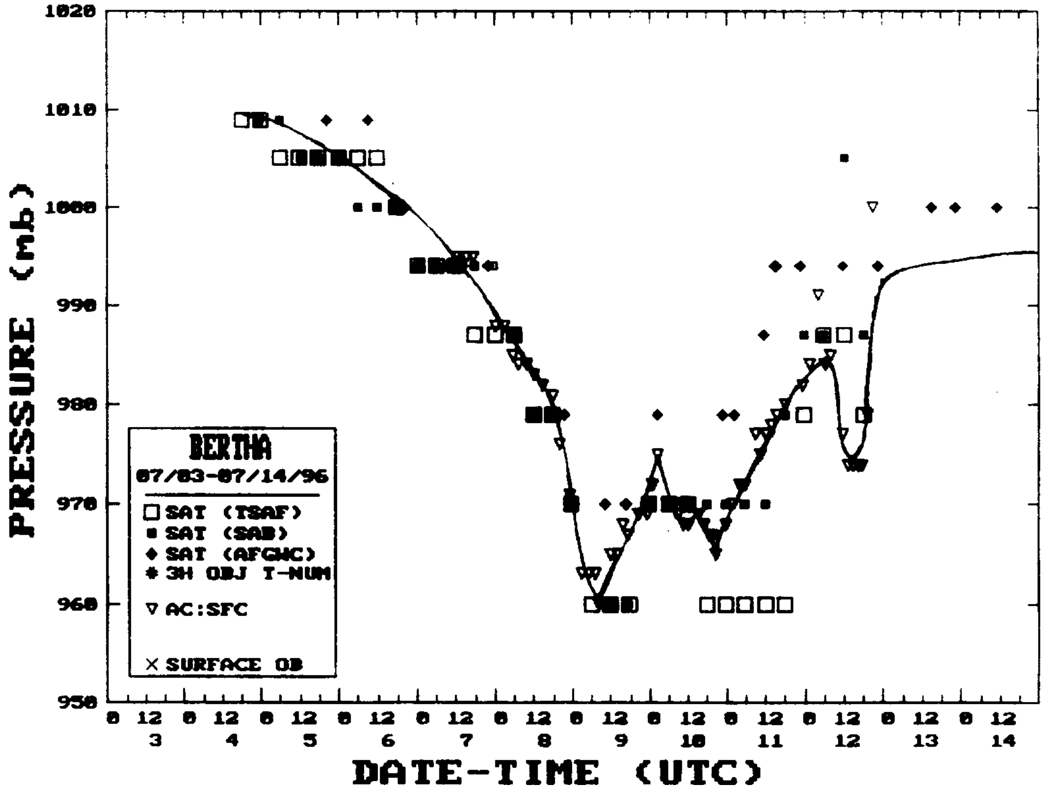


Figure 2: Curve of minimum central sea-level pressure versus time.

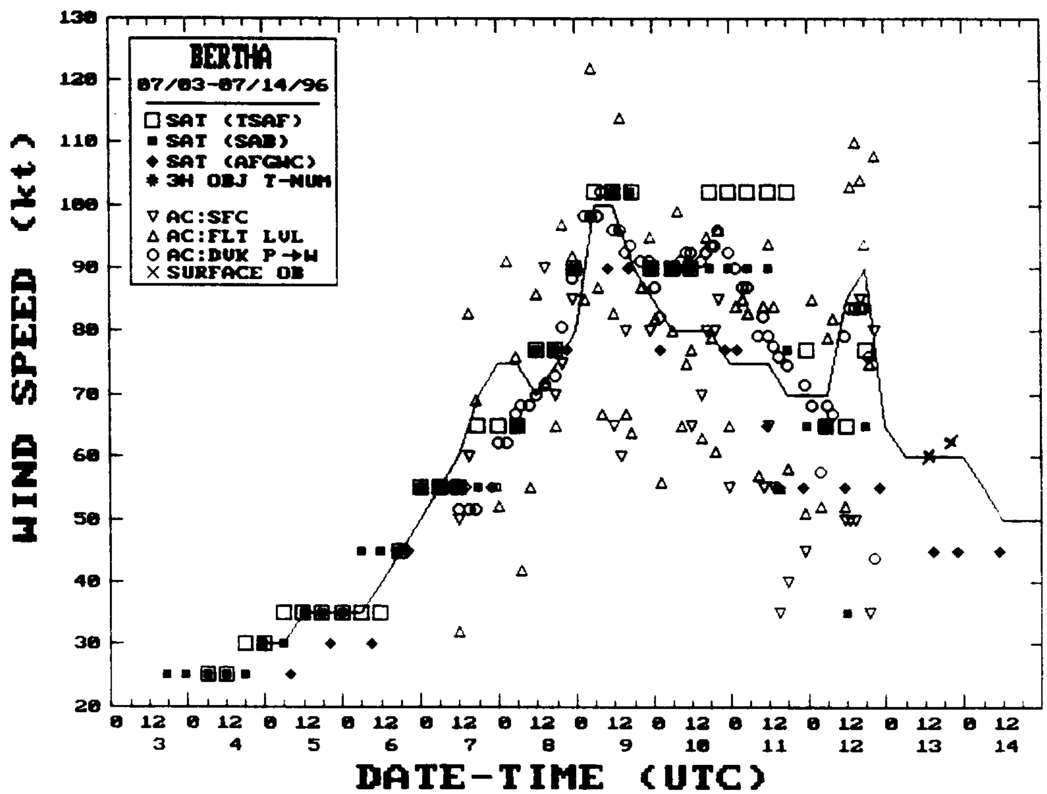


Figure 3: Curve of maximum 1-minute speed versus time.

Coastal storm surge flood heights, from Florida through New England, ranged from 1 to 4 feet, but values to 5 feet were estimated on the North Carolina coast from Cape Fear to Cape Lookout. A storm surge of 6 feet or a little higher was indicated near Swansboro, where 5 to 6 feet of water was "inside of businesses on the waterfront" (from Newport, North Carolina, National Weather Service Forecast Office Preliminary Storm Report). Values were forecast to be between 4-6 feet.

Six tornadoes (four in Virginia, one in North Carolina and one in Maryland) have been confirmed during the passage of an outer rain band.

Casualty and Damage Statistics

There were 12 deaths related to Hurricane Bertha. Four in Florida included one from an evacuating military jet crashing into a house and three drownings from rip currents and high surf. Two deaths were reported in North Carolina (automobile accident and rip current drowning), while one surfer died in New Jersey. In Puerto Rico, one death occurred in an automobile accident and another died while surfing. On the French half of St. Martin, one person was electrocuted and another drowned after falling off a boat.

The U.S. Virgin Islands, along with North Carolina, has been declared a Federal disaster area. Surveys indicate that Bertha damaged almost 2,500 homes on St. Thomas and St. John. For many, it was a second hit in the 10 months since Hurricane Marilyn devastated the same area.

It is likely that there was beach erosion on the north coast of the Dominican Republic as Bertha passed to the north. The Bahamas were also affected by the weak side of the hurricane, but there are no damage figures available from either of these locations.

The primary effects in North Carolina were to the coastal counties and mostly due to storm surge flooding and beach erosion, roof damage, piers washed away, fallen trees and damage to crops. A survey indicated more than 5,000 homes were damaged, mostly from storm surge. FEMA estimated 250,000 persons evacuated in South and North Carolina. Minor wind damage and flooding also spread along the path of the storm all the way to New England.

The Insurance Institute estimates $135 million in insured property damage, primarily along coastal North Carolina. A conservative ratio between total damage and insured property damage, compared to past land-falling hurricanes, is two to one. This would increase the total U.S. damage estimate to $270 million. No figures are available from the Caribbean.

Warning and Forecast Critique

Bertha moved on a fairly smooth track. The average official track forecast errors for Bertha ranged from 92 miles at 24 hours (32 cases) to 169 miles at 48 hours (29 cases) to 258 miles at 72 hours (27 cases). These errors are 15 percent or more lower than the previous 10-year averages of the official track errors and are from 15 to 40 percent lower than the CLIPER forecast errors for the same cases.

Overall, the track model guidance also performed very well. However, the 8 p.m. EDT (0000 UTC) Aviation Model run on July 9, when Bertha was located just north of Puerto Rico, inexplicably showed the track recurving significantly further east than the previous run. All of the track guidance models that use the Aviation Model as a background environment also showed a similar track. This resulted in rather large official track forecast errors on July 9, with a 705-mile, 72-hour error on the 8 a.m. EDT (1200 UTC) forecast. The Aviation Model and some of the track guidance models recovered to an excellent forecast only 12 hours later. Fortunately, this guidance problem occurred three days prior to landfall in North Carolina and did not have a significant impact on U.S. warnings or on warnings for the Bahamas.

Appendix B, Table 4, lists the various watches and warnings that were issued. Hurricane warnings were issued from Sebastian Inlet, Florida, to Chincoteague, Virginia, as well as for the Bahamas and for the islands of the northeastern Caribbean Sea from Antigua through Puerto Rico. Tropical storm warnings were issued from Sebastian Inlet to north of Deerfield Beach, Florida, and from north of Chincoteague to Watch Hill, Rhode Island. Almost all of the U.S. east coast was involved with some watch or warning which is the result of the storm track’s expected close passage to the southeast U.S. coast. The hurricane watch for the North Carolina landfall area was issued 65 hours before landfall, and the hurricane warning was issued 47 hours before landfall. This is far more than the 36- and 24-hour lead times that the NHC strives for and is the result of the forward motion decreasing at a faster rate than expected.

User Response

For about 2 days, Bertha aimed at the north-central Florida east coast. During that time, all of the NWS track guidance models were predicting a turn to the north, near 76 degrees west. This was uncomfortably close to some of Florida's barrier islands and Cape Kennedy which have evacuation times exceeding 24 hours. At 11 p.m. EDT on July 9 and again during the early morning hours of July 10, the State of Florida emergency management officials requested that NHC post a hurricane watch for the northern parts of their east coast, but NHC hurricane specialists felt that this was premature. On July 10, the governor issued mandatory evacuation notices at 10 a.m. EDT, and NHC put up hurricane warnings at 11 a.m. EDT for the state, north of Sebastian Inlet. Early that afternoon, Bertha began its recurvature toward the north in close agreement with the guidance models.

Similarly, South Carolina state officials became concerned about possible nighttime evacuations on the evening of July 10 and were in great need of the latest information prior to the 11 p.m. coordination call. The governor wanted to make a decision whether or not to order mandatory evacuations before the 11 p.m. news. Working and coordinating closely with NWSFO Columbia, NHC was called at 7:30 p.m. EDT on July 10, requesting additional forecast track information. This request was received more than an hour before the hurricane specialist was to begin preparing the next forecast. The hurricane specialist and the HLT provided intermediate information on Bertha's location and strength, however, NHC could not release any track and intensity forecasts until the next NWS hurricane hotline call at 10 p.m. EDT, at which time the track and intensity forecasts would be coordinated and agreed upon. The HLT believed they kept state officials well informed regarding Bertha from an emergency management perspective.

Hydrometeorological Prediction Center

Meteorology of Heavy Rainfall

Hurricane Bertha made landfall on the North Carolina coast on July 12 and was downgraded to a tropical storm shortly thereafter. The storm accelerated north-northeastward across coastal sections of the Mid-Atlantic and northeast United States prior to moving off the eastern New England coast late on July 13. Precipitable water values increased significantly to values in excess of 2 inches along the Eastern Seaboard as deep layered easterly flow developing in advance of the storm advected tropical moisture inland. Heavy rain occurred from the eastern Carolinas to Maine with many locations receiving 2- to 4-inch amounts (see Figure 4). Coastal North Carolina and southeast New York had isolated reports of over a half foot of rain. Amounts could have been much greater had Bertha's rapid motion not acted to limit rainfall duration.

Guidance Products

Primary guidance that aided HPC forecasters included varied output from numerical models (Geophysical Fluids Dynamical Lab [GFDL] model, Aviation Model [AVN], ETA Model [ETA], Nested Grid Model [NGM], Naval Operational Global Atmospheric Prediction System [NOGAPS], Medium-range Forecast Model [MRF], the MRF ensemble package, Medium-range Forecast Model Experimental [MRFX], European Center for Medium Range Weather Forecasting [ECMWF], United Kingdom Meteorological Office [UKMET], meso-ETA, NHC hurricane models, etc.), satellite imagery (Geostationary Operational Environmental Satellite [GOES]-8/9 Visible [VIS], Infrared [IR], Water vapor [WV], and Special Sensor Microwave Imagery [SSMI] microwave data), NEXRAD data, surface and upper-air observations and aircraft reconnaissance data.

Model output was varied. While all models correctly indicated the potential for heavy rainfall over the eastern United States, the AVN forecast a Bertha track and associated quantitative precipitation forecast (QPF) that was shifted farther to the west than the ETA or NGM. The AVN track implied that a significant upslope rain event was imminent in the favored upslope region on the eastern side of Appalachian Mountains. The ETA and NGM supported a heavy rainfall event farther to the east. Weather pattern recognition and upper-air data analysis combined with trends from satellite imagery and radar to prompt HPC forecasters to prefer a solution close to but wetter than that depicted by the ETA. Subsequent observations deemed that our model assessments were on the right track.

