Service Assessment

HURRICANE FRAN

August 28 - September 8, 1996

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

July 1997

Preface

The primary purpose of this Service Assessment is to document the National Weather Service's (NWS) performance in fulfilling its mission of providing timely warnings and accurate forecasts prior to and during Hurricane Fran. The NWS's products and services used by emergency managers and others are key to preparedness for and the mitigation of a tropical cyclone's impact. This 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.

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APPENDICES

Acronyms

AFOS	Automation of Field Operations and Services
ALERT	Automated Local Evaluation in Real-Time
ASOS	Automated Surface Observing System
AVN	Aviation Model
BAMD	deep-layer Beta and Advection Model
COE	U.S. Army Corps of Engineers
DARDC	Device for Automatic Remote Data Collection
ECMWF	European Center for Medium Range Weather Forecasting
EDT	Eastern Daylight Time
EMWIN	Emergency Managers Weather Information Network
EOC	Emergency Operations Center
ERH	Eastern Region Headquarters
ESF	Flood Potential Statement
Eta	Eta Model
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FFA	Flood/Flash Flood Watch
FFW	Flood/Flash Flood Warning
FLS	Flood Statement
FLW	River Flood Warning
ft	feet
GFDI	Interpolated version of the Geophysical Fluid Dynamics Laboratory model
GOES	Geostationary Operational Environmental Satellite
HAS	Hydrometeorological Analysis and Support
HCM	Hydrometeorological Coordination Message
HLS	Hurricane Local Statement
HLT	Hurricane Liaison Team
HPC	Hydrometeorological Prediction Center
HSA	Hydrologic Service Area
IFLOWS	Integrated Flood Observing and Warning System
kts	knots
km	kilometer
m	meter
MAR	Modernization and Restructuring
MARFC	Middle Atlantic River Forecast Center
mb	millibar
MIC	Meteorologist in Charge
MPC	Marine Prediction Center
mph	miles per hour
MRF	Medium-Range Forecast Model
msl	mean sea level
NAWAS	National Warning System

NCEP	National Centers for Environmental Prediction
NERFC	Northeast River Forecast Center
NEXRAD	Next Generation Weather Radar
NGM	Nested Grid Model
N.G.V.D.	National Geodetic Vertical Datum
NHC	National Hurricane Center
nm	nautical miles
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
OH	Office of Hydrology
OHRFC	Ohio River Forecast Center
OM	Office of Meteorology
QPF	Quantitative Precipitation Forecast
RFC	River Forecast Center
SERFC	Southeast River Forecast Center
SLOSH	Sea, Lake, and Overland Surge from Hurricanes
SOO	Science and Operations Officer
SPC	Storm Prediction Center
TPC	Tropical Prediction Center
UKMET	United Kingdom Meteorological Office
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
WCM	Warning Coordination Meteorologist
WSH	Weather Service Headquarters
WSR-88D	Weather Surveillance Radar-1988 Doppler

Acknowledgments

Each NWS field office and NWS Regional Office affected by Fran conducted a survey of the services they provided. Additionally, assessments were prepared by the National Centers that provided products and services related to Fran. The Office of Meteorology (OM) and Office of Hydrology (OH) then collated these reports into the final Service Assessment report. The individuals primarily responsible for the assessment are as follows.

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Executive Summary

Background

Fran was a category 3 hurricane on the Saffir-Simpson Hurricane Scale (see Appendix A) when it made landfall on the North Carolina coast near Cape Fear on September 5, 1996. Besides sustained winds of 115 miles per hour (mph), the storm surge and high water marks to nearly 13 feet in some coastal areas of North Carolina and Virginia exceeded those of Hurricane Hazel in 1954, although Hazel was a category 4 storm. Heavy rains created extensive inland flooding from the Carolinas into Virginia, West Virginia, and Pennsylvania. Additionally, strong inland winds created severe damage and power outages with hurricane-force wind gusts extending to near Raleigh, North Carolina. Hurricane Fran was directly responsible for 26 deaths.

Widespread 5- to 10-inch amounts of rain were recorded over the Middle Atlantic region with 14 to nearly 16 inches in parts of Virginia and West Virginia. The rains brought many rivers in North Carolina, Virginia, and central Pennsylvania to, or above, flood stage. Particularly hard hit were Virginia and North Carolina, where record or near-record river levels occurred at many gage sites.

Fran was the worst recorded natural *economic* disaster ever to occur in North Carolina. Nearly a half-million tourists and residents were evacuated from the coasts of North and South Carolina. Press reports from Reuters News Service stated that 4.5 million people in the Carolinas and Virginia were left without power.

Issues

Products and Services

The NWS field offices, TPC, and ERH performed extremely well and effectively. Hurricane warnings were posted for the hardest hit portions of the North Carolina coast 27 hours before landfall. Flash flood watches were issued with lead times from 24 to 36 hours. Lead times for river flood warnings ranged from 6 to 24 hours. There were a few flood warnings with negative lead times (i.e., issued after flooding began), mainly in headwater areas due to gage outages.

Communication/Coordination

Internal and external coordination worked well. Based on briefings from NWS offices in Wakefield, Blacksburg, and Sterling, Virginia, the Governor of Virginia declared a state of emergency by noon, September 5, before Fran even made landfall. Twice daily briefings were provided to the Federal Emergency Management Agency (FEMA) by the Hurricane Liaison

Team (HLT) up to and including landfall. Once Fran was over land, ERH provided daily briefings to FEMA concerning the impacts of the storm. The conference calls between ERH and FEMA did not include the HPC. The HPC felt that they had useful information regarding heavy rainfall potential which would have added value to these briefings.

Equipment

There remains a lack of sufficient land and marine real-time observations sites to adequately monitor and forecast storms, such as Fran. Also, the distribution of surface observing equipment varies widely among county warning areas. For example, NWSO Wilmington, North Carolina, has access to only four automated coastal observing sites along its 125-mile coastal area of responsibility. NWSO Morehead's area of responsibility is generally well covered by the Automated Surface Observing System (ASOS) sites, Data loggers, and the Device for Automatic Remote Data Collection (DARDC) wind equipment. Equipment outages were noted because of loss of power. For NWSO Wilmington, only one gage remained in operation. Amateur radio operators were used to gather information throughout the storm and proved to be a most reliable data-gathering source.

Within some river basins, budget cutbacks have forced the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (COE) to eliminate gaging stations thus adding to the difficulty of providing real-time data. This slow but steady erosion of stations has been particularly noticed in Pennsylvania where 10 sites have been eliminated since 1981 and West Virginia where 16 gages have been removed since 1981. An excellent working relationship though remains between these agencies and the NWS. Where in place, the Integrated Flood Observing and Warning System (IFLOWS) worked well with a few exceptions. In Pennsylvania, some IFLOWS data were lost due to communication problems, and the Automation of Field Operations and Services (AFOS) provided some but not complete backup capabilities. A COE centralized data collection office in North Carolina was affected by flooding, and data flow was sporadic for about a week. This emphasizes the need for robust backup procedures.

Although the Weather Surveillance Radar-1988 Doppler (WSR-88D) network performed well, precipitation estimates in mountainous terrain were off at times by a factor of three. Orographic effects can cause large variability in rainfall amounts, especially during tropical events. Not all offices switched their radars to the tropical Z/R relationship ("Z" represents radar reflectivity and "R" rainfall rate). While this caused some initial confusion between offices in their reporting of precipitation amounts, the hydrologic forecasting activities were not impacted because the River Forecast Center's (RFC) Stage III precipitation processing algorithms were able to account for the differences in Z/Rs used by each radar.

Summary of Findings and Recommendations

Finding 1: The media is a necessary component of the NWS watch/warning process but does not respond to NWS hydrologic forecasts unless a watch or warning is issued. This limited widespread dissemination of valuable river stage information to the public.

Recommendation 1: River flood watches should be issued when the forecast crest based on the Quantitative Precipitation Forecast (QPF) is expected to reach flood stage or above.

Finding 2: In order for Hydrologic Service Area (HSA) offices to have a better understanding of the forecast and observed precipitation data, RFCs need to provide composite data (QPF/Mean Areal Precipitation) to HSA offices.

Recommendation 2: Each RFC, through its HAS function, should provide Stage III radar/precipitation information and mean areal precipitation estimates on a routine basis (either hourly or three hourly). RFCs should also provide final QPF composites to HSAs.

Finding 3a: Due to evacuation of their building, the COE data from the Wilmington, North Carolina, District (dam water elevation and discharges) were not received during Fran and were sporadic for about a week after Fran.

Finding 3b: Some river and rainfall gages, primarily in Virginia, were unable to report due to power outages and communication systems failures.

Finding 3c: The failure of the IFLOWS microwave radio link interrupted transmission of the Pennsylvania data at the most crucial time. Hourly IFLOWS data were transmitted via AFOS. However, the entire data set was not received at all offices due to incompatibility of the AFOS network/IFLOWS backbone structure.

Recommendation 3: NWS offices should have complete backup procedures and systems in place to receive data when centralized reporting networks fail, such as what was experienced with the COE, or when IFLOWS or other automated river and rain gage networks falter.

Finding 4: Currently in the Eastern Region, NWSFOs are responsible for the QPF along with their long-fused watches, while HSA support is provided by both the NWSFO and NWSO. This split responsibility is awkward and makes coordination cumbersome for NWSOs that have HSA responsibility serviced by more than one NWSFO.

Recommendation 4: Transfer QPF and HSA responsibility to NWSOs concurrently.

Finding 5: The numerous video conferencing and teleconferencing calls involving the HLT, ERH, and FEMA generally went well. Once Fran made landfall though, the HPC was not involved nor informed of the timing of the briefings and therefore could not provide valuable QPF input to the coordination and planning process.

Recommendation 5: The National Centers for Environmental Prediction (NCEP) should be included in all conference calls, teleconferences, briefings, etc., when their particular specialization is warranted. WSH should work with NWS Regions and NCEP to ensure future briefings will involve all relevant NWS line offices.

Finding 6: Coastal flood warnings and forecasts could be improved with access to better ocean level data. There is a lack of real-time observations along the most critical east-facing beaches. For example, NWSO Wilmington, North Carolina, has access to only four automated coastal observing sites along its 125-mile coastal area of responsibility.

Recommendation 6: Efforts to properly equip coastal areas with real-time ocean level observations, for *both* land and marine areas, should be intensified. The NWS and the National Ocean Service (NOS) should collaborate to provide NWS operational access to NOS data and real-time graphing of data. The Chesapeake Bay and other Sea, Lake, and Overland Surge from Hurricanes (SLOSH) basins should be updated on a scheduled basis to maximize the model's output and subsequent NWS surge forecasts.

Finding 7: Many rivers in the affected areas had no gage points precluding the possibility of quantitative river forecasts. Additionally, Federal cutbacks have affected the USGS and COE, the primary supporters of river gages. Many river gaging stations have been eliminated over the past few years. If there is no gage, a specific river stage forecast cannot be issued. The use of categorical or a non-numeric forecast though would allow the forecast offices the ability to define the general magnitude of the flooding on ungaged rivers with wording, such as minor, moderate, or major.