HPC staff produced an array of graphic products and accompanying narratives. These products provided an assessment of guidance and an excellent forecast of quantitative precipitation, flash flood potential and the sea level pressure pattern from current conditions up to five days (see Figures 5-7).

Internal Coordination

HPC forecasters participated in at least four regularly scheduled hurricane coordination calls each day that included verbal input from NHC, SPC, MPC, WFO's, WSH, SRH, ERH, Naval Atlantic Meteorology and Oceanography Center at Norfolk, Virginia, and the Naval Meteorology and Oceanography Facility at Jacksonville, Florida. Information discussed included Bertha's forecast strength and track from zero to five days and associated QPFs. Routine coordination calls were also performed with FEMA.

Marine Prediction Center

Marine Meteorology

As Bertha moved along the east coast recurving across the Maritimes and then well out to sea, it created significant marine meteorological conditions for an extensive segment of the MPC High Seas area of responsibility. The most notable conditions are chronicled below.

- As Bertha passed near the Bahamas on July 10 at 8 a.m. AST (1200 UTC), well before the center entered MPC's area, 13-foot southerly swells had propagated as far north as 34N west of 69W.

- On July 11 at 8 a.m. AST (1200 UTC), while hurricane and tropical storm force winds remained south of 32N, the southern limit of the MPC forecast area, seas increased to 20 feet over the area south of 34N west of 70W. Near gale force winds extended out to 520 miles over the north semicircle.

- By July 12 at 8 a.m. EDT (1200 UTC), the center of Bertha had crossed 32N, approaching the coast of the Carolinas. Packing maximum sustained winds of 104 mph, the storm generated a maximum wave height estimated at 39 feet just south of Frying Pan Shoals.

- On July 13, Bertha moved inland across eastern North Carolina and southeast Virginia, weakening to a tropical storm with sustained winds of 52 mph and gusts to 63 mph at 8 a.m. EDT (1200 UTC). Winds near tropical storm force and 13-foot seas also occurred within 485 miles from the center.

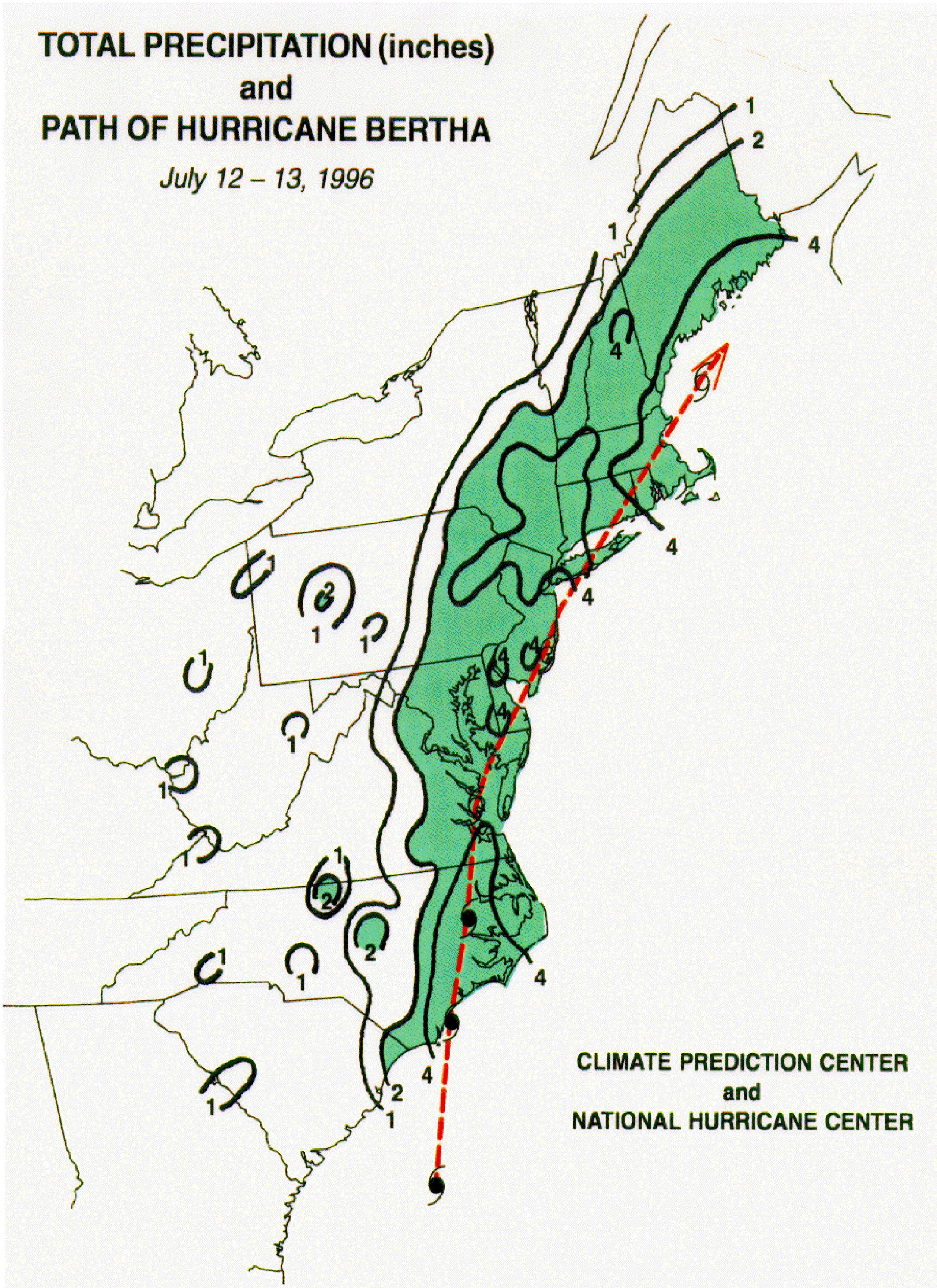

TOTAL PRECIPITATION (inches)
and
PATH OF HURRICANE BERTHA
July 12 – 13, 1996
CLIMATE PREDICTION CENTER
and
NATIONAL HURRICANE CENTER

Figure 4

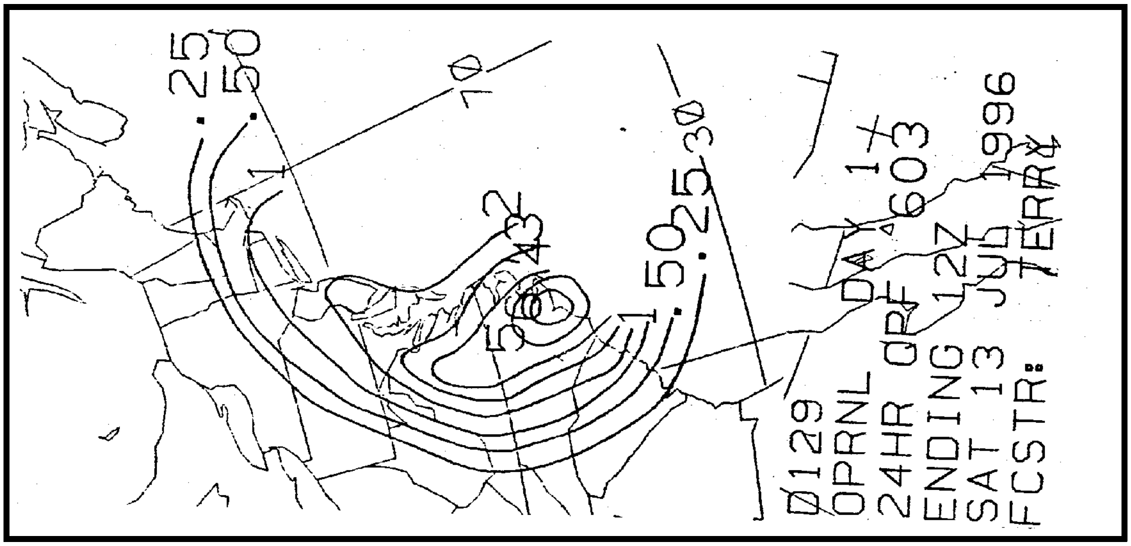


Figure 5: Quantitative Precipitation Forecast Guidance - 8 am, July 13.

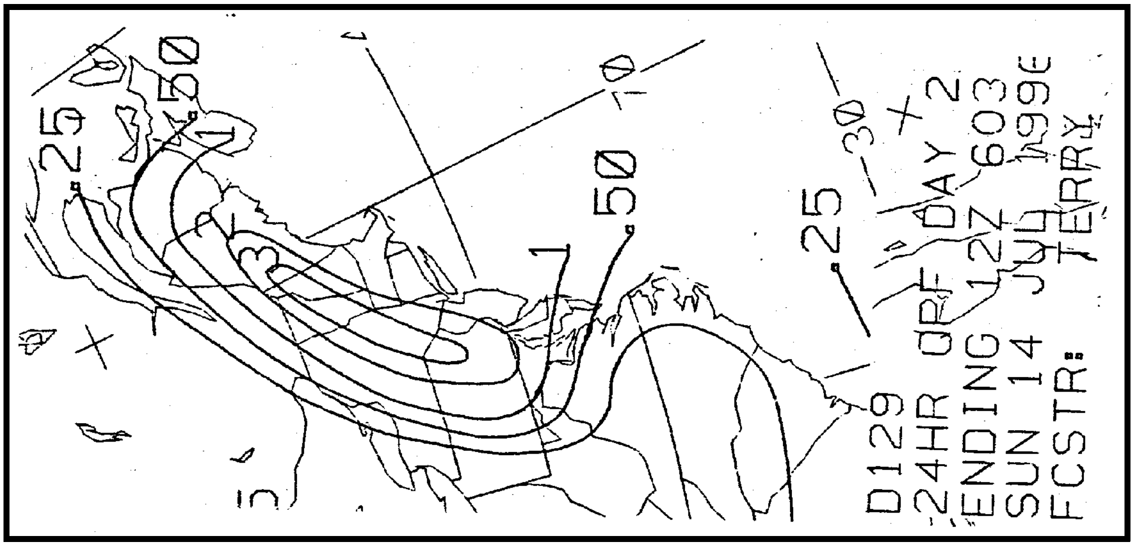


Figure 6: Quantitative Precipitation Forecast Guidance - 8 am, July 14.

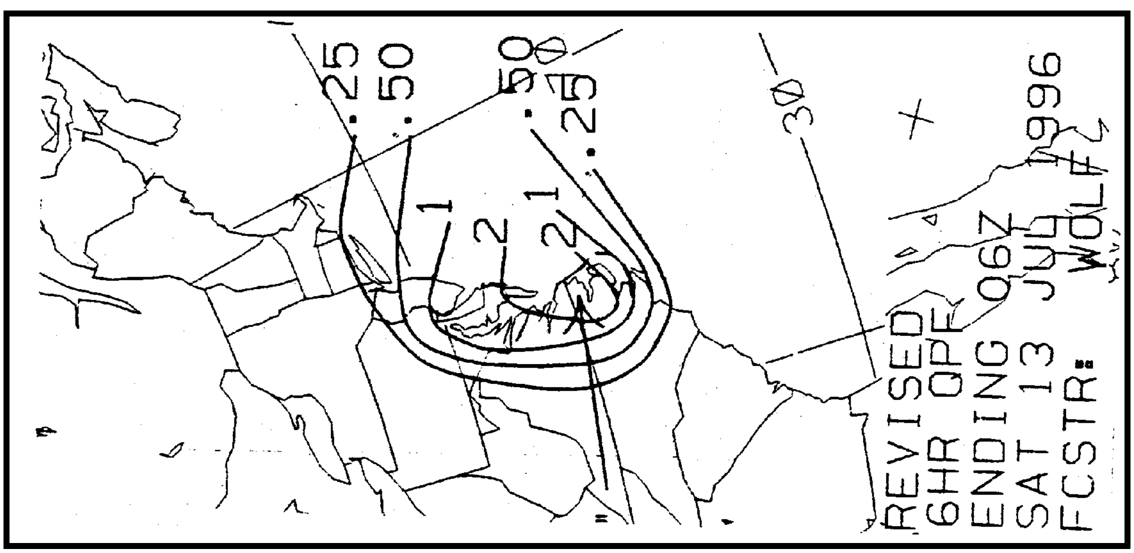


Figure 7: Revised Quantitative Precipitation Forecast Guidance - 2 am, July 13.

- By July 14 at 8 a.m. EDT (1200 UTC), Bertha had lost most of its tropical characteristics and was declared extratropical, becoming the sole responsibility of the MPC. Located along the New Brunswick coast, storm force winds to 63 mph and seas to 20 feet occurred within 485 miles over the southeast semicircle. Gale force winds and seas to 16 feet extended out to 620 miles over the southeast semicircle and 345 miles over the northwest semicircle.

- On July 15 at 8 p.m. EDT (0000 UTC), former Bertha was downgraded from an extratropical storm to a gale, still packing winds to 52 mph with seas to 18 feet southeast of the center.

- As the low moved northeast across the open ocean, gale warnings were continued until July 17 at 2 a.m. EDT (0600 UTC). Through its final weakening stages as a gale from Newfoundland to just south of Cape Farewell, an extensive area of 13- to 21-foot seas continued east and south of the center.

Forecast and Guidance Products

MPC forecast and analysis products are routinely broadcast to ships at sea. This is done through the U.S. Coast Guard high frequency communication facilities. The products consist of high seas text bulletins and graphic surface analysis and forecast products. In addition, voice broadcasts of warnings and forecasts which originate at the MPC are broadcast over station WWV, Boulder, Colorado. Although all of these products are produced according to a regular schedule, they all contain warning and forecast information as provided in the official TPC bulletin.

The frequency of transmission for these products is every 6 hours and is based on the synoptic reporting times (0000 UTC, 0600 UTC, 1200 UTC, 1800 UTC).

Coordination

Coordination took place using the Hurricane Hotline or through telephone calls. TPC's conference calls were routinely monitored and telephone calls to TPC's Tropical Analysis and Forecast Branch were made for purposes of coordination. In anticipation of the system becoming extratropical and to cover expected conditions in offshore waters, MPC provided input for adjustments of TPC's tropical force wind/12-foot seas radius as the storm crossed north of 32N prior to making landfall along the southern North Carolina coast. The input was accepted and incorporated into the advisory.

Storm Prediction Center

Forecast and Guidance Products

Tornado watches associated with Bertha (see Appendix D).

Tornado Watch	issue (CDT)	valid	end
764	12/9:37 a.m.	10:00 a.m.	7:00 p.m.
765	12/1:36 p.m.	2:00 p.m.	7:00 p.m.
768	12/6:16 p.m.	7:00 p.m.	4:00 a.m.
770	12/11:41 p.m.	midnight	7:00 a.m.
771	13/3:00 a.m.	3:15 a.m.	10:00 a.m. (replaced 768 and 770)
772	13/12:20 p.m.	12:45 p.m.	7:00 p.m.

Mesoscale Meteorology and Coordination

The SPC participated in all hurricane hotline discussions concerning Bertha during its lifetime, however, this was due to the fact that SPC forecasters were monitoring the hotline. NHC failed to roll call the SPC nor did it invite input from the SPC. NHC should include the SPC in its roll call list for coordinating advisories when a tropical cyclone threatens the U.S. mainland. During the 10 a.m. EDT coordination on July 12, the SPC forecaster commented that the tornado threat for the east coast was increasing and that he should probably issue a tornado watch (the first in a series). The hurricane specialist suggested that the SPC handle the details off-line with the individuals involved, and that he would mention the possibility of tornadoes in the next bulletin. After the hotline call ended, the SPC forecaster called the offices in Raleigh, North Carolina, and Columbia, South Carolina, to coordinate the tornado watch (No. 764) which extended from northeastern South Carolina into southeastern and east-central North Carolina.

During the course of the morning and early afternoon, several tornado warnings were issued in North Carolina with some occurring near the western and northern boundaries of the watch. Damage was reported with a thunderstorm near Raleigh. Since there was a strong surface high to the north (1026 mb center), the resulting pressure gradient was producing relatively strong low level flow (and shear) well to the north of the tropical storm center. Further, instability along and east of a surface trough extending from eastern North Carolina into southeastern Virginia had reached moderate values. These factors raised the concern that the tornado threat would be developing northward along and east of the trough line during the afternoon hours and that a watch would be needed northward from the original watch into southeastern Virginia. To make it simpler for the NWSFOs and NWSOs, the ending time 8 p.m. EDT (0000 UTC) was chosen to be the same as that with the original watch. The SPC forecaster called NWSFOs Raleigh, North Carolina, and Sterling, Virginia, to propose the new watch (No. 765). SPC mentioned that there was rotation with a cell on the Virginia/North Carolina border and that NWSO Wakefield, Virginia, had issued a tornado warning as a result. All agreed to the watch although Sterling was a little hesitant. On several occasions, the SPC noted that it is apparent that during hazardous weather events when staffs at local offices are busiest, it can be difficult for them to stay abreast of evolving and immediate post-weather events in nearby NWSFOs/NWSOs areas of responsibility. Later in the evening, tornado watch Nos. 768 and 770 were issued as the tropical system tracked north.

By early Saturday morning, July 13, the main east-west "spiral band" of isolated supercells which was over northern Virginia continued northward and had reached a northern Maryland/southern New Jersey line by around daybreak. Two rotating storms on the far western end of this activity were edging dangerously close to the western edge of the previous weather watch and nearing the eastern suburbs of Washington, D.C. Therefore, upon consultation with NWSFOs Sterling, Virginia; Philadelphia, Pennsylvania; and New York City, New York, the SPC forecaster decided to issue a new watch (No. 771) which covered a bit more of the "western shore" region of the Chesapeake Bay. Shortly after the watch was issued, a new thunderstorm began to rotate along the same spiral band which had produced the rotating storms east of Washington. This latter cell moved right across Baltimore and prompted a tornado warning from Sterling, but no tornadoes were reported.

During the coordination call for Tornado Watch No. 771, NWSFO Philadelphia had no trouble accepting the watch as there had already been isolated rotating storms over Delaware Bay earlier. These storms were well in advance of the Virginia/Maryland spiral band. On the other hand, NWSFO New York City really didn't want the watch (No. 771), but they were unaware of the fact that isolated supercells had been occurring as close to them as Delaware Bay earlier. There was good agreement with NWSFO Boston, Massachusetts, to the effect that any tornado threat in New England would be delayed for a while due to the presence of cooler/drier air near the surface (dew points were in the 60s vs. low to mid 70s in Maryland). As has been pointed out in several instances, the long standing procedures of watch coordination with field offices were, in general, effective. The coordination process provided the field with opportunities to contribute and, in most cases, coming to a consensus was not a problem. The SPC also noted the ability to dial into the WSR-88Ds that were being affected proved to be a valuable tool in assessing the tornado threat from Bertha.

Chapter 3

Regional Perspectives

Southern Region

- ***Puerto Rico and the U.S. Virgin Islands***

Data Collection

WSR-88D

Performance of the San Juan WSR-88D, an FAA radar, was acceptable as Bertha moved across the Virgin Islands and north of Puerto Rico. However, as of Saturday, July 6, the radar was inoperative with no apparent plans to return it to service. Representatives from SRH, WSH, Office of Systems Operation, and the Operational Support Facility spent several hours during the evening of July 6 coordinating and attempting to isolate the problem. On the morning of July 7, the FAA electronics technician (ET) had identified the problem as irregular fluctuations in the frequency of the generator used to power the RDA. Due to the remoteness of the site, the RDA does not have commercial power. The permanent fix to the generator's problem was to install an electronic governor on the generator, but this could not be done before Bertha's arrival. The FAA ET would attempt to temporarily stabilize the signal on a short-term basis but could not promise any definite success. The efforts were in fact successful as the WSR-88D remained operational for the duration of the event. Once the scope of the WSR-88D problem was made known to the appropriate FAA representatives, they were cooperative and restored the radar to service as quickly as possible.

Automated Surface Observing System (ASOS)

The ASOS units on St. Thomas and St. Croix functioned normally until Monday, July 8. On the morning of July 8, the control towers at both islands' airports were abandoned. FAA personnel have instructions to power down all equipment, including ASOS, when the towers are abandoned. Thus, no ASOS data were available as the storm impacted the islands, and no official wind or pressure data were available in real-time or after the event. The ASOS at San Juan remained operational, recording a maximum wind gust of 60 mph and a minimum pressure of 996.8 mb.

Warning and Forecast Services

NWSFO San Juan began issuing HLSs at 11:20 p.m. AST, Saturday, July 6. The HLSs were issued at 6 hourly intervals through 5 p.m. on July 7, at which time they switched to 3 hourly statements. The statements contained a great deal of information presented in a segmented form as recommended by the *Hurricane Marilyn Disaster Survey Report*. Separate sections of the HLS were used to describe preparedness actions, the storm's position, storm surge, etc. This enabled customers to quickly find information regarding a particular aspect of the storm's threat. As Bertha approached and moved by Puerto Rico, HLSs were composed and disseminated every 2 hours. These HLSs were a marked improvement over those issued for Hurricane Marilyn.

NOWs were prepared by NWSFO San Juan throughout the event. The NWSFO staff utilized information primarily from the WSR-88D when composing their NOWs. While the NOWs were informative, some of them were written in a style similar to the radar narrative summary (i.e., "At xxx pm...radar indicated the center of Bertha..."). This had the effect of dating the products and focusing customers' attention to the storm's history rather than its forecast track and impacts.

Dissemination and Coordination

NWSFO San Juan communicated information regarding Bertha in a variety of ways. The primary dissemination means were NWR and NWWS. Local EMCs and media took an active role in relaying information to the citizens, using methods ranging from facsimile transmissions to live television and radio broadcasts.

On St. Thomas, NWR broadcasts are provided through a service contract with radio station WAH. Normally, WAH provides NWR service between 6 a.m. AST and midnight. However, with the approach of Bertha, WAH conducted 24-hour operations from one day before the storm's arrival to two days after Bertha's impact. The St. Thomas office of the Virgin Islands Territory Emergency Management Agency (VITEMA) has the "state" NWWS drop provided by the NWS. The system was operational until mid-afternoon Monday, July 8, when power was lost to the VITEMA facility. The VITEMA-St. Thomas office was in frequent contact with NWSFO San Juan, as coordination calls were held at least five times daily starting on Friday, July 5.

On St. Croix, VITEMA officials were still not receiving all NWWS products from the drop on St. Thomas. However, the St. Croix staff obtained the necessary information via coordination calls with the NWSFO San Juan, the Internet, The Weather Channel, and the VIFreenet. The VIFreenet is a free Internet-based service for Virgin Islands citizens. The service is maintained by private sources. VITEMA-St. Croix staff also gathered weather information from the FEMA Region I HF radio network. Although some problems were encountered with the NWWS, the VITEMA-St. Croix staff utilized multiple dissemination methods to receive information regarding Bertha.

Preparedness

As in previous years, the staff at NWSFO San Juan conducted an aggressive hurricane preparedness campaign. From October 1995 through June 1996, the office participated in 48 conferences, workshops, seminars, presentations and interviews related to hurricane preparedness. Among these activities was a 2-day workshop, conducted in cooperation with TPC/NHC, for VITEMA officials. The office also conducted an in-house hurricane seminar which was also attended by two members of the VITEMA-St. Croix staff. NWSFO continues their noteworthy preparedness efforts.

Customer Response

The local media was proactive, especially the print media outlets. The St. Croix Avis, the local newspaper on the island, covered Bertha as their headline story beginning on Saturday, July 6. NWS Public Information Statements documenting preparedness activities were printed in the Sunday and Monday (July 7 and 8) editions. VITEMA officials on both St. Thomas and St. Croix were satisfied with the information they received during the event, including the forecast track and intensity. Although Bertha was a fast-moving storm as it approached the islands, VITEMA staff and citizens felt they had ample time to prepare. Thus, the VITEMA staff believed that they received better services than during Hurricane Marilyn in 1995.

■ *Florida and Georgia*

Data Collection

All of the data collection equipment in place along the Florida and Georgia coasts was operational during the event. The WSR-88D, ASOS, upper air equipment, and data buoys performed well throughout Bertha's trip up the east coast.

However, NWSFO Miami, Florida, noted a problem with a lack of data off the southeast Florida coast. Without the data, no wave information is available south of Melbourne, Florida. Wave heights can be estimated from local wind forecasts, but no observations of swells are routinely available and no "ground truth" wind/wave data can be accessed by forecasters. The NWSFO Miami WCM has talked to the Beach Patrol units in southeast Florida, asking them to call in rough surf reports to the office. This practice is not consistently done.

Warning and Forecast Services

All coastal offices issued frequent HLSs for their areas of responsibility. The HLSs roughly coincided with the release of advisory packages or intermediate advisories from TPC/NHC.

Because Bertha remained well away from the coastline, none of the Florida coastal offices needed to document the storm's progress in short term forecasts (NOW).

During the evening of July 9, Bertha approached southeast Florida and TPC/NHC issued the Tropical Storm Warning from Deerfield Beach, Florida, northward. This was upgraded to a Hurricane Warning from Sebastian Inlet northward during the morning of July 10. NWSFO Miami, NWSO Melbourne, and NWSO Jacksonville, Florida, began issuing HLSs at around midnight on July 10. The HLSs were issued about every 3 hours until the warnings were discontinued (5 p.m. EDT on July 10 for Miami, 5 a.m. on July 11 for Melbourne, and 5 a.m. on July 12 for Jacksonville). Overall, the offices' HLSs were detailed and accurate. In cases where the HLSs were lengthy, a segmented approach was used. As at NWSFO San Juan, the Florida offices' segmented HLSs contained separate paragraphs discussing topics such as the storm itself, evacuation instructions, and tide information. It should be noted that all of Florida's coastal NWS offices issued timely and informative HLSs as Bertha passed offshore.