Recommendation 7: Regional Headquarters should work with the appropriate RFCs to analyze the impact of the reduced gaging networks on hydrologic warning and forecast services and determine stream gage requirements to support adequate river forecasts. Once the requirements are defined, it should be determined what type of forecast service can be provided. If establishing a new forecast point is not possible, categorical forecasts should be investigated. Although no quantitative stage forecast can be made, some sense of the extent of flooding could be noted by use of the terms of minor, moderate, or major.

Finding 8: WSR-88D algorithms (Z/R relation) that converts radar reflectivity (Z) to precipitation estimates (R) in the eastern U.S. mountainous terrain during tropical events needs to be improved. During Fran, accuracy of precipitation estimates from mountainous areas ranged from near observed values to being in error by a factor of three. Gaged data was used qualitatively to calibrate WSR-88D data with some success.

Recommendation 8a: The Operational Support Facility and Eastern Region's Systems Operations Division should define optimum radar operations during these events.

Recommendation 8b: There is an urgent need to develop the operational gage data support system (Geostationary Operational Environmental Satellite [GOES] Data Distribution System).

Finding 9: In South Carolina, some user complaints were received regarding the application of the inland wind display model. These complaints largely resulted from the forecast of strong inland winds in the NHC forecast/ advisory product which did not reflect later observed surface conditions. The *forecast* track brought Fran further inland over South Carolina than what was observed. Since the inland wind display model is based upon the forecast track, it showed winds that were too strong given the actual track of Fran was farther east. Users need to be aware that the model wind forecast may differ from those observed winds if the forecast track is in error.

Recommendation 9: The NWS and FEMA should jointly fund and develop a distance learning module for emergency managers and NWS offices that explains the inland winds display model and how it should be used. In spite of the current limitations, the Office of Meteorology should encourage FEMA to distribute the latest hurricane inland wind display model to all emergency management jurisdictions under the threat of the impacts of hurricanes.

Finding 10: Hurricane Fran was a good reminder that extensive damage can be caused as a hurricane moves inland. Typically, participation in hurricane exercises has focused on coastal areas.

Recommendation 10: Regional Headquarters should expand these exercises to include inland areas.

Chapter 1

National Perspective

National Hurricane Center

Synoptic History

Hurricane Fran formed from a tropical wave that emerged from the west coast of Africa on August 22, 1996. Deep convection associated with the wave was organized in a banding-type pattern, and animation of satellite images suggested a cyclonic circulation. Ship reports soon confirmed a surface circulation. The post-analysis “best track” in Figure 1 shows that the system became a tropical depression just southeast of the Cape Verde Islands at 8 a.m. Eastern Daylight Time (EDT), August 23. Best track position, central pressure, and maximum 1-minute sustained wind speed are listed for every 6 hours in Appendix B, Table 1.

The tropical depression moved westward near 17 mph for the next few days without significant development. This lack of development may be attributed, in part, to disrupted low-level inflow due to the large and powerful Hurricane Edouard which was centered about 850 miles to the west-northwest. Satellite intensity estimates suggested that the depression became Tropical Storm Fran at 8 a.m. EDT, August 27, while located about 1,000 miles east of the Lesser Antilles.

Fran then began to track toward the west-northwest in the wake of Hurricane Edouard. Deep convection became more concentrated, and Fran was estimated to have reached hurricane status at 8 p.m. EDT, August 28, while centered about 450 miles east of the Leeward Islands. The center of Fran was about 175 miles to the northeast of the Leeward Islands near 8 a.m. EDT, August 30.

The tropical cyclone weakened to just below hurricane strength later on August 30, possibly due to the low-level inflow being disrupted again by Edouard. About this time, changing steering wind currents caused Fran to turn toward the northwest and slow to about 6 mph.

By 8 a.m. EDT, August 31, as Edouard moved farther away, Fran regained hurricane strength. As Hurricane Edouard moved northward off the U.S. Middle Atlantic coast, the subtropical ridge became better established to the north of Fran, causing Fran to resume a west-northwestward motion with an increased forward speed of about 11 mph. Fran moved on a track roughly parallel to the Bahama Islands with the eye remaining a little more than 115 miles to the northeast of the islands.

Fran strengthened to a category 3 hurricane by the time it was northeast of the central Bahamas on September 4. The powerful tropical cyclone began to be influenced by a cyclonic circulation

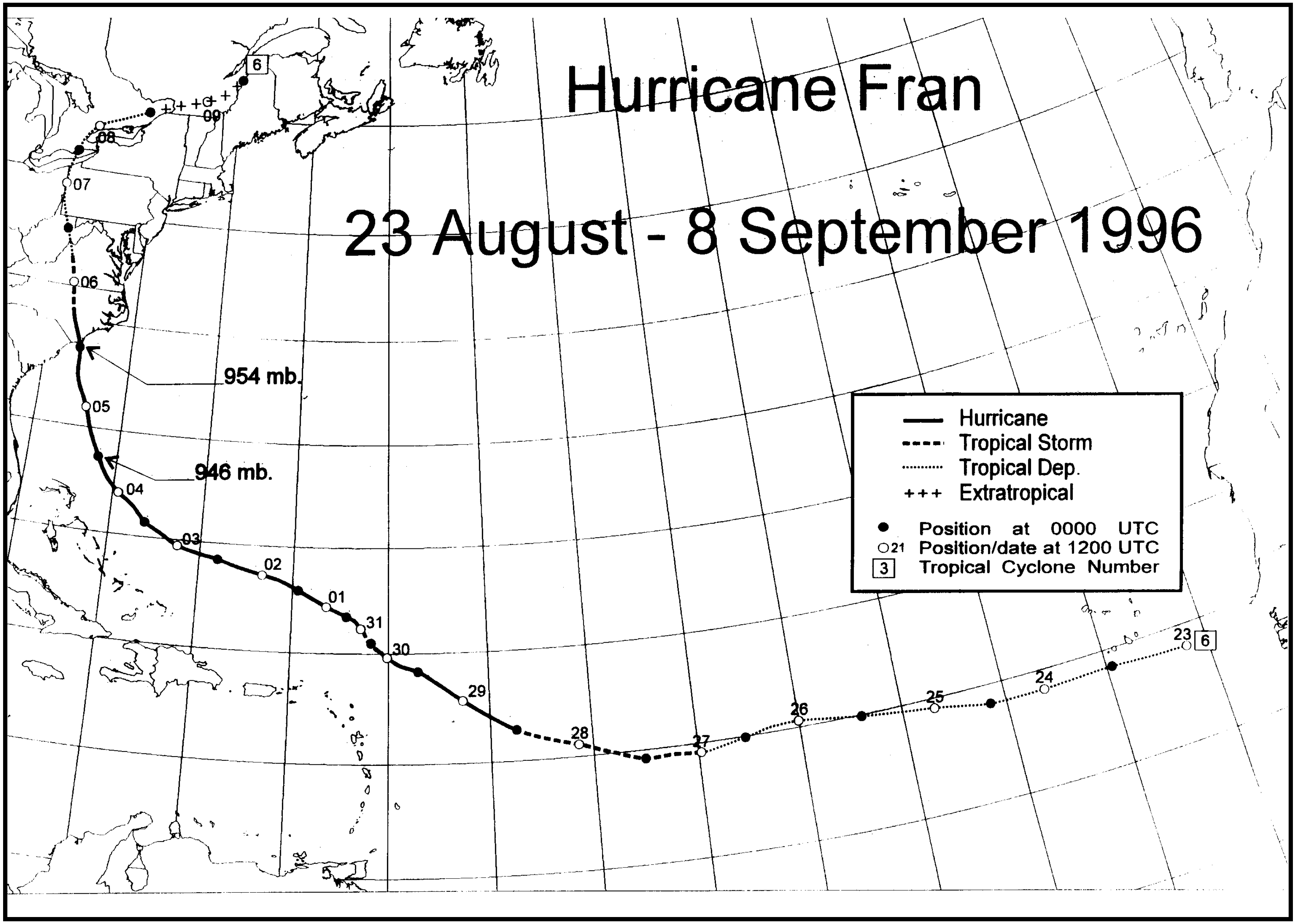


Figure 1: Best track positions for Hurricane Fran, August 23–September 8, 1996.

centered over Tennessee that was most pronounced in the middle to upper levels of the atmosphere. Fran was steered by the resulting flow around the low over Tennessee and the western extension of the subtropical ridge over the northwest Atlantic. The hurricane gradually turned toward the northwest to north-northwest and increased in forward speed.

The central pressure dropped to its lowest point of 946 millibars (mb) and maximum sustained surface winds reached 120 mph, Fran's peak intensity, near 8 p.m. EDT, September 4, when the hurricane was centered about 300 miles east of the Florida coast.

Fran was moving northward near 16 mph when it made landfall on the North Carolina coast. The center moved over the Cape Fear area around 8:30 p.m. EDT, September 5, but the circulation and radius of maximum winds were large and hurricane-force winds likely extended over much of the North Carolina coastal areas of Brunswick, New Hanover, Pender, Onslow, and Carteret Counties. At landfall, the minimum central pressure was estimated at 954 mb and the maximum sustained surface winds were estimated at 115 mph. The strongest winds likely occurred in streaks within the deep convective areas north and northeast of the center.

Fran weakened to a tropical storm while centered over central North Carolina and subsequently to a tropical depression while moving through Virginia. The tropical cyclone gradually lost its warm core as it moved over the eastern Great Lakes and became extratropical the evening of September 8, while centered over southern Ontario, Canada. The remnants of Fran were absorbed into a frontal system near 2 a.m. EDT, September 10.

Meteorological Statistics

Figures 2 and 3 show the evolution of Fran's central sea-level pressure and maximum 1-minute "surface" (33 feet above ground) wind speed, respectively, as a function of time. The observations on which the curves are based consist of aircraft reconnaissance data and Dvorak-technique estimates using satellite imagery as well as synoptic fixes after landfall.

All operational aircraft reconnaissance flights into Fran were provided by the U.S. Air Force Reserves. These "Hurricane Hunters" made 71 center fixes during 17 flights. The minimum central pressure reported by the aircraft was 946 mb at 7:06 p.m. EDT, September 4. A circular eye with a diameter of 29 miles was observed on the aircraft radar at this time. The 946 mb minimum pressure was measured by dropsonde. The maximum winds of 131 mph from a flight level of 700 mb (near 10,000 feet) were measured about 6 hours prior to the 946 mb pressure report. Flight-level winds in excess of 115 mph were reported several times during the two days prior to landfall. At 7:14 p.m. EDT, September 5, 130 mph winds were reported from aircraft 60 miles east of the hurricane center, and 123 mph winds were reported 47 miles northeast of the center at the time of landfall. However, the core of the hurricane weakened somewhat on radar presentations, and a closed eyewall was not reported by aircraft during the two hours prior to the center moving onshore.