In addition to the HLSs, NWSFO Miami issued heavy surf advisories and statements advising of rough surf conditions and potential strong rip currents through July 12. Unfortunately, one death occurred on July 10 due to a rip current off Jacksonville Beach. Later in the week, due to the lack of wave/swell data from off the southeast coast, the heavy surf advisory was prematurely canceled. Two more people were drowned and more than 100 were rescued along Dade County beaches on July 12 and 13 due to rip currents caused by swells from Bertha. The NWSFO Miami also issued a wind advisory on the morning of July 10 for inland portions of central and southern Florida with winds forecast to 35 mph. The wind advisory was extended to portions of north-central Florida during the late morning of July 10.

Internal and External Coordination

Although Bertha's meteorological impacts on the Florida and southeast Georgia coasts were minimal in the form of heavy surf and minor beach erosion, the storm was the subject of tense coordination between NHC and the State of Florida EMC. Because the NHC forecasters felt that the storm would turn to the north and eventually to the northeast, no watches or warnings were originally issued for the coast. By Tuesday, July 9, the storm still had not made an appreciable turn to the north. During a coordination with the state EMC on the evening of July 9, the state EMC virtually insisted that a watch or warning be issued so that their coastal county EMCs could initiate their hurricane plans. The storm still had not made an appreciable turn by the morning of July 10. During the 10 a.m. EDT conference call between NHC and the local offices, it was agreed that an upgrade to a hurricane warning was the best course of action. Bertha finally slowed and started to turn north by the afternoon of July 10, but the warnings were left up for precautionary reasons. In retrospect, the NHC official forecasts were accurate in depicting Bertha's decrease in forward speed and turn to the north. Although the turn did occur, the uncertainty involved with the forecast made coordination with the State of Florida EMC difficult.

The local offices along the coast were active in coordinating with their local emergency management officials. Staffs at the offices were involved with both the NHC coordination calls and the State of Florida conference calls as well. Offices utilized telephone and amateur radio communication when needed to elaborate on the information contained in HLSs.

Customer Response

Despite the coordination issues which occurred during Bertha's approach, local customers were satisfied in general with the services they received. The Palm Beach County EMC was supportive of the NWS warnings and forecasts and expressed displeasure only at the tenseness of the coordination between NHC and the state EMC. The Broward County EMC was concerned about the breakpoint chosen for the tropical storm warning (north of Deerfield Beach) since Deerfield Beach is in Broward County but the warning was for the area north of Broward County.

Along the central Florida coast, there was some second-guessing of the warnings and evacuations. These concerns were especially evident in the local print media. However, the majority of the customers in the area felt that the actions taken were prudent considering the history and past track of the storm. The NWSO Melbourne WCM has engaged in ongoing meetings with local emergency managers to evaluate the communication and coordination issues.
In northeast Florida and southeast Georgia, customers were satisfied as well with the services from NWSO Jacksonville, Florida. The regional media were centrally located in the Duval County EMC. On the afternoon of July 10, the NWSO Jacksonville MIC relocated to the Duval County, Florida, EMC to field media inquiries and to enhance coordination with Duval County and other local emergency management officials. Community response in the coastal areas was immediate upon issuance of the hurricane warning. NWSO Jacksonville received a letter of appreciation from the Camden County, Georgia, EMC, and several other local agencies gave verbal compliments to the office. As in east-central Florida, the NWSO Jacksonville WCM and SOO have engaged in frequent evaluation meetings with local customers.

Eastern Region

Impacts

Hurricane Bertha was an unusual early season Category 2 hurricane which made landfall near Wrightsville Beach, North Carolina. Bertha was the first significant hurricane to directly affect the state between Wilmington and Morehead City since Hurricane Donna in 1960.

The American Insurance Association estimates that $135 million of insured property losses occurred during Bertha with $100 million having occurred in North Carolina, $25 million in Virginia, and $10 million in South Carolina. Claims represent insured losses resulting from factors other than tidal inundation (i.e., mostly wind).

The hardest hit area was just to the east of the eye at landfall...Topsail Beach and Swansboro, North Carolina. Water was 5 to 6 feet deep in waterfront businesses in Swansboro. Highest wind gusts reported on land were 108 mph at Camp Lejeune and Jacksonville and 95 mph at Wrightsville Beach (all in North Carolina). Wind gusts of 80 mph were observed at NWSO Newport, North Carolina. In Wilmington, North Carolina, just to the west of the eye, winds gusted to 70 mph. Over water, the Frying Pan Shoals C-Man tower, 35 miles off the North Carolina coast, registered a gust to 115 mph. NWSO Wilmington, North Carolina, recorded 5.66 inches of rain during Bertha's passage.

In North Carolina, moderate to severe amounts of beach erosion occurred in areas of Bertha's greatest impact. Mason Inlet lost 50 feet of land, leaving the inlet that much closer to Shell Island Resort. At Emerald Isle, the dunes dropped vertically 8 to 10 feet at the erosion line. At Kure Beach, there was 4 feet of vertical erosion against the boardwalk, leaving the strand narrower by 40 feet. On the Outer Banks, more than 150,000 people (mostly tourists) evacuated back to the mainland. Further south, well over 100,000 people evacuated to the west of I-95 and out of harms way.

Outside the areas of greatest impact, Bertha's effects were much less dramatic. In South Carolina, the highest measured wind was at the downtown Charleston Handar with a peak gust of 58 mph. Higher peak gusts likely occurred along the barrier island beachfronts. No significant beach erosion occurred as the maximum tide departure occurred near the time of low tide. Rainfall was generally between 1 and 2 inches. Widespread power outages occurred over North Carolina with as many as 250,000 customers without power in the eastern portions of the state. About 80,000 people were evacuated in South Carolina and 20,000 in Georgia. Revenue losses due to evacuations of tourists and residents were estimated to be about $40 million. One person drowned off Myrtle Beach in advance of the storm while attempting to surf the large waves and swells.

In Virginia, four tornadic storms associated with Bertha resulted in much of the damage across eastern portions of the state. The strongest tornado struck Northumberland County, Virginia, and resulted in nine injuries. Rainfall totals ranged from 3 to 6 inches on the Virginia Capes and the lower Maryland shore to 2 to 4 inches over inland sections of Virginia east of Interstate 95. Mostly minor to locally moderate tidal flooding and beach erosion occurred. Extensive power outages occurred over eastern Virginia, with as many as 115,000 customers without power in the eastern sections of the state. In the NWSO Wakefield, Virginia, county warning area (CWA), nearly 1,800 people were evacuated.

Inland portions of Delaware and Maryland experienced heavy rain and gusty winds from what was now Tropical Storm Bertha although the most significant impact was from several weak tornadoes. There was some attendant wind damage associated with the stronger thunderstorms in Bertha's rain bands. The Patuxent River, Maryland, Naval Air Station recorded a gust of 48 mph and 4.03 inches of rain. Rainfall totals ranged from 4 to 4.5 inches along the western shore of the Chesapeake Bay and 1 to 2.5 inches across metropolitan Washington, D.C. In Bertha's aftermath, about 2,000 homes were without power in northern Virginia, 5,000 around the District of Columbia and surrounding Maryland suburbs, and 10,000 in and around Baltimore.

In New Jersey, the most significant impact from Bertha was the heavy rain with 2- to 4-inch storm totals common in coastal sections, with a few isolated reports greater than 6 inches. One such report was 6.69 inches in Estelle Manor, New Jersey. Generally, coastal and flash flooding were not a problem although moderate wave action was responsible for one surfing fatality. Harvey Cedars, New Jersey, reported a 63-mph gust with some downed trees and resultant power outages which were a consequence of the area's experiencing strong gusty winds and saturated soils.

On Long Island, winds gusted to 64 mph on Babylon Village, New York. Rainfall totals were as high as 4.65 inches at Pomona in Rockland County, New York. In New York City and Long Island, rainfall amounts ranged from 0.76 inches in Quogue to 2.49 inches at Mt. Sinai (both on Long Island). Mostly minor to locally moderate beach erosion occurred.

In southern New England, most of Bertha's adverse effects were minimal and resulted in only minor coastal flooding. One strong band of convection, however, resulted in strong winds and numerous power outages across Rhode Island and southeast Massachusetts. The highest reported gust was 87 mph in New Bedford, Massachusetts. The maximum reported rainfall was 7.20 inches at Billerica, Massachusetts. Rainfall totals exceeded 5 inches at several locations in northern Rhode Island, northeast Connecticut and interior parts of eastern Massachusetts.

The remainder of New England essentially had to deal with the locally heavy rains associated with Bertha's remnants. Total rainfall across the area was generally in the 2- to 4-inch range with lower amounts in northern Maine and northern New Hampshire. There were several reports of water over the roads in the areas covered by flood warnings, but no significant problems or damage was reported. (See Appendix E for the Aerial Survey.)

Warning and Forecast Services

Timely hurricane watches and warnings were posted commensurate with the threat posed by Bertha. However, intensity forecasts prior to landfall in North Carolina were not on target. Information from NHC indicated that Hurricane Bertha had weakened as she approached the North Carolina coast. The hurricane had been gradually weakening since its top speed of 115 mph on July 9 to 81 mph on July 11. Then 12 hours before landfall, the estimated maximum 1-minute winds increased to 104 mph. Information relayed to eastern North Carolina emergency managers mirrored information received from the NHC. Forecast wind speeds, especially inland, were too low.

Forecasts of sound-side flooding of the Outer Banks were based on a numerical model developed at North Carolina State University. The forecast based on the late afternoon advisory on July 11 called for a 6- to 8-foot surge. This forecast did not take into account decreasing wind speeds as Bertha moved north through eastern North Carolina. As a result, the surge forecast was too high. Actual surges were on the order of 1 to 2 feet. South of this area from Cape Lookout to Cape Fear, the storm surge was between 5 and 6 feet and was forecast to be between 4 and 6 feet.

Some lower Maryland Eastern Shore emergency managers expressed concern with the lack of a Hurricane or Tropical Storm Watch north of the Hurricane Warning area. It was their feeling that a Watch would have afforded them the freedom to take action commensurate with the level of threat they perceived existed.

Further north, local NWSFO and NWSO products were excellent and accurately depicted the hazards posed by the now weakening tropical storm. Early on in the event, there was some initial forecast disagreement across southern New Hampshire. This was subsequently resolved by a joint telephone call with the New Hampshire Office of Emergency Management by staffs at NWSFOs at Taunton, Massachusetts, and Gray, Maine. Generally, the accurate and timely NWS warnings and forecasts allowed customers both on land and water to adequately prepare for Bertha.

Internal and External Coordination

Internal NWS and external coordination during Bertha's passage through Eastern Region went well in most instances. Timely notification to Federal, state, county and local agencies were initiated by local NWS offices well in advance of the official watches and warnings. This ensured that users were well-prepared days in advance of the hurricane's impact.

External coordination was accomplished primarily via telephone. Some users in the heart of Bertha's path obtained information through a bulletin board system at NWSO Newport, North Carolina. The primary backup system at the NWSO, amateur radio operators, was used to gather information but was not needed for coordination purposes since the telephone system did not fail.

Internal NWS coordination was accomplished primarily via telephone, the hurricane hotline, and AFOS.

Some user complaints were also received regarding the utility of the inland winds model. As noted earlier, this largely resulted from the forecast of strong inland winds in the NHC marine advisory not reflecting observed conditions.

In northeast North Carolina, the hurricane revealed some coordination problems with regard to the timely dissemination of important weather information between NWSO Wakefield, Virginia, and the emergency managers of the coastal counties within Wakefield’s CWA. The MIC and SOO met with the emergency managers and resolved these issues. Additionally, emergency management officials stated they continue to have tight budgets and cannot afford NWWS. EMWIN was emphasized while the use of Internet and the bulletin board service was mentioned.

In North Carolina, some problems were noted regarding NHC initiated calls to the EMC. When a hurricane warning is posted for the North Carolina coast, the NWSFO Raleigh MIC and WCM brief the state EMC *in person* when each new advisory is issued. State emergency management officials also call the NWSFO as appropriate, between visits by the MIC or WCM, to get intermediate updates on the hurricane's progress. NHC briefing calls frequently came at times when state officials were already in the midst of a briefing by the NWSFO or with local emergency management officials along the coast.

At a number of NWS offices, HAM radio SKYWARN volunteers received and passed along information. In at least one instance (NWSO Wilmington, North Carolina), Packet Radio was their primary communication device. Local emergency management officials with Packet Radio often received the hurricane advisories and local office statements more than a half hour before they were received by other means. Additionally, the Packet Radio also provided them with Doppler (WSR-88D) radar images from the radar coded message product.

Data Collection and Communication

The coastal portion of the NWSO Morehead City, North Carolina, CWA is covered with data collection devices ranging from ASOS sites, Datalogger, and DARDC wind equipment. Most units failed once power was lost. Amateur radio operators were used to gather information throughout the storm and proved to be NWSO Morehead City's most reliable data-gathering source. Generally, though, the sparsity of land and over water real-time observations proved once again to be an obstacle as Bertha slammed onshore and traversed through eastern North Carolina.

Local NWS office work on fine-tuning the WSR-88D rainfall estimates continued during Bertha. With the passage of each tropical system through the region, more radar data are helping local offices to fine tune the most accurate reflectivity (Z-R) relationship to utilize. This will aid NWSFO/NWSO assessments of the (rainfall) flooding potential during future tropical system passages.

WSR-88D level II, III, and IV data were archived by NWS offices in Bertha's path. Unfortunately, the archive level II data at NWSO Morehead City was inoperative throughout the event. In addition, many NWSFOs and NWSOs archived upper level plots, surface observations and model gridded data during the hurricane.

In North Carolina, the New Bern and Cape Hatteras NWR failed for a time as the hurricane was reaching peak strength. This is a problem which the Region is attempting to minimize for future hurricanes and other severe weather episodes through the use of NWS-owned and operated uninterruptible power supply and back-up generator equipment at NWR transmitter locations.

A number of offices noted a truncation of some of the more lengthy HLS on TWC. Moreover, it was also noted that some of the NOWs were cut off at six, as opposed to eight lines. Obviously, this premature truncation of the HLS and NOW will result in need-to-know information not being passed on to the viewer and as such needs to be resolved with TWC.

A telephone company problem led to the NWR's Blue Hill transmitter, which serves the Greater Boston area, being off the air for several hours during the height of the storm. Additionally, the Providence ASOS temperature and dew point sensor went out of service during Bertha's passage through the area.

User Response

User response was quite good. The successful evacuations and low casualty rates reflect the growing sophistication and team efforts of the NWS and the emergency management community although a number of false perceptions as pertains to the hurricane's perceived threat linger.

Emergency management personnel in North Carolina are well trained and made the appropriate evacuation decisions. All used either the "HurrTrak" or "Hurrevac" computer software to aid in their decision-making process. Conference calls that included all emergency managers as well as NWSO Morehead City and NWSO Wakefield personnel were initiated by the North Carolina Area A Coordinator (includes northeastern North Carolina counties). Occasional conference calls were initiated by the Area C Coordinator (central and southeastern North Carolina counties).

The media and public responded quite well. Most tourists evacuated when ordered, however, the majority of the year-round residents remained on the North Carolina barrier islands.

Further north, the states of Maryland and Virginia were contacted after the event to assess their reaction. Feedback from the state level was strongly positive. Some concern was expressed by one emergency manager on the Maryland Eastern Shore, regarding the NWS use of one of the hurricane break points during the event.

Just to the south of Bertha's greatest impact, individuals who were not allowed to return to evacuated areas immediately after the hurricane and subsequently saw only limited damage noted that they would not evacuate when the next hurricane approached. This attitude is a continuing problem that the NWS and FEMA will have to resolve in present and future educational outreach efforts.

Preparedness

The true measure of a warning program's effectiveness is the degree of response that the warning elicits from the public and local officials. The NWS must work closely with emergency managers, officials and the media to gain their trust and to ensure that their requirements for technical information are met. Similarly, active public awareness campaigns conducted with local officials and the media foster heightened awareness of hazards presented by hurricanes.

Numerous pre/early season hurricane preparedness activities were conducted throughout the Region prior to Bertha making landfall in North Carolina and then moving up the east coast, a short distance inland. Most individuals knew how to respond to Bertha's threat, and thereby demonstrated that NWS community preparedness/outreach efforts indeed paid off. It was interesting to note, however, that North Carolina Preparedness Week was scheduled in North Carolina for the week following Bertha’s passage. Needless to say, the week's activities were canceled in lieu of the "real-life" experiences associated with this early season hurricane.

In South Carolina, working relations with local and state emergency managers are in excellent condition thanks to regular South Carolina Hurricane Task Force meetings and work accomplished through the local NWSO Charleston and NWSFO Columbia preparedness programs. Similar actions at other Eastern Region coastal NWSFOs/NWSOs translated to successful local preparedness efforts during the days leading up to Bertha's passage through the Region.

During state conference calls, the state and local officials displayed reasonable expectations and asked pertinent questions of the local office NWS participants. These emergency managers seemed to understand well the role local NWSFO and NWSO offices play and used NWS-provided information to their full advantage.

Finally, Eastern Region NWSFOs and NWSOs were well prepared internally for Bertha with appropriate staffing changes initiated well in advance of the hurricane/tropical storm. This ensured that local NWS offices were properly staffed to meet the challenges posed by this hurricane. Externally, shelters were opened where needed, and again, no preparedness problems were noted.

Appendix A

Saffir-Simpson Hurricane Scale*

Category	Definition—Likely Effects
ONE	**Winds 74-95 mph:** No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal road flooding and minor pier damage.
TWO	**Winds 96-110 mph:** Some roofing material, door, and window damage to buildings. Considerable damage to vegetation, mobile homes, and piers. Small craft in unprotected anchorages break moorings.
THREE	**Winds 111-130 mph:** Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.
FOUR	**Winds 131-155 mph:** More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Major damage to lower floors of structures near the shore. Terrain may be flooded well inland.
FIVE	**Winds greater than 155 mph:** Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Major damage to lower floors of all structures located near the shoreline. Massive evacuation of residential areas may be required.

* In operational use, the scale corresponds to the 1-minute average sustained wind speed as opposed to gusts which could be 20 percent higher or more.

Appendix B

Meteorological Tables

Table 1. Best track, Hurricane Bertha, 5 - 14 July, 1996 (updated 4 August 1996)

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
05/0000	9.8	34.0	1009	30	tropical depression
0600	10.2	36.3	1008	30	"
1200	11.0	39.0	1007	35	tropical storm
1800	12.0	41.2	1006	35	"
06/0000	12.7	43.9	1005	35	"
0600	13.1	46.6	1004	35	"
1200	13.7	48.7	1002	40	"
1800	14.2	51.0	1000	45	"
07/0000	14.9	52.9	999	50	"
0600	15.6	54.8	997	55	"
1200	16.4	56.9	995	60	"
1800	16.5	58.4	992	70	hurricane
08/0000	17.0	60.1	988	75	"
0600	17.5	61.8	985	75	"
1200	18.0	63.5	983	70	"
1800	18.6	64.9	978	75	"
09/0000	19.4	66.1	970	80	"
0600	20.3	67.7	960	100	"
1200	21.4	69.4	965	100	"
1800	22.5	71.1	967	90	"
10/0000	23.6	72.6	969	85	"
0600	24.5	74.0	971	80	"
1200	25.4	75.3	968	80	"
1800	26.4	75.8	966	80	"
11/0000	27.5	76.4	968	75	"
0600	28.3	76.8	972	75	"
1200	29.2	77.5	977	75	"
1800	30.0	78.0	980	70	"
12/0000	30.7	78.3	982	70	"
0600	31.2	78.6	984	70	"
1200	32.2	78.4	975	85	"
1800	33.6	78.1	974	90	"
13/0000	35.0	77.6	993	65	"
0600	36.7	77.0	993	60	tropical storm
1200	38.3	76.1	994	60	"
1800	40.2	74.5	994	60	"
14/0000	42.1	71.9	994	60	"
0600	44.1	69.0	995	55	"
1200	46.0	66.0	995	50	extratropical
1800	47.0	62.0	995	50	"
15/0000	48.0	57.0	995	50	"
0600	49.0	52.0	996	45	"
1200	51.0	47.0	996	40	"
1800	54.0	44.0	996	40	"
16/0000	57.5	42.5	991	40	"
0600	58.5	42.5	988	40	"
1200	59.5	42.0	988	45	"
1800	59.8	41.0	985	45	"
17/0000	60.0	40.0	993	40	"
0600	60.5	39.0	1001	35	"
09/0600	20.3	67.7	960	100	minimum pressure
12/2000	34.3	77.8	974	90	landfall* midway between Wrightsville and Topsail Beaches

*The eyewall also passed over Antigua, Barbuda, St. Barthelemy, Anguilla, St Martin, St Thomas, and the British Virgin Islands and passed close to a number of other islands in the northeastern Caribbean Sea.

Table2. Hurricane Bertha selected surface observations. July 1996.

Location	Press. (mb)	Date/time (UTC)	Sustained wind(kt)[a]	Peak gust	Date/time (UTC)[b]	Storm surge(ft)[c]	Storm tide(ft)[d]	total rain(in.)
Florida								
Jacksonville	1011.9	11/2256	22(2 min)	27	11/1721			trace
Jacksonville Beach							2	
Georgia								
Sea Island							3	
St. Simon							3	
South Carolina								
Charleston international airport	1008.5	12/1155	30 (2-min.)	39	12/0130			1.48
Charleston city office			36	50	12/1130			0.94
Charleston harbor						2.7		
Cheraw								0.38
Cherry Grove pier				68				
Garden City pier				54				
Loris								2.77
Myrtle Beach								2.40
Myrtle Beach, Sands Resort								4.73
Myrtle Beach Springmaid pier						3.3		
Myrtle Beach pavilion				52				
Summerville								1.40
North Carolina								
Beaufort Duke marine lab						2.8		
Beaufort				56	12/2125			
Bath							6	
Bellhaven							7	
Brunswick							5	
Carolina Beach							6	
Cherry Point (NKT)				64	12/2242			
East Wilmington				70				
Greenville				76				4.11
Hatteras ferry ofice				63	13/0100			
Kure Beach			49	80	12/1835			
Lake Waccamaw								2.39
Newport	994.3			78				2.95
New Bern				62	12/2208			4.56[e]
New River (NCA)				94	12/2021			
Pongo River							4.5	
Seymour Johnson AFB	986.3	12/2355	33	52	12/2155			4.03
Snow Hill								5.44
S. Pamlico River							3	
Southport (Nixon)	978.3	12/1835	55	74	12/1703			
Surf City (Horodner)	977	12/2005						
Swansboro							8	
Williamston								4.10
Wilmington (ILM)	978.7	12/2028	46(2-min)	61	12/1902	1.3		5.66
Wilmington NC state port				77				
Wilmington port terminal	980.1	12/1850	NOAA ship Whiting, 34.2N 77.96W					
Cape Lookout Buoy				62	12/2300			
Diamond Shoals Buoy				71	13/0200			
FPSN7 (CMAN, 80 ft asl)	977.5	12/1800	77(10 min)	101	12/1610			
Wrightsville Bch. Banks ch.				80				
Virginia								
Andrews AFB (ADW)	1000.6	13/1155		35	13/0750			0.94
Baltimore Washington airport	1000.3	13/1349		41	13/0704			2.28
Cape Charles				61	13/0330			
Eastville, Northhampton Co.								7.00

Table2(continued). Hurricane Bertha selected surface observations, July 1996.

Location	Press. (Mb)	Date/time (UTC)	Sustained wind(kt)[e]	Peak gust	Date/time (UTC)[f]	Storm surge(ft)[g]	Storm tide (ft)[h]	total rain(in.)
Virginia								
Elizabeth City (ECG)	998.9	13/1313	39	48	13/0055			
Newport News (PHF)	993.1	13/0750						
Norfolk International airport	995.1	13/0756	31	42	13/0740			2.44
Norfolk NAS (NGU)	994.4	13/0755	30	42	13/0155			
Norfolk, Sewells Point						2.5		
Oceana NAS (NTU)	997.2	13/0755						
Pasquotank River							5	
Patuxent River NAS (NHK)	995.0	13/1100		42	13/0603			4.03
Plantation Creek								7.20
Potomac river at Wisc. Ave.							5	
Wallops Island			42	47	13/0605			
Washington Dulles airport				29	13/1218			1.12
Washington National airport	1001.7	13/1221		29	13/1346			1.24
Willis Wharf, Accomac Co.								5.80
Chesapeake Light Stn. Buoy			49	56	13/0700			
Fenwick Is. Buoy (44009)			41	48	13/1300			
Maryland								
Nanticoke, Wicomico Co.								5.03
Salisbury								5.62
Delaware								
Dover	995.6	13/1155	30	50				
Lewes						1.58		
New Jersey								
Atlantic City						2.27		2.41
Estelle Manor								6.59
Harvey Cedars				55				
Newark airport			25 (2-min.)	35	13/1521			
Teterboro airport			26 (2-min.)	38	13/1547			
River Vale								2.17
West Milford								4.85
Pennsylvania								
Philadelphia		29	36					2.43
New York								
Ambrose Light Tower buoy				48				
Babylon Village, L.I.				64				
Buoy southwest of Fire Is.				37				
Brookhaven airport			26	36	13/1947			
East Quogue, Suffolk co.								0.76
JFK airport			31(2-min.)	37	13/1458			
LaGuardia airport			29 (2-min.)	38	13/1518			
Mt. Sinai(New York City)								2.49
Ossining, Westchester Co.								3.09
Pomona, Rockland Co.								4.65
Connectucut								0.91
Bridgeport airport			27	34	13/1547			
Orange								
Preston				48				
Shelton								4.06
Vernon								5.50

Table2(continued). Hurricane Bertha selected surface observations, July 1996.