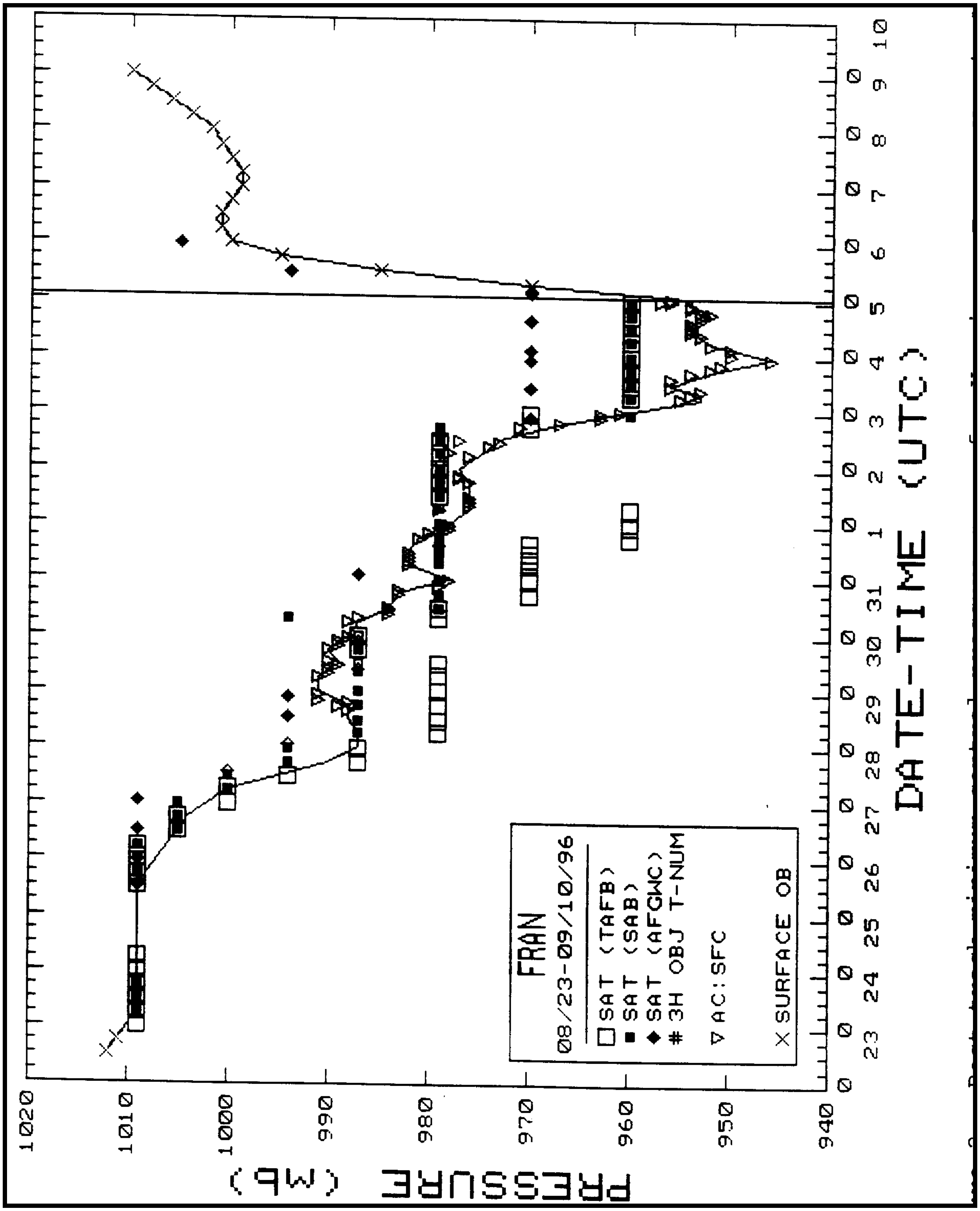


Figure 2: Best track minimum central pressure curve for Hurricane Fran. Vertical line denotes landfall. X's indicate estimates from surface analyses.

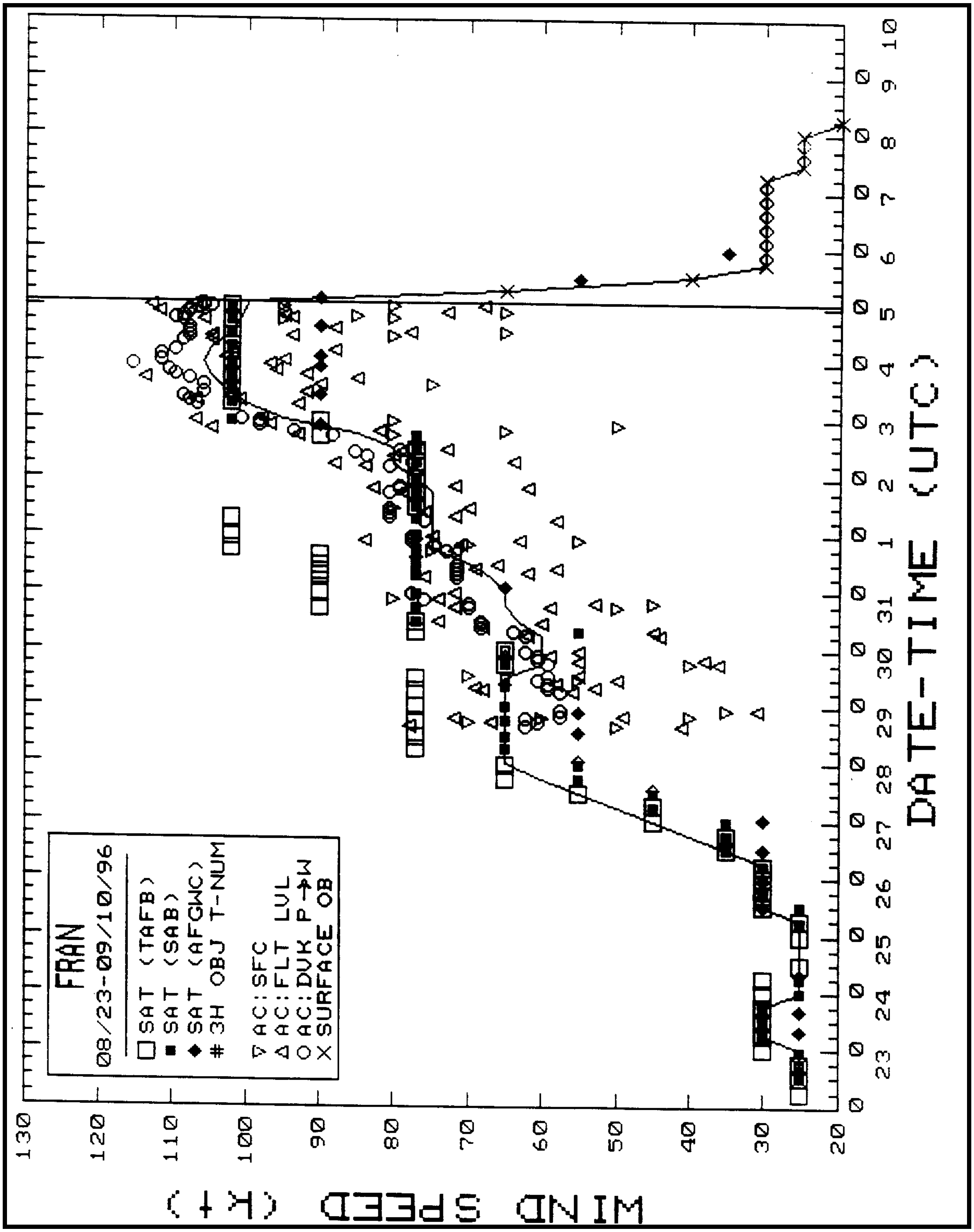


Figure 3: Best track maximum sustained wind speed curve for Hurricane Fran. Vertical line denotes landfall. Not all aircraft observations are a sampling of the maximum wind. X's indicate estimates from surface analyses.

The WSR-88D at Wilmington, North Carolina, measured winds in excess of 138 mph aloft as the inner convective bands approached the Cape Fear area at 5:30 p.m. EDT, September 5.

A ship with call sign **LAVX4** reported 98 mph winds and a pressure of 984 mb at 2 p.m. EDT, September 5, while located about 69 miles northeast of the hurricane center. Several other ship reports were helpful in defining the extent of tropical storm-force winds, as were reports from a network of drifting buoys deployed offshore of the Carolinas in advance of Fran. Appendix B, Table 2, lists ship reports of at least tropical storm-force winds in the vicinity of Fran.

Several wind gusts to hurricane force were measured from coastal areas in North Carolina. As usual for landfalling hurricanes, however, reports of sustained hurricane-force winds are difficult to find. Appendix B, Table 3, lists selected U.S. surface observations. The National Oceanic and Atmospheric Administration (NOAA) C-MAN station at Frying Pan Shoals (about 58 miles south-southeast of Wilmington, North Carolina) reported sustained winds of 91 mph and gusts to 124 mph from a tower about 145 feet above sea level.

Numerous pressure and wind reports from North Carolina were relayed to the NHC through amateur radio volunteers. The lowest measured pressure was 954 mb from Southport. The highest measured wind gust was 137 mph at an elevation of 30 feet (mounted on a house approximately 3 feet above the chimney) from a wind instrument located on Hewletts Creek in Wilmington, North Carolina. Gusts to 128 mph were measured in Long Beach, 125 mph in Wrightsville Beach, and 122 mph on Figure Eight Island. Although these measurements are very much desired to supplement the more official observations, they will not be listed in Table 3 unless their accuracy can be verified.

Survey results (Figure 4) show an extensive storm tide along the North Carolina coast primarily southwest of Cape Lookout. Storm tide is the actual sea level resulting from the astronomical tide combined with the storm surge. Still water mark elevations on the inside of buildings, indicative of the storm tide, range from 9 to 12 feet National Geodetic Vertical Datum (N.G.V.D.). Outside water marks on buildings or debris lines are higher due to the effect of breaking waves.

Warning and Forecast Critique

During Fran's life as a tropical storm or hurricane, the average official track forecast errors ranged from 76 miles at 24 hours (37 cases) to 158 miles at 48 hours (33 cases) to 213 miles at 72 hours (29 cases). These errors are at least 25 percent less than the previous 10-year averages of the official track errors.