Location	Press.	Date/time (UTC)	Sustained wind[i]	Peak gust	Date/time (UTC)[j]	Storm surge(ft)[k]	Storm tide(ft)[l]	total rain(in.)
Rhode Island								
Fox Point hurricane barrier						2.1		
Sachuest Point (Middletown)			54	64	14/0010[g]	hand-held anemometer		
Providence	995.9	13/2336						5.41
Maine								
Goshen								5.70
Billerica								7.20
Boston	996.3	14/0056						
New Bedford			45	76	13/2030	1.7		
Taunton ASOS	995.6	14/0041						
Puerto Rico								
San Juan	996.8	08/2056	39	49	08/2056			

[a] averaging period is 1 min unless otherwise indicated.

[b] Date/time is for sustained wind when both sustained and gust are listed.

[c] Storm surge is water height above normal astronomical tide level.

[d] Storm tide is water height above NGVD.

[e] Top of rain gage blew off and "a lot of rain was sucked out".

Table 3. Ship reports of 34 knots or higher wind speed, associated with Hurricane Bertha, July 1996.

date/time (UTC)	ship name	latitude (°N)	longitude (°W)	wind dir/ speed(knots)	pressure (mb)
07/1200	FNOR	17.1	53.8	110/39	1014.2
08/1800	WZJE	21.6	64.3	130/35	1013.0
09/0000	WCHF	21.6	64.7	080/036	1009.1
09/0300	WZJE	20.0	64.6	100/38	1007.0
09/0300	WCHF	21.0	65.0	100/48	1008.9
09/0600	WZJE	16.9	65.1	130/40	1007.5
09/0600	WCHF	20.6	65.1	130/48	1006.9
09/0900	WCHF	20.4	65.3	130/42	1009.0
09/1800	WZJF	23.0	67.9	100/43	1012.0
09/1800	P3TA4	24.3	67.0	110/34	1013.2
11/1800	KIRF	28.5	78.8	270/35	1006.0
11/1800	C6YC	29.6	73.5	150/040	1020.5
11/1800	KRPP	30.8	79.9	050/40	1010.0
11/1800	PCAM	31.6	80.4	040/43	1010.0
11/1800	DQFT	32.4	72.6	140/35	1022.5
11/2100	C6YC	28.9	74.3	140/42	1018.8
12/0000	C6YC	28.3	74.8	140/38	1017.5
12/0000	KRPP	30.8	80.1	030/38	1004.7
12/0000	PCAM	31.0	80.9	020/47	1010.0
12/0600	DQFT	30.7	74.7	140/58	1019.0
12/0600	PCAM	31.1	80.6	360/66	1005.0
12/0600	KRLZ	31.3	76.5	130/45	1008.0
12/0900	KRLZ	30.8	76.4	150/55	1007.3
12/1200	P3HR2	28.6	79.7	270/34	1015.5
12/1200	KRLZ	30.4	76.4	150/43	1008.8
12/1200	ELSD9	30.9	75.4	150/37	1016.0
12/1200	SHIP	34.9	71.1	180/52	
12/1500	DQFT	30.0	77.3	180/39	1015.0

Table 3(continued). Ship reports of 34 knots or higher wind speed, associated with Hurricane Bertha, July 1996.

date/time (UTC)	ship name	latitude (°N)	longitude (°W)	wind dir/ speed(knots)	pressure (mb)
12/1800	DQFT	30.1	78.1	210/47	1015.5
12/1800	9VKR	30.5	74.8	170/35	1013.0
12/1800	ELSD9	30.7	76.3	150/37	1017.5
12/1800	SHIP	32.7	73.6	160/40	1016.8
12/1800	9VBK	33.8	73.9	140/34	1017.8
13/0000	WCJY	32.7	75.2	180/35	1022.2
13/0000	9VBK	33.6	75.1	170/38	1012.2
13/0600	3FWI3	32.2	73.7	180/37	1017.0
13/0600	9VBK	33.3	76.0	200/38	1013.3
13/1200	4XGS	39.3	73.9	140/60	1006.0
13/1200	9VUM	37.9	73.2	150/40	1008.1
13/1500	3FEB5	36.5	69.9	180/40	1019.6
13/1500	9VUM	37.6	73.9	210/44	1006.5
13/1500	4XGS	38.7	74.1	160/60	1000.0
13/1800	3FEB5	36.0	70.0	170/37	1017.9
13/1800	9VUM	37.3	74.8	210/62	1009.6
13/1800	4XGS	38.1	74.3	210/40	1005.0
13/1800	LENA3	40.6	72.4	170/40	1004.0
13/2100	DDQS	39.5	69.0	170/37	1012.6
14/0000	DDQS	39.6	69.5	210/47	1009.8
14/0000	NJPJ	41.9	70.3	180/35	1006.1
14/0600	DDQS	39.7	70.4	240/35	1013.3
14/0900	VOLG	45.0	60.4	170/35	1011.4
14/1200	JKPS	37.4	66.5	230/39	1022.0
14/1200	CG2683	43.3	62.6	230/50	1007.0
14/1200	3EXP6	43.9	61.3	180/48	1007.8
14/1200	VOLG	45.2	59.4	170/35	

Table 4. Watch and warning summary, Hurricane Bertha, July 1996.

Date/time (UTC)	Action	Location
06/1500	hurricane watch	Antigua, Barbuda, Nevis, Montserrat, St Kitts, Anguilla, Saba, St Eustatius, Dominica, and Dutch St Maarten
06/2100	hurricane watch	Guadeloupe, St Barthelemy, French St Martin, U.S. and British Virgin Islands
07/0300	hurricane warning	Dominica northward to Anguilla and St Maarten
07/1200	hurricane watch	Puerto Rico
07/1500	hurricane warning	U.S. and British Virgin Islands and Puerto Rico
08/0000	tropical storm watch	Dominican Republic from Isla Saona to Cabo Frances Viejo
08/0300	hurricane watch	Dominican Republic from Isla Saona to Cabo Frances Viejo
08/0900	hurricane watch	Turks and Caicos Islands
08/1200	hurricane warning	Dominican Republic from Cabo Caucedo to Monte Cristo, southeastern Bahamas
08/1500	hurricane warning discontinued	Dominica
08/1800	hurricane watch	Haiti from St Nicolas to border of Dominican Republic
08/1800	huricane warning discontinued	Leeward Islands south and east of St Eustatius
08/2100	hurricane warning	Turks and Caicos Islands and southeastern Bahamas
08/2100	hurricane warning discontinued	Leeward Islands
08/2100	hurricane watch	central Bahamas
09/0100	hurricane warning discontinued	U.S. and British Virgin Islands
09/0300	hurricane warning discontinued	Puerto Rico
09/0300	tropical storm warning	Haiti from St Nicolas to border of Dominican Republic
09/0900	hurricane warning	central Bahamas
09/0900	hurricane watch	northwestern Bahamas
09/1500	watches and warnings discontinued	Dominican Republic and Haiti
09/2100	hurricane warning	northwestern Bahamas
10/0300	tropical storm warning	north of Deerfield Beach, FL to Brunswick, GA
10/0300	hurricane watch	north of Brunswick to NC/VA border including Pamlico and Albemarle Sounds

Table 4(cont.). Watch and warning summary, Hurricane Bertha, July 1996.

Date/time (UTC)	Action	Location
10/0900	hurricane warning discontinued	Turks and Caicos Islands and southeastern Bahamas
10/1500	hurricane warning	Sebastian Inlet, FL to Cape Romain, SC
10/1800	hurricane warning discontinued	central Bahamas
10/2100	hurricane warning	Cape Romain to NC/VA border including Pamlico and Albemarle Sounds
10/2100	tropical storm warning discontinued	south of Sebastian Inlet, FL
11/0300	hurricane watch	NC/VA border to Chincoteague VA including southern Chesapeake Bay
11/0600	hurricane warning discontinued	northwestern Bahamas
11/0900	hurricane warning discontinued	south of Brunswick, GA
12/0900	hurricane warning discontinued	Savannah, Ga southward
12/1500	tropical storm warning	NC/VA border to Chincoteague, VA including southern Chesapeake Bay
12/1900	hurricane warning discontinued	Cape Romain, SC southward
12/2100	hurricane warning	NC/VA border to Chincoteague, VA including the Hampton Roads area
12/2100	tropical storm warning	north of Chincoteague, VA to Watch Hill, RI including the lower Delaware Bay
12/2100	tropical storm watch	east of Watch Hill to the Merrimack River, MA
13/0300	hurricane warning discontinued	south of Topsail Beach, NC
13/0300	hurricane watch discontinued	lower Chesapeake Bay
13/0300	tropical storm warning	all of Chesapeake Bay and the lower tidal Potomac River and all of Delaware Bay
13/0700	hurricane warning to tropical storm warning	Topsail Beach, NC to Chincoteage, VA including Albemarle and Pamlico Sounds
13/0900	hurricane warning discontined	NC/VA border southward
13/1200	tropical storm warning discontinued	south of Fenwick Island, DE
13/1500	tropical storm warning discontinued	south of Brigatine, NJ and Delaware Bay
13/2100	tropical storm warning discontinued	south of Fire Island, NY
14/0000	tropical storm warning discontinued	south of Watch Hill, RI
14/0300	tropical storm warning discontinued	remainder of U.S east coast

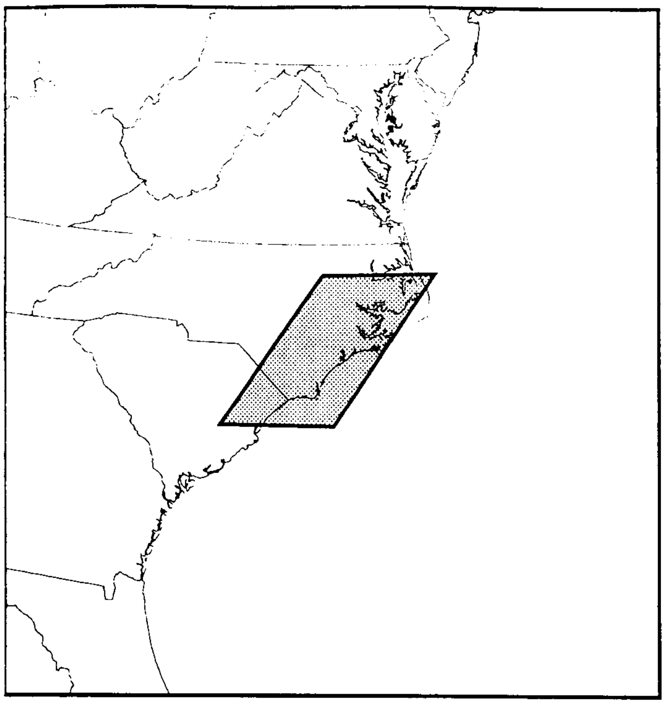
Appendix C

Fujita Tornado Intensity Scale

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

Appendix D

Storm Prediction Center
Tornado Watch Areas



TORNADO #0764

Issue Time: 1437 UTC 07/12/1996
Valid Time: 1500 UTC 07/12/1996
End Time: 0000 UTC 07/13/1996

Area: 19244 sq. mi.

Issuing Forecaster: JOHNS

ZCZC MKCSAW4 ALL 130000;332,0800 360,0774 360,0751 332,0773;
WWUS40 KMKC 121437 COR
MKC AWW 121437 COR
WW 764 TORNADO SC NC AND ADJ CSTL WTRS 121500Z - 130000Z
AXIS..70 STATUTE MILES EAST AND WEST OF LINE..
20SSE MYR/MYRTLE BEACH SC/ - 70NNE EWN/NEW BERN NC/
..AVIATION COORDS.. 60NM E/W /65SE FLO - 24SW ECG/
WIND GUSTS..70 KNOTS.
MAX TOPS TO 550. MEAN WIND VECTOR 12035.
NNNN

<NO CANCELLATION>

ZCZC MKCSEL4 ALL 130000;332,0800 360,0774 360,0751 332,0773;
WWUS9 KMKC 121437 COR
MKC WW 121437 COR
SCZ000-NCZ000-130000-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 764
NATIONAL WEATHER SERVICE KANSAS CITY MO
1037 AM EDT FRI JUL 12 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF SOUTH CAROLINA
PARTS OF NORTH CAROLINA
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS FRIDAY MORNING AND EVENING UNTIL 800 PM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING
THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 70 STATUTE MILES EAST AND WEST
OF A LINE FROM 20 MILES SOUTH SOUTHEAST OF MYRTLE BEACH SOUTH
CAROLINA TO 70 MILES NORTH NORTHEAST OF NEW BERN NORTH CAROLINA.