The BAMD (deep-layer Beta and Advection Model) and the GFDI (interpolated version of the Geophysical Fluid Dynamics Laboratory model) provided the best guidance in terms of the lowest track forecast errors. The guidance from the GFDI model, which is generally acknowledged to be the most accurate one operationally available to the NHC, resulted in some left bias in the official forecasts near landfall (Figure 5). This tendency though was well within

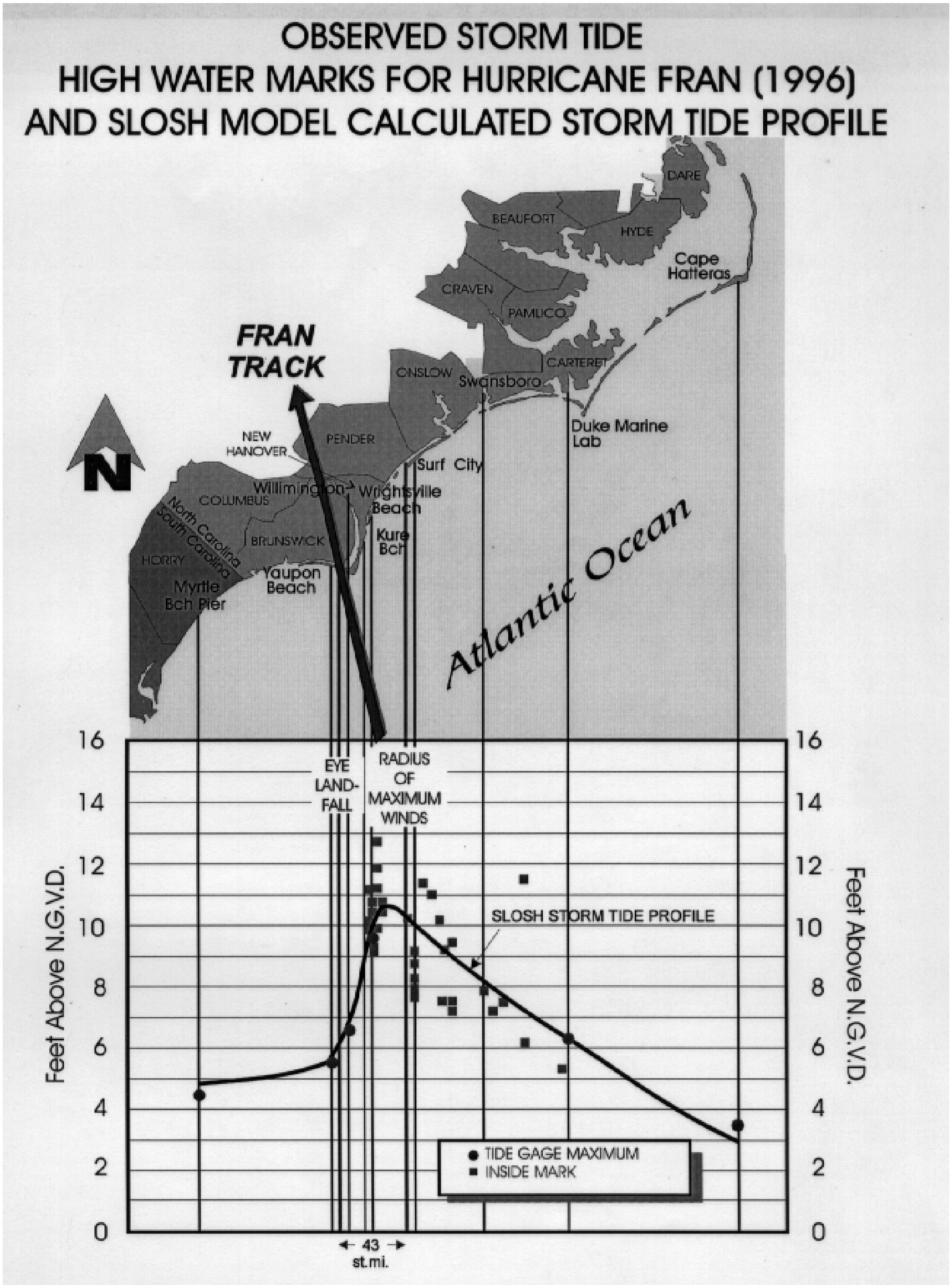


Figure 4: High Water Marks.

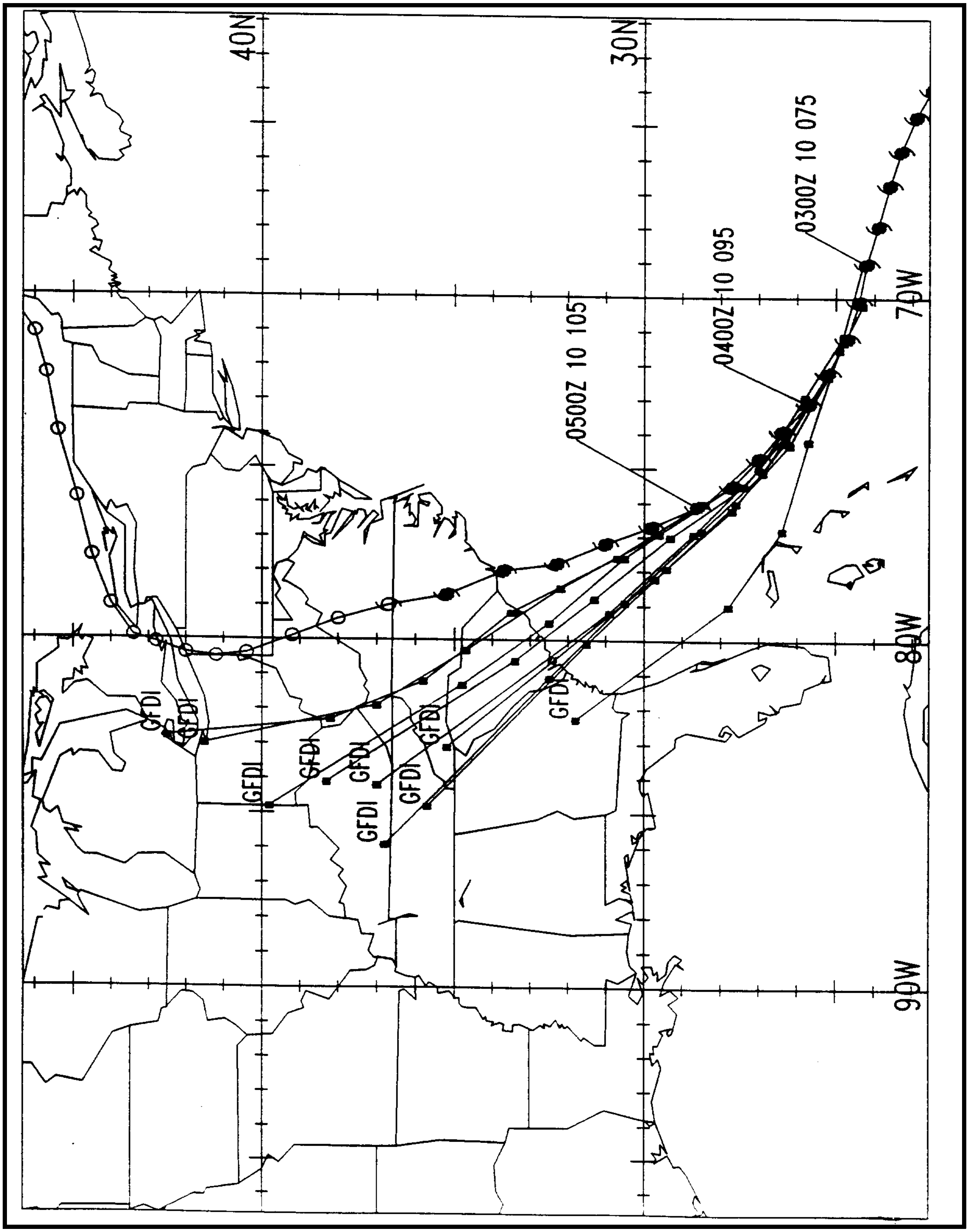


Figure 5: GFDI guidance on Hurricane Fran from 8 p.m. September 2 (0000 Coordinated Universal Time [UTC] September 3) to 8 p.m. September 4 (0000 UTC September 5), showing a left bias.

the model's normal performance range. The Geophysical Fluid Dynamics Laboratory, in a follow-up study, failed to find any systematic cause for the bias.

Most NHC intensity forecast errors were 20 mph or less. All but one intensity forecast made after 5 p.m. EDT, September 2, correctly indicated a landfalling category 3 hurricane.

Appendix B, Table 4, lists the various watches and warnings that were issued. Hurricane warnings were posted for the hardest hit portions of the North Carolina coast about 27 hours prior to landfall.

Internet hits on the TPC server were remarkably high. Peak demand was 737,880 hits during a 24-hour period on August 30. A total of 3,488,695 hits were tallied for the period August 27-September 3.

Hydrometeorological Prediction Center

Storm Track After Landfall

After making landfall along the southeastern North Carolina coast Thursday evening, September 5, Fran tracked north-northwest for approximately the next 24 to 30 hours and steadily weakened. The system began to slow and turn north along the Ohio-Pennsylvania border, and by early Sunday, the remnants of Fran were in southern Ontario, Canada.

A persistent middle- to upper-level low over the Tennessee and lower Mississippi Valleys and a strong subtropical high centered over the western Atlantic Ocean influenced Fran's motion prior to and during the first 24 hours after landfall. These features combined to produce a south to southeasterly flow at the middle and upper levels, drawing Fran inland. The subsequent slower movement Saturday and Sunday resulted from a ridge building directly north of the storm in response to an upper-level trough amplifying in the western Atlantic Ocean and a strong upper-level trough progressing through central Canada.

Meteorology of Heavy Rainfall

As Fran approached the North Carolina coast, deep easterly flow associated with the strong circulation around the storm brought copious tropical moisture and heavy rainfall to much of the North and South Carolina coasts by early Thursday afternoon, September 5. Heavy rains spread quickly north-northwestward across central North Carolina through the afternoon and evening hours of September 5. After making landfall, drier air suppressed organized convection south of the storm center. Widespread heavy rainfall continued north of the center and spread across much of central and south-central Virginia by early Friday morning, September 6. By 8 a.m. EDT, Friday, an area extending from northeastern South Carolina north to the central Virginia/North Carolina border had received 5 to near 9 inches of rain. In this area, the greatest amounts were found along and just inland from the North Carolina coast and farther north over Raleigh, where a 24-hour rainfall total of 8.8 inches was recorded. A strong upslope flow component into the Appalachian chain resulted in some isolated 5- to 7-inch rains over southern and central Virginia by Friday morning.

While Fran continued to weaken during Friday, tropical moisture still accompanying the system in concert with upslope flow north of the storm center led to excessive rains through the morning and early afternoon hours Friday across western Virginia. Widespread 6- to 10-inch amounts were recorded, with over 14 inches in Augusta and Page Counties in Virginia, while nearly 1 foot fell in nearby Nelson County. In 24 hours, Big Meadows in Page County, Virginia, received 15.61 inches of rain. Heavy rainfall also spread northward through eastern West Virginia, northern Virginia, western Maryland, and south-central Pennsylvania on Friday. Amounts in these regions generally ranged from 4 to 6 inches; however, isolated totals near 14 inches were found in favored upslope regions of eastern West Virginia, and 7-8 inch totals occurred over south-central Pennsylvania. A secondary rainfall maximum developed later Friday and continued into early Saturday morning, September 7, northwest of the storm track over eastern Ohio, with Cleveland reporting 4.3 inches of rain by 8 a.m. EDT, Saturday.

On Saturday, September 7, much of the organized rainfall associated with the remnants of Fran lifted northward into southern Ontario and diminished in intensity. Isolated heavy amounts from 2 to 3 inches were found across sections of eastern Michigan and along the Erie lakeshore of eastern Ohio, where up to 6 inches fell near Cleveland. Precipitation in both regions may have been enhanced by added moisture from Lakes Huron and Erie. Another maximum of rainfall was found over Rhode Island and eastern Massachusetts where the interaction between a southerly flow of Atlantic moisture and a stationary front just to the south of the region produced an extended period of steady rains Saturday afternoon into Sunday morning, September 8, with up to 3.5 inches falling over southeastern Massachusetts. Figure 6 shows the total rainfall amounts from September 5-8 associated with Fran.

The heavy precipitation amounts associated with Fran led to numerous flood and flash flood warnings from South Carolina northward through the eastern Great Lakes from September 5-8. Additionally, the rains brought many rivers in North Carolina, Virginia, and central Pennsylvania to or above flood stage. Particularly hard hit were Virginia and North Carolina, where record or near record river levels occurred at many gage sites. However, these record river rises were not attributable to Fran alone. In western and central Virginia, significant rains had fallen for two days prior to Fran's landfall. The aforementioned middle- to upper-level low over the Tennessee Valley combined with a high pressure ridge that had developed in the wake of Hurricane Edouard to produce a deep-layered southeasterly flow of Atlantic moisture directly into the central Appalachians. Rainfall amounts of 3 to 6 inches were common across much of central and western Virginia and north-central North Carolina Tuesday and Wednesday, September 3 and 4, with upwards of 10 inches of rain falling across favored upslope regions in south-central Virginia. The additional 6- to 10-inch rains from Fran on Thursday and Friday (which brought totals to more than 20 inches across some sections of central and western Virginia) over already saturated soil led to the major surface runoff problems and subsequent record river and stream flooding in Virginia and North Carolina.

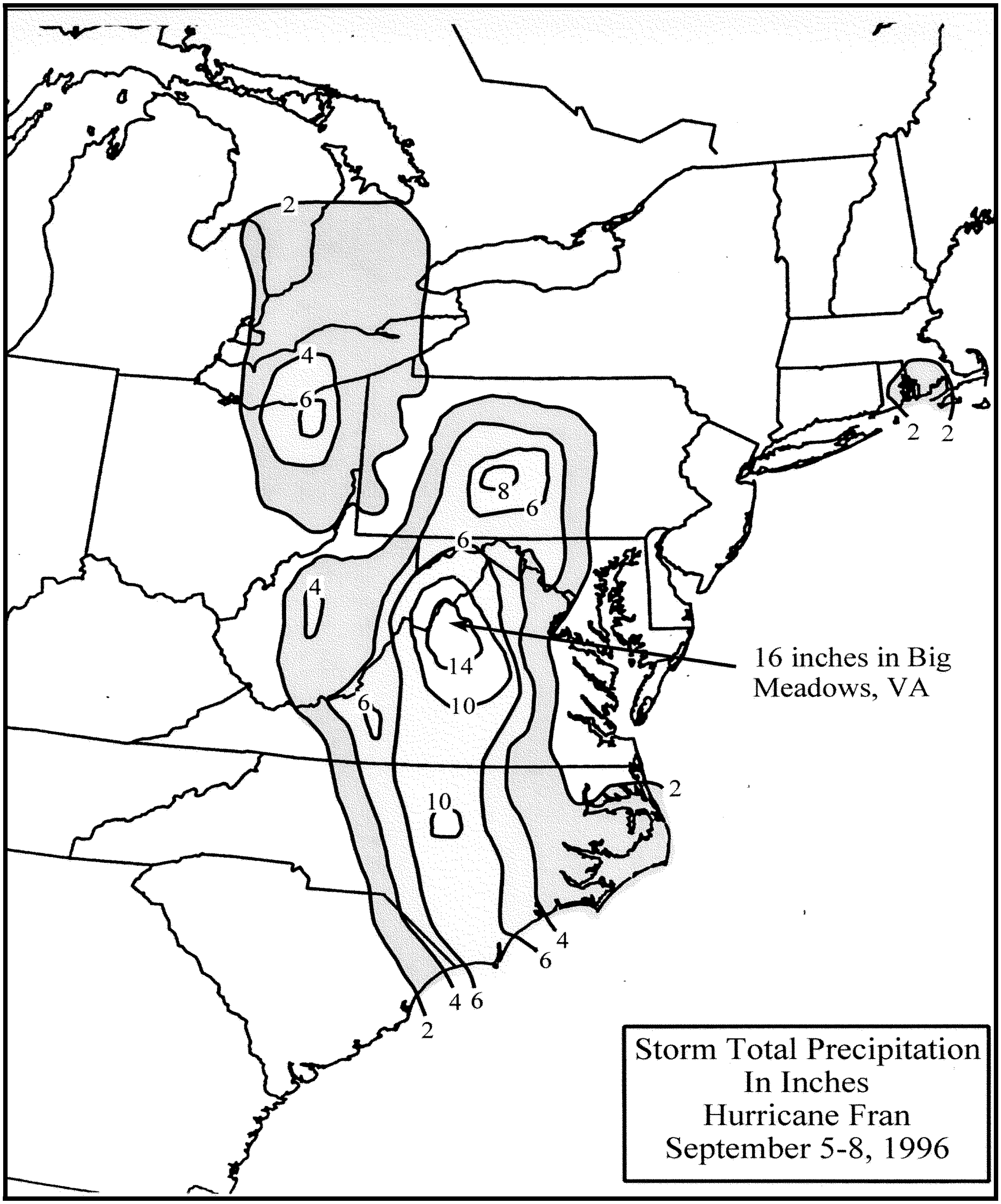


Figure 6: Storm Total Precipitation in Inches. Hurricane Fran, September 5–8, 1996.

Guidance Products

As early as three days before landfall, the HPC's medium-range forecasters recognized Fran's potential to bring flooding rains to the Middle Atlantic region. From the extended forecast discussion dated Tuesday, September 3:

> *"Heavy rains are expected in North Carolina and the southern Middle Atlantic region. There may be flooding along the east slopes of the southern and central Appalachians."*

Output from the NCEP Medium-Range Forecast Model (MRF), the European Center for Medium-Range Weather Forecasting (ECMWF), and the United Kingdom Meteorological Office (UKMET) provided the primary medium-range guidance to HPC forecasters. Overall, the ECMWF was superior to both the MRF and UKMET for all 3-5 day forecasts verifying September 5-8. It was the only model that lifted Fran northward through the Middle Atlantic states, albeit too slowly. None of the UKMET model forecasts succeeded in bringing Fran onshore, while the MRF consistently advanced the system too slowly and forecasted landfall along the Georgia and South Carolina coasts, which was considerably south of the observed landfall.

After September 3, forecast responsibility shifted from the medium-range to the short-range (12- to 48-hour) forecasters in HPC. From September 4-8, the QPFs and excessive rainfall outlooks were prepared utilizing Eta Model, Nested Grid Model (NGM), and Aviation (AVN) Model guidance. These models significantly underforecast rainfall amounts along the track of the system, a typical bias for tropical systems, and failed to draw the deep tropical moisture far enough northward. Also underforecast was the very heavy rain that fell along the eastern slopes of the Appalachians on September 6-7, as the models had difficulty simulating the intensity of the vertical motions induced by the higher terrain. Manual QPFs consistently improved upon model forecast guidance, pinpointing more accurately both rainfall coverage and amounts.

For the 24-hour period ending 8 a.m. EDT, September 6, the Eta's guidance was superior to that from the NGM and AVN (Figure 7). It correctly forecast the location of the axis of heaviest precipitation and accurately predicted the maximum rainfall along the North Carolina coast. The NGM showed little consistency from model run to model run with its track guidance and subsequent QPFs. The NGM, initialized at 8 a.m. EDT, September 4, moved the system too quickly inland and tracked it too far westward, resulting in a poorly forecast precipitation axis and significantly underpredicted rainfall amounts (not shown). The later model run, initialized at 8 p.m. EDT, September 4, moved the storm and its associated QPFs (shown in Figure 7) too far to the east. The AVN guidance was the worst of the three models. It tracked Fran too slowly and too far to the south, severely degrading its precipitation forecasts. QPFs prepared by the HPC represented a significant improvement over the model forecasts as shown in Figure 7. Like the Eta, manual forecast products successfully predicted both the location of the heavy precipitation