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

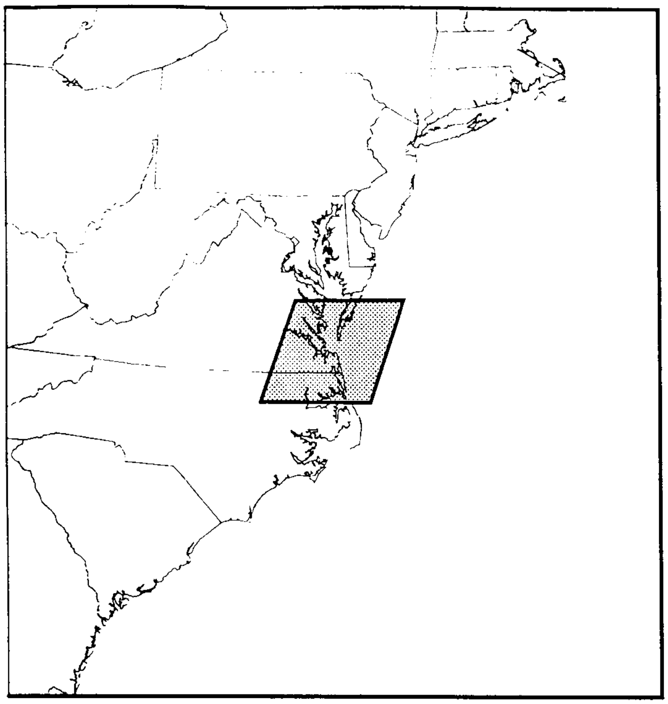
C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO EXTRM
TURBC AND SFC WIND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO
550. MEAN WIND VECTOR 12035.

D...

E...OTR TSTMS...

...JOHNS

NNNN



TORNADO #0765

Issue Time: 1836 UTC 07/12/1996
Valid Time: 1900 UTC 07/12/1996
End Time: 0000 UTC 07/13/1996

Area: 13139 sq. mi.
Issuing Forecaster: JOHNS

ZCZC MKCSAW5 ALL 130000;375,0742 360,0751 360,0774 375,0765;
WWUS40 KMKC 121836
MKC AWW 121836
WW 765 TORNADO VA NC AND ADJ CSTL WTRS 121900Z - 130000Z
AXIS..70 STATUTE MILES EAST AND WEST OF LINE..
70NNE ORF/NORFOLK VA/ - 25SW ECG/ELIZABETH CITY NC/
..AVIATION COORDS.. 60NM E/W /32SSW SBY - 21SW ECG/
WIND GUSTS..65 KNOTS.
MAX TOPS TO 530. MEAN WIND VECTOR 12030.
NNNN

<NO CANCELLATION>

ZCZC MKCSEL5 ALL 130000;375,0742 360,0751 360,0774 375,0765;
WWUS9 KMKC 121836
MKC WW 121836
VAZ000-NCZ000-130000-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 765
NATIONAL WEATHER SERVICE KANSAS CITY MO
236 PM EDT FRI JUL 12 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF SOUTHEASTERN VIRGINIA
PARTS OF NORTHEASTERN NORTH CAROLINA
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS FRIDAY AFTERNOON AND EVENING UNTIL 800 PM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 70 STATUTE MILES EAST AND WEST OF A LINE FROM 70 MILES NORTH NORTHEAST OF NORFOLK VIRGINIA TO 25 MILES SOUTHWEST OF ELIZABETH CITY NORTH CAROLINA.

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

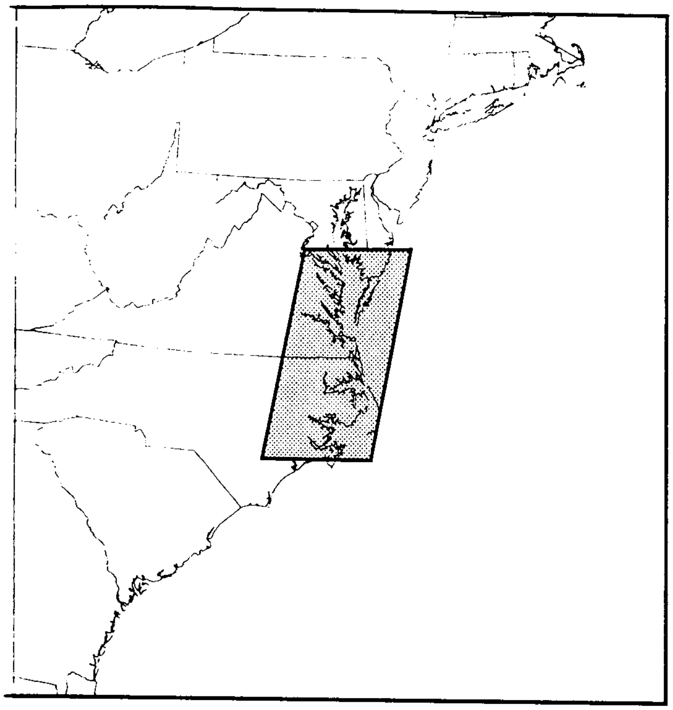
C...TORNADOES AND A FEW SVR TSTMS WITH EXTRM TURBC AND SFC WIND GUSTS TO 65 KNOTS. A FEW CBS WITH MAX TOPS TO 530. MEAN WIND VECTOR 12030.

D...WIND FIELDS ARE INCRG NWD ALG SFC TROF THRU NERN NC AND SERN VA WHERE AMS IS MODERATE. TORNADO PTNL WL BE INCRG NWD WITH TIME INTO SERN VA.

E...OTR TSTMS... CONT..WW 764..

...JOHNS

NNNN



TORNADO #0768

Issue Time: 2316 UTC 07/12/1996
Valid Time: 0000 UTC 07/13/1996
End Time: 0900 UTC 07/13/1996
Replace Time: 0815 UTC 07/13/1996

Area: 27993 sq. mi.

Issuing Forecaster: WIESS

ZCZC MKCSAW8 ALL 130900;344,0780 382,0771 382,0743 344,0753;
WWUS40 KMKC 122316
MKC AWW 122316
WW 768 TORNADO NC VA MD AND ADJ CSTL WTRS 130000Z - 130900Z
AXIS..70 STATUTE MILES EAST AND WEST OF LINE..
25SSE EWN/NEW BERN NC/ - 25WNW SBY/SALISBURY MD/
..AVIATION COORDS.. 60NM E/W /57NE ILM - 20WNW SBY/
HAIL SURFACE AND ALOFT.. 1/2 INCHES. WIND GUSTS..70 KNOTS.
MAX TOPS TO 500. MEAN WIND VECTOR 17050.
REPLACES WW 764..SC NC AND ADJ CSTL WTRS
REPLACES WW 765..VA NC AND ADJ CSTL WTRS
NNNN

ZCZC MKCSEL8 ALL 130900;344,0780 382,0771 382,0743 344,0753;
WWUS9 KMKC 122316
MKC WW 122316
NCZ000-VAZ000-MDZ000-130900-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 768
NATIONAL WEATHER SERVICE KANSAS CITY MO
716 PM EDT FRI JUL 12 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF EASTERN NORTH CAROLINA
PARTS OF SOUTHEAST VIRGINIA
PARTS OF SOUTHEAST MARYLAND
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS FRIDAY NIGHT AND SATURDAY MORNING UNTIL 500 AM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING
THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 70 STATUTE MILES EAST AND WEST
OF A LINE FROM 25 MILES SOUTH SOUTHEAST OF NEW BERN NORTH CAROLINA
TO 25 MILES WEST NORTHWEST OF SALISBURY MARYLAND.

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

B..OTHER WATCH INFORMATION.. THIS TORNADO WATCH REPLACES TORNADO
WATCH NUMBER 764...TORNADO WATCH NUMBER 765. WATCH NUMBERS
764...765 WILL NOT BE IN EFFECT AFTER 800 PM EDT.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 1/2
INCHES. EXTRM TURBC AND SFC WIND GUSTS TO 70 KNOTS. A FEW CBS
WITH MAX TOPS TO 500. MEAN WIND VECTOR 17050.

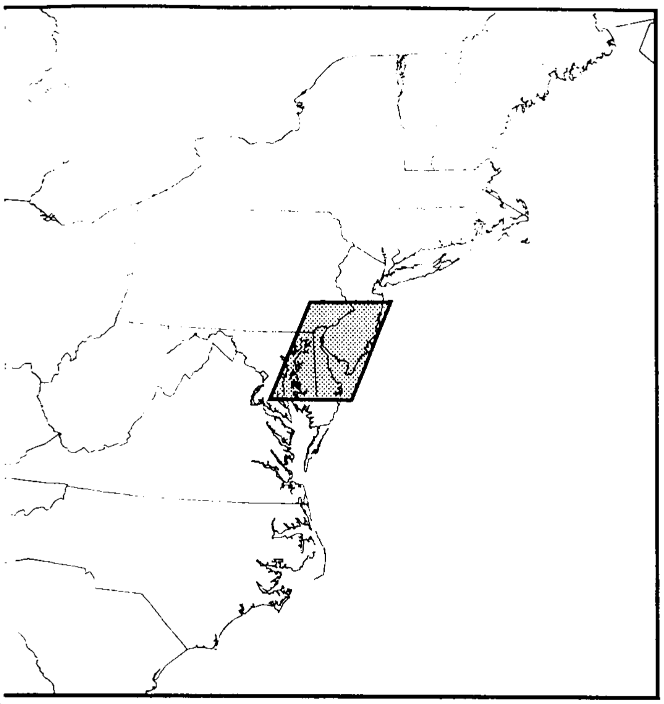
D...BANDS OF CNVTN ASSOCD WITH HURCN BERTHA EXPCD TO CONT ROTG NWD
AND NWWD THRU THE NERN QUAD OF THE CRCLN CENTER. IR STLT IMAGERY
INDCS COOLING CLD TOPS NR THE EYEWALL RGN AS WELL AS IN THE
OFFSHORE FEEDER BANDS. 50-70 KT LOW LVL WINDS ABV THE SFC EAST OF
THE CENTER WILL MAINTAIN VERY STG LOW LVL SHEAR/HELICITY FVRBL FOR
THREAT OF ISOLD TORNADOES AS BERTHA MOVES NWD TNGT.

E...OTR TSTMS... THIS WATCH REPLACES..WW 764..WW 765.. CONT..WW
766..WW 767..

...WEISS

NNNN

<NO CANCELLATION>



TORNADO #0770

Issue Time: 0441 UTC 07/13/1996
Valid Time: 0500 UTC 07/13/1996
End Time: 1200 UTC 07/13/1996
Replace Time: 0815 UTC 07/13/1996

Area: 10567 sq. mi.
Issuing Forecaster: WEISS

ZCZC MKCSAWO ALL 131200;382,0765 401,0755 401,0734 382,0744;
WWUS40 KMKC 130441 COR
MKC AWW 130441 COR
WW 770 TORNADO MD DE NJ PA AND ADJ CSTL WTRS 130500Z - 131200Z
AXIS..55 STATUTE MILES EAST AND WEST OF LINE..
50SSW DOV/DOVER DE/ - TTN/TRENTON NJ/
..AVIATION COORDS.. 45NM E/W /16WNW SBY - 39SW EWR/
HAIL SURFACE AND ALOFT.. 1/2 INCHES. WIND GUSTS..70 KNOTS.
MAX TOPS TO 450. MEAN WIND VECTOR 17040.
NNNN

ZCZC MKCSELO ALL 131200;382,0765 401,0755 401,0734 382,0744;
WWUS9 KMKC 130441 COR
MKC WW 130441 COR
MDZ000-DEZ000-NJZ000-PAZ000-131200-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 770
NATIONAL WEATHER SERVICE KANSAS CITY MO
1241 AM EDT SAT JUL 13 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF MARYLAND
PARTS OF DELAWARE
PARTS OF NEW JERSEY
PARTS OF PENNSYLVANIA
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS SATURDAY MORNING UNTIL 800 AM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING THUNDERST
E POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 55 STATUTE MILES EAST AND WEST (
OM 50 MILES SOUTH SOUTHWEST OF DOVER DELAWARE TO TRENTON NEW JERSE

REMEMBER...A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR TORN
ERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE A
D BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOF
TEMENTS AND POSSIBLE WARNINGS.
$$

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 1/2 INCHES.
TURBC AND SFC WIND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO 450.
ND VECTOR 17040.