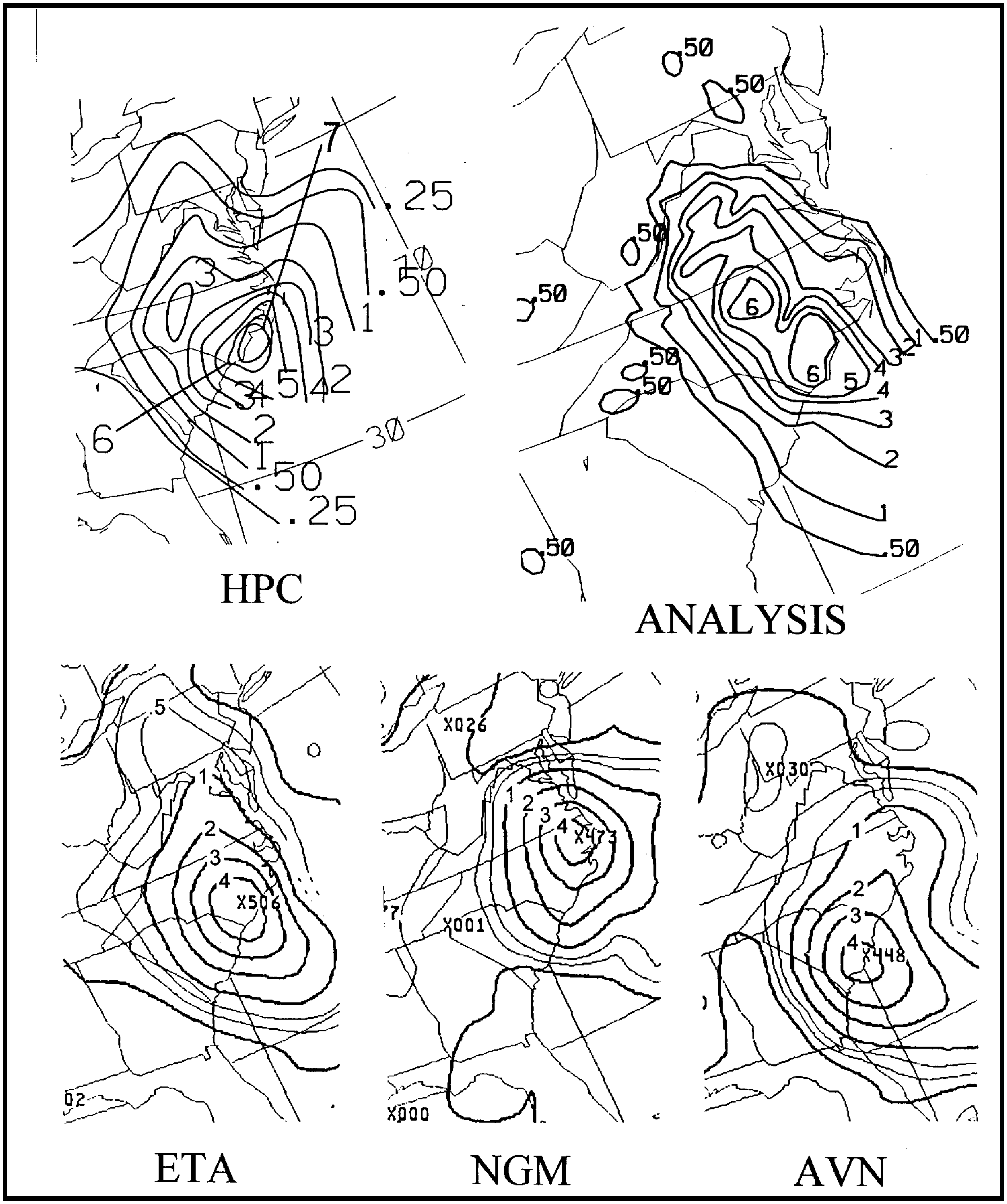


Figure 7: 24-hour QPFs and verifying analysis for the period 8 a.m. (1200 UTC) September 5 to 8 a.m. (1200 UTC) September 6, 1996.

axis and the coastal North Carolina rainfall maximum, and they correctly increased model-forecast rainfall totals along the coast. Additionally, the secondary precipitation maximum along the east slopes of the central Appalachians, absent in the models, was well depicted in the manual QPFs. Narrative discussions accompanying the graphical QPFs described the excessive rain expected along the coast and the flooding potential over the Appalachians. From a discussion dated September 4:

> *"Some 8-9 inch amounts possible vicinity of the North Carolina/South Carolina coasts"* and *"With recent heavy rains (in the central Appalachians)...situation will become serious in terms of flooding/flash flooding in upslope regions."*

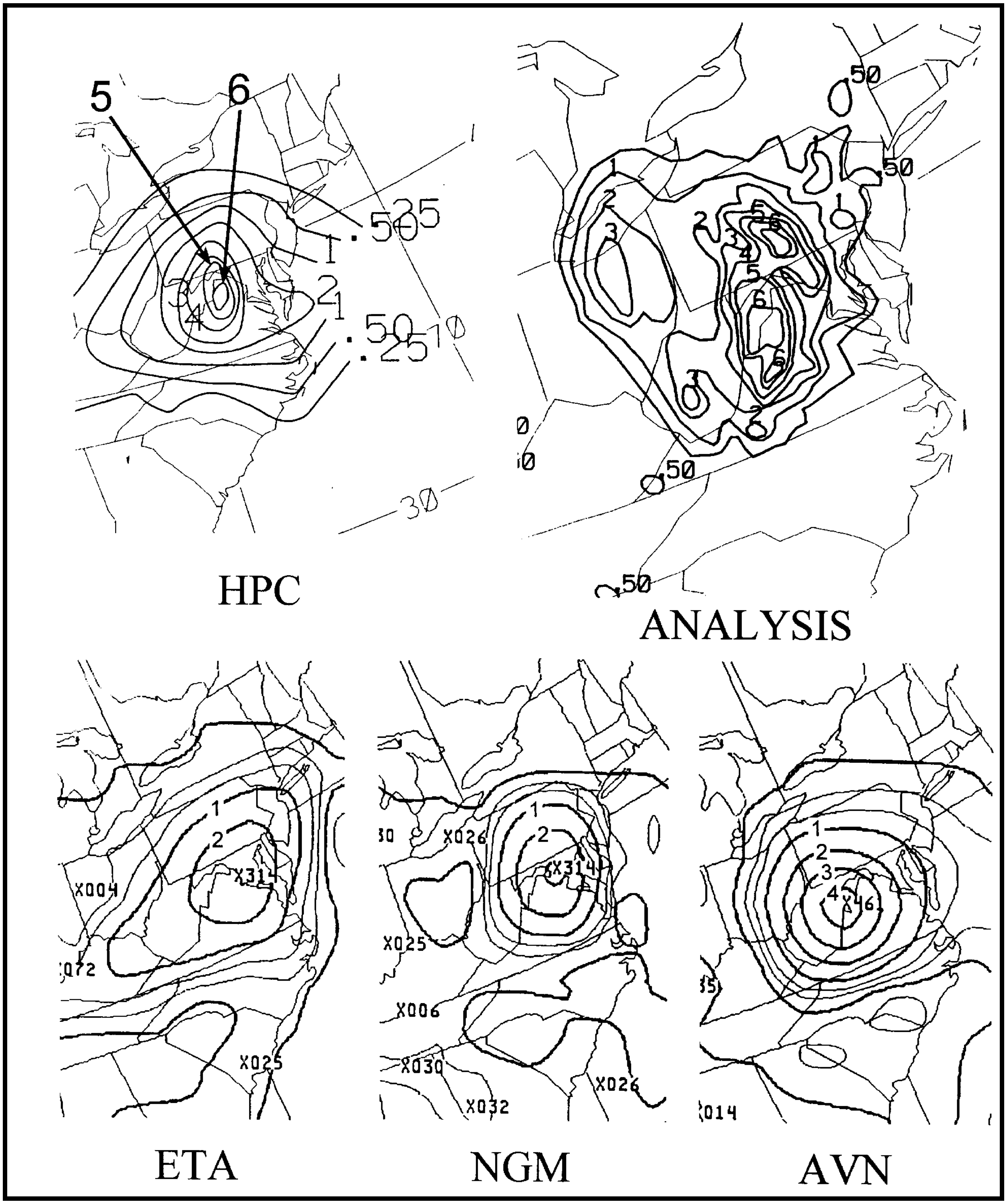
Both model and manual forecasts, however, underpredicted the northward extent of the heavy rains.

During the following 24 hours, ending at 8 a.m. EDT, September 7, agreement between the model forecast tracks and the QPFs increased. Except for the 8 a.m. EDT AVN run from September 5, all models predicted the location of the heaviest rain in northwestern Virginia within 100-150 kilometers (km). They, however, underpredicted the amounts. HPC forecasters correctly recognized the heavy rain potential due to the strong upslope flow in western Virginia, Maryland, and eastern West Virginia and substantially increased model QPFs. Model and manual forecasts are shown in Figure 8. The flooding potential and rainfall totals in this region were consistently highlighted in HPC's excessive rainfall outlooks and QPF discussions. From a discussion issued on September 5:

> *"Rainfall amounts over portions of western Virginia could exceed 10 inches."*
> *"This is a dangerous situation with widespread flooding expected over the Mid-Atlantic states."*

Similar to the previous day, both model and manual forecasts failed to lift heavy rains far enough northward, missing the precipitation maxima in Pennsylvania and northeastern Ohio.

For the 24 hours ending at 8 a.m. EDT, September 8, the NGM and AVN guidance correctly lifted the bulk of Fran's precipitation northward into Canada. These models failed, however, to wrap moisture far enough west of the storm center, significantly underpredicting the heavy precipitation totals in northeastern Ohio and eastern Michigan. The Eta, on the other hand, while too slow in moving Fran and its associated rains into Canada, was successful in drawing the tropical moisture farther west. Manual prognoses made some improvement to model guidance. Like the NGM and AVN, HPC forecasts brought the heaviest rain into Canada but recognized these models were deficient with the westward extent of precipitation. All models and manual forecasts underpredicted the rainfall amounts in Rhode Island and eastern Massachusetts.



HPC

ANALYSIS

ETA

NGM

AVN

Figure 8: 24-hour QPFs and verifying analysis for the period 8 a.m. (1200 UTC) September 6 to 8 a.m. (1200 UTC) September 7, 1996.

Coordination

Coordination between HPC and NHC was excellent. The HPC participated in four conference calls per day with NHC, forecast offices along the East Coast, Eastern Region Headquarters, and Navy facilities in Norfolk and Jacksonville, where model differences and the forecast track were discussed. Also, one call per day took place between HPC's medium-range forecaster, NHC, and Navy personnel, discussing the storm's track beyond 72 hours. As Fran approached the coast, several discussions occurred between NHC, HPC, and the SPC, involving QPFs and severe storm potential.

Additionally, HPC participated in a conference call with FEMA and various other agencies on September 5, the day Fran made landfall. HPC forecasters discussed QPFs and pinpointed areas likely to receive significant flooding as the storm moved over land. After this call, FEMA said that HPC's input was greatly appreciated and requested HPC participation in the next call, scheduled for the morning of September 6. Problems existed with this call, however. FEMA and ERH coordinated about QPFs and flooding potential without asking for HPC's input. Additional conference calls were scheduled during September 6 and 7; however, again HPC's input was not requested.

The transition of responsibility from NHC to HPC went quite smoothly as Fran was downgraded to a tropical depression at 5 p.m. EDT, September 6. The first storm summary was issued at 7:30 p.m. EDT, September 6, and two more storm summaries followed during the succeeding 12 hours. These summaries described Fran's position, strength, movement, and forecast positions and included current watches and warnings relating to the heavy rains and high winds, up-to-date rainfall totals, and a complete list of rivers experiencing or expecting major flooding. Storm summaries were discontinued as the remnants of Fran moved into Canada.

Chapter 2

Eastern Region Perspective

Overview

Fran made landfall as a category 3 hurricane, resulting in significant storm surge flooding on the North Carolina coast, widespread wind damage over North Carolina and Virginia, and extensive river and flash flooding and, in a few cases, record river flooding from the Carolinas to Pennsylvania.

Hurricane Fran was the second hurricane to make landfall on the North Carolina coast during the 1996 hurricane season; category 2 Hurricane Bertha was the first. The last time two or more hurricanes made landfall in North Carolina during the same hurricane season was in 1955 when Hurricanes Connie, Diane, and Ione severely affected the state. Fran was the worst recorded natural *economic* disaster ever to occur in North Carolina.

In some coastal areas of North Carolina and Virginia, the storm surge and high water marks exceeded those of Hurricane Hazel in 1954, which until Fran, had been considered the benchmark hurricane for these localities. The hardest hit areas in Fran's path were coastal South Carolina, the eastern third of North Carolina, Virginia, and the eastern panhandle of West Virginia.

The American Insurance Association estimates that $1.6 billion of insured property losses occurred during Fran with $20 million in South Carolina, $1.275 billion in North Carolina, $175 million in Virginia, $50 million in Maryland, $20 million in West Virginia, $40 million in Pennsylvania, and $20 million in Ohio. Claims represent **insured** losses resulting from factors other than tidal inundation. A conservative ratio between total damage and insured property damage, compared to past landfalling hurricanes, is two to one. Therefore, the total U.S. damages estimate is $3.2 billion.

Considering the magnitude of the event, it was fortunate that only 26 deaths occurred. This number could have been higher was it not for the significant lead time and accuracy of NWS products. Appendix C summarizes reported fatalities.

State by State Summary

- ***South Carolina***

In South Carolina, the impact from Fran was greatest near the North Carolina border in the eastern part of the state. Uninsured revenue losses due to evacuations of tourists and residents was estimated at $15 million. There was also a significant amount of crop loss.

- ***North Carolina***

The effects of Fran on North Carolina were extensive and noticed well inland. The highest wind gust was 137 mph, as noted earlier, in Wilmington. Some 125 miles north in Raleigh, winds gusted to hurricane force. The strong inland winds coupled with saturated ground resulted in several hundred thousand trees being uprooted or broken. This resulted in thousands of homes being damaged by the falling trees.

It took more than 10 days for power to be restored in many areas. Schools were closed for a week in the hardest hit counties. Automobile travel was almost impossible the day after the storm due to downed trees and flooding. A full 12 days after the event, 150 secondary roads were still closed.

The storm surge on North Topsail beach cut a 100-foot wide inlet through the middle of the barrier island. On Topsail Island, up to 40 feet of beach was eroded and this lead to most of the first row of houses closest to the shore being destroyed. North Carolina State Route 1568 was washed out and highway NC210 was covered with sand. The storm surge in Swansboro was measured at 10 feet. Several businesses along the waterfront were demolished and water covered Main Street where a storm surge approaching 9 feet flooded portions of the towns of Washington and Belhaven. The storm surge in Washington was the highest since the September 3, 1913, unnamed hurricane. New Bern had a storm surge of 10 feet along the Neuse River. In northeast North Carolina, storm surge flooding posed considerable problems in Elizabeth City and Edenton along the northern Albemarle Sound, where a storm surge of 4 to 6 feet occurred.

Damage in North Topsail Beach and Carteret County alone exceeded $500 million as 6,688 structures were destroyed or damaged with approximately 90 percent of the homes in North Topsail Beach sustaining some damage from the combined impact of storm surge and wind. In Carteret County, Emerald Isle reported 67 homes destroyed and 409 with major damage. Thirty-three mobile homes were destroyed. The Emerald Isle fishing pier was destroyed, and the Bogue Sound Pier lost 150 feet. Erosion along the dunes ranged from 5 to 20 feet.

Twelve river forecast points exceeded flood stages, with four points cresting at record flood stages and three others close to record flood. Rainfall amounts totaled from 5 to 10 inches.

■ *Virginia*

Virginia was outside the area of Fran's greatest coastal impact, however, wind-related tree and power line damage and flooding was significant. On September 6, the Virginia Power and Electric Company reported 415,000 customers were without power. This represents the largest power outage in the company's history.

In Tappahannock, which is on the Rappahannock River, a storm surge of more than 5 feet caused considerable damage to boats, wharfs, docks, and bulkheads. Longtime residents reported that the water had not been this high since Hurricane Hazel in 1954. Further north in the Delmarva region, storm surge flooding was minor to moderate.

Tidal flooding was also a problem in the Chesapeake Bay area. Further upstream on the Potomac River, the Old Town section of the City of Alexandria saw extensive tidal flooding as the water continued to rise into Friday afternoon, September 6. Water was 5 feet deep in the lower portion of the city and many shops were flooded. National Airport in southern Arlington County also had damage due to the cresting of the Potomac River late on September 7 into the morning of September 8.

In northern and western Virginia, rainfall of 8 to almost 16 inches fell over much of the mountains and the Shenandoah Valley. All rivers in central Virginia experienced major flooding. Record-level flooding occurred on the Dan River at South Boston and on the North and South Forks of the Shenandoah River at Lynnwood, Strasburg, and Cootes Store. During the height of the storm, 78 primary roads and 853 secondary roads were closed due to flooding and downed trees. Shenandoah National Park closed and was not opened to vehicle traffic until near the end of September.

Evacuations began on Friday afternoon, September 6. In portions of north-central Virginia, hundreds of people were reported stranded with nearly 300 homes destroyed by flooding and more than 225 sustaining major damage. In Virginia alone, some 100 people were rescued from Fran's flood waters. Access to isolated communities continued to be a problem for several weeks due to washed out bridges and roads. Thirteen counties in western and northern Virginia reported damages greater than $1 million. Estimated damages to state roads were $37 million.

■ *Maryland*

Fran’s impact on Maryland was through flash flooding, high winds, and tidal flooding. Central and western Maryland were the hardest hit by significant flash flooding. Allegheny County reported 500 homes suffered damage, about a dozen homes were destroyed, and another dozen sustained major damage.

River and tidal flooding also caused extensive damage in Maryland. About 150 homes were damaged on the Chesapeake Bay from Baltimore south to Point Lookout, with roads and piers washed away in Charles County and severe flooding in downtown Annapolis. Along portions of the Chesapeake Bay, some counties indicated this was the worst tidal flood since Hurricane Hazel in 1954.

River flooding along the Potomac Basin in Maryland also caused damage from Hancock to Point of Rocks. Flood damage was similar to the January 1996 flood and estimated at $1.4 million to public property (does not include insured or private losses).

■ *Washington, D.C.*

In the Nation's Capital, tidal flooding closed roads around the Tidal Basin. Businesses in the Georgetown section of the city witnessed flooding similar to that of January 1996. Due to early NWS warnings and forecasts, the residents and businesses had a few days to prepare and this reduced property damage. Flash flooding also resulted in road closures. The Anacostia River (which is ungaged) caused flooding problems for the Navy Yard area. With the river not cresting until very early Monday morning, September 9, many main roads into the District of Columbia remained closed through rush hour, causing a commuter nightmare through much of the day. Constitution and Independence Avenues were closed through the heart of the city.

Local officials and the public were prepared for this flood, especially having experienced the January 1996 flood. Volunteers sandbagged around historic buildings in the National Capitol Park area and dismantled wooden bridges that were rebuilt after the January flood. In spite of these efforts, $20 million in damage occurred to the park alone.

■ *West Virginia*

Heavy rains and flooding caused most of the damage in West Virginia. Hardest hit were Pendleton and Hardy Counties where up to 14 inches of rain was reported. Substantial flooding occurred along the South Branch of the Potomac River with lesser flooding along the North Branch.

The agricultural community endured the worst damage. Additionally, hundreds of low bridges and culverts were swept away, and many state roads and bridges were damaged. There were evacuations throughout the eastern Panhandle. Several loose propane tanks posed another serious hazard, in addition to a gas leak in Hardy County. Many water plants were left inoperable through the end of September.

■ *Pennsylvania*

Flash flooding was the main impact of Fran in Pennsylvania with significant flash flooding confirmed across 15 counties. Rainfall from Fran ranged from around 1 inch in north-central Pennsylvania to more than 6 inches in the south-central areas. One report of 9.8 inches was received from a cooperative observer near Newville in Cumberland County. There was also river flooding on the Juniata River in the Susquehanna River Basin.

■ ***Ohio***

By Friday night, September 6, and into Saturday morning, September 7, Fran moved north-northwest into western Pennsylvania and extreme eastern Ohio. There was neither flash flooding nor river flooding in Ohio mainly due to the dry antecedent conditions in the area. Although the remnants of Fran dumped up to 6 inches of rain over northeast Ohio, the damage was confined mainly to localized street and small stream flooding.

As Fran weakened and moved north, river flooding along Fran's track lessened as the storm pushed into western Pennsylvania and eastern Ohio. By the afternoon of September 7, Fran was centered just southeast of Erie, Pennsylvania, and was increasing its forward speed as the flood-producing rainfall continued to lessen.

Warning and Forecast Services

Timely hurricane watches and warnings were posted by the NHC. One of the "benefits" of having gone through the North Carolina "Bertha experience" during the previous month was an overall smoother operation in the areas of Fran's greatest impact.

Early forecasts targeted the Charleston, South Carolina, area. Subsequent NHC forecasts edged the point of landfall up the coast. Needless to say, the NHC track forecasts had a great impact on evacuation decisions made by local emergency managers. The track forecast errors, while well within the standard average for tropical cyclones, nevertheless, did pose some difficulties.

The updated SLOSH model did quite well for the western Pamlico Sound, North Carolina, predicting a maximum storm surge of 9 to 12 feet at New Bern and Washington, North Carolina. This information was incorporated in the Hurricane Local Statements (HLSs) issued by NWSO Morehead City, North Carolina.

Considering the magnitude of the event, deaths which were directly attributed to the hurricane would have likely been much higher were it not for the significant lead time and accuracy of products from NWS local field offices. For example, NWSFO Raleigh's timely "call to action" issuances (short-term forecasts, local statements, and forecasts) included the strongest wording possible regarding the danger of inland hurricane-force winds and flood-producing rains. Similarly, the local products prepared by NWSOs Morehead City and Wilmington, North Carolina, included strongly worded statements which emphasized the impending danger of coastal flooding and hurricane-force winds.

NWS offices in areas affected by flash flooding and river flooding did an excellent job forecasting and preparing the public and emergency management community on what to expect from the storm well before the event. This “call to action” was consistent in its message and helped to reduce the loss of life and property damage.

Throughout the affected HSAs, NWSFOs issued flash flood watches with lead times from 24 to 36 hours before flooding began. A full 24 hours before flooding began in Virginia, NWSFO Sterling issued an updated flood watch with strongly worded information, specifically stating:

> *"Even heavier rains are likely later tonight and Friday as the remnants of Hurricane Fran approach the region. This may result in catastrophic flooding in some locations . . . particularly over the Piedmont and mountains of West Virginia."*

The QPF played a critical role in helping to provide long lead times for forecasts of flash flooding and river flooding by focusing attention on the potential for large amounts of rain and by forecasting record/near record river levels.

Initial QPF identified the potential for river flooding especially targeting the Shenandoah and the Potomac basins. The QPF was updated as the event approached and provided increased lead times for the flood stage forecasts. Lead time for most river flood warnings issued by HSAs ranged from 6 to 24 hours. There were a few warnings with negative lead times (i.e., warnings issued after the flooding began), mainly in headwater areas due to gage outages. This issue could be resolved by issuing flood/flash flood warnings based on QPF and WSR-88D precipitation estimates. However, observed rainfall data is necessary to make the warning process more accurate. Noteworthy was the forecast for the flood crests on the main stem of the Potomac River. The forecast provided more than 12 hours lead time before flood stage was first observed and 38 to 50 hours lead time prior to flood crest. These lead times were so effective that people in Point of Rocks, Maryland, had time to rent trucks and trailers to remove all of their belongings from the flood plain.