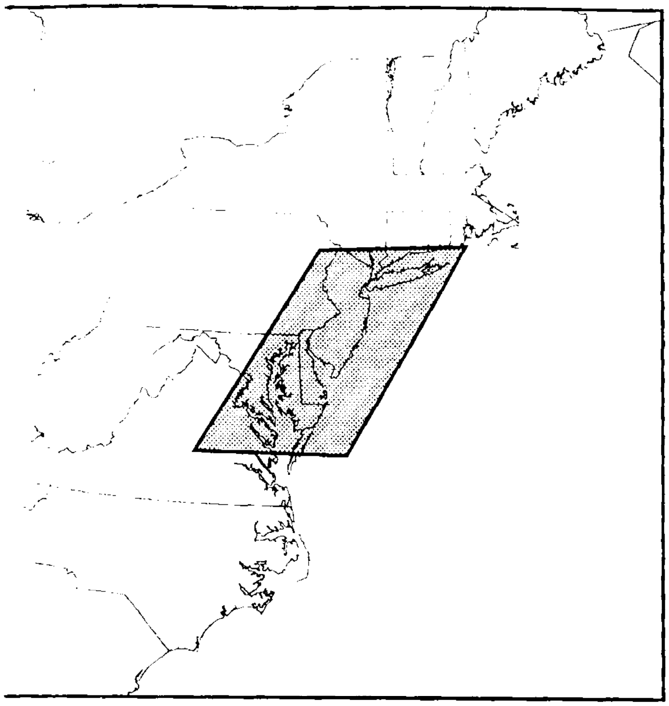
D...

E...OTR TSTMS... CONT..WW 768..WW 769..WW 770..

...WEISS

NNNN

<NO CANCELLATION>



TORNADO #0771

Issue Time: 0800 UTC 07/13/1996
Valid Time: 0815 UTC 07/13/1996
End Time: 1500 UTC 07/13/1996

Area: 41048 sq. mi.

Issuing Forecaster: CORFIDI

ZCZC MKCSAW1 ALL 131500;372,0781 411,0751 411,0712 373,0743;
WWUS40 KMKC 130800
MKC AWW 130800
WW 771 TORNADO VA DC MD PA NJ NY CT DE AND ADJ CSTL WTRS 130815Z
- 131500Z
AXIS..100 STATUTE MILES EAST AND WEST OF LINE..
50E RIC/RICHMOND VA/ - 15NW BDR/BRIDGEPORT CT/
..AVIATION COORDS.. 85NM E/W /37NNW ORF - 13NW BDR/
WIND GUSTS..70 KNOTS.
MAX TOPS TO 450. MEAN WIND VECTOR 17040.
REPLACES WW 768..NC VA MD AND ADJ CSTL WTRS
REPLACES WW 770..MD DE NJ PA AND ADJ CSTL WTRS
NNNN

ZCZC MKCSEL1 ALL 131500;372,0781 411,0751 411,0712 373,0743;
WWUS9 KMKC 130800
MKC WW 130800
VAZ000-DCZ000-MDZ000-PAZ000-NJZ000-NYZ000-CTZ000-DEZ000-131500-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 771
NATIONAL WEATHER SERVICE KANSAS CITY MO
400 AM EDT SAT JUL 13 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF EASTERN VIRGINIA
DISTRICT OF COLUMBIA
PARTS OF CENTRAL AND EASTERN MARYLAND
DELAWARE
PARTS OF EASTERN PENNSYLVANIA
NEW JERSEY
PARTS OF SOUTHEASTERN NEW YORK
PARTS OF SOUTHWESTERN CONNECTICUT

AND ADJACENT COASTAL WATERS

EFFECTIVE THIS SATURDAY MORNING UNTIL 1100 AM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING
THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 100 STATUTE MILES EAST AND WEST
OF A LINE FROM 50 MILES EAST OF RICHMOND VIRGINIA TO 15 MILES
NORTHWEST OF BRIDGEPORT CONNECTICUT.

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

B..OTHER WATCH INFORMATION.. THIS TORNADO WATCH REPLACES TORNADO
WATCH NUMBER 768...TORNADO WATCH NUMBER 770. WATCH NUMBER
768...770 WILL NOT BE IN EFFECT AFTER 415 AM EDT.
$$

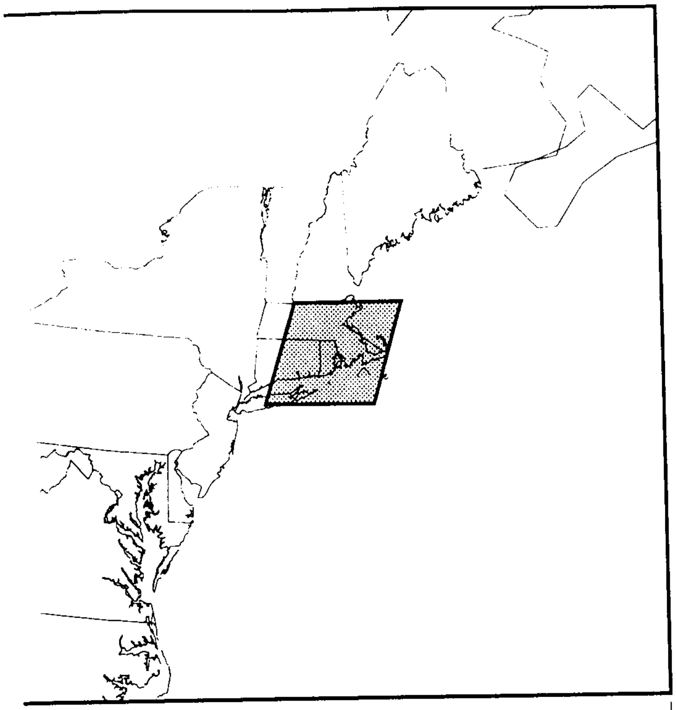
C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO EXTRM
TURBC AND SFC WIND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO
450. MEAN WIND VECTOR 17040.

D...THREAT FOR ISOLD TORNADOES LKLY TO CONT INVOF FEEDER BANDS E/NE
OF BERTHA...WHERE SFC DWPTS HAVE RECOVERED TO AOA 70F AND LOLVL
SPD/DIREC SHEAR RMNS VRY STG.

E...OTR TSTMS... THIS WATCH REPLACES..WW 768..WW 770..

...CORFIDI

<NO CANCELLATION>



TORNADO #0772

Issue Time: 1720 UTC 07/13/1996
Valid Time: 1745 UTC 07/13/1996
End Time: 0000 UTC 07/14/1996

Area: 15600 sq. mi.

Issuing Forecaster: VESCIO

ZCZC MKCSAW2 ALL 140000;404,0731 424,0722 424,0693 404,0702;
WWUS40 KMKC 131720
MKC AWW 131720
WW 772 TORNADO MA CT RI NY AND ADJ CSTL WTRS 131745Z - 140000Z
AXIS..75 STATUTE MILES EAST AND WEST OF LINE..
30SSW BID/BLOCK ISLAND RI/ - 25N BOS/BOSTON MA/
..AVIATION COORDS.. 65NM E/W /59SSW PVD - 38SE CON/
HAIL SURFACE AND ALOFT.. 1/2 INCHES. WIND GUSTS..70 KNOTS.
MAX TOPS TO 450. MEAN WIND VECTOR 20030.
NNNN

ZCZC MKCSEL2 ALL 140000;404,0731 424,0722 424,0693 404,0702;
WWUS9 KMKC 131720
MKC WW 131720
MAZ000-CTZ000-RIZ000-NYZ000-140000-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 772
NATIONAL WEATHER SERVICE KANSAS CITY MO
120 PM EDT SAT JUL 13 1996

A...THE STORM PREDICTION CENTER HAS ISSUED A
TORNADO WATCH FOR

PARTS OF CENTRAL AND EASTERN MASSACHUSETTS
PARTS OF CENTRAL AND EASTERN CONNECTICUT
RHODE ISLAND
PARTS OF EASTERN LONG ISLAND NEW YORK
AND ADJACENT COASTAL WATERS

EFFECTIVE THIS SATURDAY AFTERNOON AND EVENING UNTIL 800 PM EDT.

TORNADOES...LARGE HAIL...DANGEROUS LIGHTNING AND DAMAGING THUNDERSTORM WINDS ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 75 STATUTE MILES EAST AND WEST OF A LINE FROM 30 MILES SOUTH SOUTHWEST OF BLOCK ISLAND RHODE ISLAND TO 25 MILES NORTH OF BOSTON MASSACHUSETTS.

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

C...TORNADOES AND A FEW SVR TSTMS WITH HAIL SFC AND ALF TO 1/2 INCHES. EXTRM TURBC AND SFC WIND GUSTS TO 70 KNOTS. A FEW CBS WITH MAX TOPS TO 450. MEAN WIND VECTOR 20030.

D...CNVTN IS INCRG JUST S OF LONG ISLAND ON E SIDE OF T.S. BERTHA. THIS ACTVTY IS XPCD TO LIFT NWD DURG THE AFTN AND EARLY EVE. DRY INTRUSION NOTED ON LATEST WATER VAPOR IMAGERY MAY ALLOW FOR SUFF AMS DESTABILIZATION FOR A FEW SVR TSTMS PRODUCING DAMAGING WNDS ANI ISOLD TORNADOES.

...VESCIO

NNNN

<NO CANCELLATION>

Appendix E

Aerial Survey

Introduction

Hurricane Bertha struck the North Carolina coast on the afternoon and evening of July 12, 1996. I arrived in Wilmington, North Carolina, on Monday, July 15. During the afternoon of July 15, a flight was made on the NOAA Aircraft Operations Center (AOC) DeHavilland Twin Otter. An aerial flight was made along the coastline from Cape Fear to Cape Lookout, North Carolina. This 3 ½ hour flight was spent examining wind damage along the coast and intercostal waterway area.

On Tuesday, July 16, no flight was scheduled as U.S. Geological Survey was flying on a storm surge mission. A ground survey of agricultural damage was conducted in the afternoon from Wilmington northward to just south of Warsaw, North Carolina.

Wednesday, July 17, a trip was made with the MIC and WCM of NWSO Wilmington to observe the damage at Carolina Beach and Kure Beach, North Carolina. Both locations lost piers. There were some structures with portions of roofs torn off, but most structures survived well. In the afternoon, another flight was made with the Twin Otter. This flight concentrated on inland damage from the hurricane. Damage was mainly confined to crops and trees and extended as far north as Goldsboro, North Carolina.

Coastal Damage

Wind damage was visible from the air from just north of Bald Head Island near Cape Fear to Atlantic Beach, south of Morehead City, North Carolina. The most intense damage with peak wind gusts estimated at 110 mph was located between North Topsail Beach and Emerald Isle, North Carolina. In this area, many beach homes suffered roof damage. The roof damage varied from torn off shingles to whole roofs lost. There were very few total failures to structures due to wind. Of those that did fail, it appears they were modular home or mobile home structures.

Visible coastal erosion was found, especially to beach sand dunes and to a coastal road at North Topsail Beach. However, the damage was not as severe as in other recent landfalling hurricanes, such as Opal in 1995.

Further inland along the edge of the intercoastal waterway, the primary damage was to trees. Numerous trees fell with most falling in the area northeast of the eye from west of Surf City northeastward to just east of Swansboro, North Carolina. This area extended northward to the southern portions of Jacksonville. Wind gusts in this area were estimated to be between 80 and 100 mph.

Inland Agricultural Areas

Agricultural areas were particularly exposed to high winds from Hurricane Bertha. Much of the damage was to corn and tobacco crops. Both of these crops are vulnerable to high wind gusts. Much of the agricultural damage was west of the eyewall rather than east. This is due in part to much of the corn and tobacco crops being grown further west rather than along the eastern coastal areas. The storm tracked slowly northward along the North Carolina and South Carolina coastline before making landfall. Thus, crops were exposed to strong northeast winds for an extended period of time, and this caused crops to weaken significantly. The agricultural damage extended as far as 40 miles west of the eye and as far north as Goldsboro, North Carolina, which is approximately 75 to 80 miles inland. Most of the damage occurred in unprotected (no blockage by trees or buildings) areas along the edge of fields. Some fields had more widespread damage where a streak of particularly high wind toppled several rows of corn or tobacco.

Tornadoes

The initial SPC log of tornadoes associated with Bertha indicated at least six touched down. Three of these reported tornadoes were investigated by air. There was no visible evidence of tornado damage in the three locations of New Bern, Newport, and near Winnabow, North Carolina. It is possible that some of these tornadoes either blended in with the hurricane damage or were not visible from the air. East of Jacksonville, North Carolina, a tornado track was identified from the air and was rated an F1 on the Fujita Tornado Intensity Scale (Appendix C) with a path length of approximately 1 ½ miles. The one area that a tornado most likely did not occur was near Winnabow.

Conclusions and Acknowledgments

The most severe wind damage associated with Hurricane Bertha was along the coast and east of the eye center, typical of most hurricanes. The peak wind speeds estimated from the aerial survey was 110 mph. Although damage to structures was minimal in this hurricane, agricultural damage was extensive.

The author would like to thank the AOC and their fine pilots, Lieutenants Pickett and Longenecker. The author would also like to extend thanks to the Office of the Federal Coordinator for their help in making this survey possible and to Richard Anthony and Tom Matheson from the NWSO Wilmington, North Carolina, for their assistance in conducting the survey.

Appendix B

Meteorological Tables