In the NWSFO Sterling, Virginia; NWSO Wakefield, Virginia; and NWSFO Raleigh, North Carolina, HSAs, there was flooding in all major river basins. Record flood crests were set at four locations in the Raleigh HSA and at three points in the Sterling HSA. Appendix D lists the initial public issuances of NWS products by hydrologic product category.

Internal and External Coordination

Internal (NWS) and external coordination was excellent with only a few exceptions. For the second time during the 1996 hurricane season, timely notification to Federal, state, county, and local agencies was initiated by local NWS offices well before a hurricane's landfall. Effective response was partially due to the heightened awareness since Hurricane Bertha's passage but mostly due to the long lead time of NWS products. Since 1996 was extremely wet in much of the area affected by Fran, there was also a heightened awareness of the dangerous impact of flooding.

Extensive coordination took place between NWSFOs, NWSOs, RFCs, NCEP, and state emergency management. For example, based on briefings from NWS offices in Wakefield, Roanoke, and Sterling, Virginia, the Governor of Virginia declared a state of emergency by noon, September 5, before Fran even made landfall. The Governor of Virginia brought the State

Emergency Operations Plan into effect, bringing state agency representatives to the state Emergency Operations Center (EOC) and notifying the National Guard. The NWS conference calls with the state highlighted that 5 to 8 inches of rainfall was expected in western Virginia with local amounts in the mountains over 12 inches. Major flash flooding and river flooding would result. These briefings helped in the decision for significant evacuations.

Other states also took an active role in coordinating with NWS offices. For example, in North Carolina, regional emergency managers made sure that NWSO Wakefield, Virginia, was included in all hurricane conference calls. This was a problem during Hurricane Bertha and has since been corrected. As a result, coordination between NWSO Wakefield and local emergency managers went very smoothly and was highly productive.

NWS modernized hydrologic operations in Eastern Region were well coordinated and efficient. Coordination from the field offices and national centers allowed the RFCs involved in the event to be ready to handle the flood threat with extensive lead time. Due to advanced coordination, 24-hour staffing was arranged at Southeast RFC (SERFC), Middle Atlantic RFC (MARFC), Ohio River RFC (OHRFC) and the Northeast RFC (NERFC) before the event took place.

The RFCs involved in the event all participated in extensive coordination. The HAS function at the RFCs coordinated the use of the WSR-88D tropical Z/R relationship with the HSAs involved in the forecast effort. Many Hydrometeorological Coordination Messages (HCMs) from the RFCs were used to effectively discuss QPF estimates, Stage III precipitation analyses, and contingency river forecasts.

The RFCs also had conference and coordination calls between both NWS offices and external Federal agencies, including the COE. Over 60 coordination calls were made between the SERFC/MARFC and NWSFO Sterling. Coordination also occurred between HSAs/RFCs and NHC. SERFC/MARFC coordinated 6 hourly QPF updates throughout the event. MARFC also provided QPF contingency forecasts. Frequent coordination between the Virginia and North Carolina HSAs resulted in consistent forecasts. This coordination ensured that all HSAs agreed on storm movement and expected rainfall and river response.

Coordination between all HSAs and emergency management agencies began early and continued throughout the event. The media provided good coverage of what was expected, warnings and watches in effect, and what was happening during the storm. Telephone interviews with the media occurred throughout the event, and many briefings were made to state EOCs.

ERH also provided daily briefings twice a day to FEMA Region II concerning the impacts of Fran. These briefings were done from September 6-9 in the morning and in the late afternoon. The information from these briefings was used by FEMA to plan hazard mitigation efforts in affected areas. ERH briefed FEMA on current damages and forecasted impacts. The Hydrologic Services Division was the primary Eastern Region participant for these briefings.

A by-product of a major landfalling hurricane is the possibility that NWS offices will require service backup resulting from equipment and/or communications outage. During Fran, service backup was required at various times for NWSFOs Raleigh, North Carolina; Charleston, West Virginia; NWSOs Wilmington, North Carolina; and Morehead City, North Carolina. Although service backup can pose difficulties for users since a single NWS office's products are then provided by multiple offices, this did not occur during the event. Although the workload became significant at NWSFO Raleigh, they were able to back up NWSO Wilmington and Morehead City at times during the height of the storm in spite of the fact that they experienced some power and telephone line difficulties.

The Sterling, Virginia, office experienced water problems in the building jeopardizing their ability to provide backup for NWSFO Charleston, West Virginia. As a result, NWSFO Cleveland, Ohio, took over forecast responsibility as a secondary backup office for Charleston.

Data Collection and Communication

Generally, there is a sparsity of land and over-water, real-time observations sites, and as occurred during Bertha, most units failed once power was lost. For example, NWSO Wilmington, North Carolina, has access to only four automated coastal observing sites along its 125-mile coastal area of responsibility. The coastal portion of NWSO Morehead City, North Carolina, is sufficiently covered by collection devices, such as ASOS stations, DARDC, and Data Logger units, but the primary data collection problem was the lack of backup power. Amateur radio operators were again used to gather information throughout the storm and proved to be Morehead City’s most reliable data-gathering source. There were problems with power outages, telephone outages, or drained batteries making rain and river gages unusable. The most extensive outages occurred in northern and western Virginia.

NWSO’s Morehead City and Wilmington, North Carolina, experienced power loss during the storm due to power outages and generator problems. At Morehead City, the backup power generator was recently serviced by a contractor because it had failed a few days earlier. During the contractor’s repair, a relay was not reconnected correctly, unbeknownst to the staff. When the generator came online during the hurricane, it was unable to remain functioning under load and shutdown. The office went into service backup. The NWS Eastern Region facility engineer worked through the problem over the telephone with the local electronics technician, and together they were able to bypass the problem.

A tropical Z/R relationship was used by most NWS offices operating WSR-88Ds during the event. While the tropical relationship improved the rainfall estimates, research clearly still needs to be done to improve the rainfall estimates. One item of note is that real-time rain gage observations greatly enhanced the radar estimates during the event.

Rainfall data from automated systems were used heavily and worked well, with one Virginia office exclaiming that "IFLOWS rain gage reports were invaluable during the event . . . ." The IFLOWS and the Automated Local Evaluation in Real-Time (ALERT) systems supported operations in West Virginia, Ohio, Pennsylvania, Virginia, and North Carolina. The automated flood warning systems helped forecast offices adjust WSR-88D quantitative rainfall estimates and helped NWS offices issue timely flood watches and warnings.

Local officials in Henderson County, North Carolina, cite the IFLOWS system with directly preventing many fatalities by warning of the need for evacuations with an hour lead time. In the Hickory Nut Gorge area, a group of residents evacuated before the flood waters rose and heavily damaged their homes and the bridge leading from the flooded area.

Preparedness

In North Carolina, Hurricane Fran was a significant shock for many people living inland. This was particularly true for the residents in and around the state capital in Raleigh where a disaster of this magnitude had never been experienced in their lifetimes.

For coastal residents of North Carolina, Hurricane Edouard passed off the coast a few days earlier, and Bertha's passage through the area the previous month led to heightened public awareness. Additionally, the long lead times provided by NWS forecasts allowed the emergency management community and the general population to effectively prepare for Hurricane Fran. The NWSO Wilmington, North Carolina, WCM noted that everyone in the area knew what to do for Fran, with Bertha serving as an excellent teacher of respect for tropical cyclones.

Eastern Region NWSFOs, NWSOs, and RFCs were prepared internally for Fran with appropriate staffing changes initiated well ahead of the storm. Externally, shelters were opened where needed, and no preparedness problems were noted.

Coastal offices had sufficient time to review hurricane preparedness policy and allowed the electronics technicians and staffs to double-check equipment. SKYWARN amateur radio volunteers at NWSFO Sterling, Virginia, raised a temporary HF antenna to use as backup communications to the Richmond EOC and other sites, if needed. SKYWARN at NWSFO Sterling was placed on standby Thursday, September 5, with a plan to fully activate Friday morning. The SKYWARN operators in Pennsylvania solicited rainfall reports from amateur radio operators, filling some holes left by loss of some instantaneous IFLOWS data.

In North Carolina, the NWS and state emergency management conducted an exercise of the state emergency response capability after Bertha. This was time well spent. There was also an official hurricane awareness week and a workshop on hurricanes for the media in June. The Raleigh and Morehead City HSAs had provided extensive recent outreach programs to the public and emergency officials.

Northern Virginia counties struck hard by flooding in June 1995 and January 1996 had just revised their local emergency plans after these disasters. In northern Virginia, schools and many businesses closed Friday, September 6, before the worst of the storm was forecast, substantially reducing the risk by decreasing traffic on the roads.

User Response

Response by the media and public to Hurricane Fran was quite good. Fortunately, visitor occupancy along the coast was light since the Labor Day weekend had already passed. Most tourists evacuated when ordered. In North Carolina, local officials issued evacuation orders on Ocracoke Island and North Topsail Beach (Onslow County). In addition, Surf City, which is in Pender and Onslow County, issued an evacuation and Carteret County had a strongly worded evacuation order for the Bogue Banks and low-lying areas in eastern Carteret County. However, many year-round residents remained on the barrier islands. This unfortunate decision was likely the result of not perceiving the full extent of the threat since the initial landfall was forecast in South Carolina and was only slowly edged up the coast. Additionally, after Bertha, many residents were not allowed back on the barrier islands for several days, especially on Topsail Beach. Since there were no mandatory evacuations in North Carolina, residents felt that they were free to stay during Fran and, thereby, be assured of access to their property after the storm. Fortunately, there were few deaths among those who chose to stay. The post-storm testimony of those who survived in the evacuation zone impressed upon all casual observers, and hopefully also to these barrier island residents, that evacuation is the wise course of action for future threatening hurricanes.

Forecast offices in Virginia provided briefings to the state EOC two or more times a day. In North Carolina, the response by the TV media was overwhelming. Local stations stayed on the air all night. Storm damage and flood coverage consumed almost the entire news program every day. Reports indicated that the public and emergency officials took proper steps to reduce risk to life and property due to the advanced warning.

Coordination conference calls with state, regional, and local EOCs began Tuesday afternoon, September 3, and concluded Saturday morning, September 7. As a result, emergency managers were generally well prepared for this situation although information disseminated to Essex County, Virginia, and Dorchester County, Maryland, regarding potential storm surge, was inaccurate (underestimated by a factor of 2). One reason for these higher storm surges was the underforecast wind fields on the east side of Fran after landfall as gale-force winds extended into Virginia and Maryland. NHC corrected this problem with time. A second reason was the track of the storm and the geographical configuration of the land/water boundaries in those locations. In Essex County, Virginia, and Dorchester County, Maryland, the water bodies involved (Rappahannock River and Chesapeake Bay) constrict just upstream from the damage areas. This led to a build-up of water and the resultant flooding. This flooding was quite localized and anomalous from the overall impact. For example, the observed surge at Crisfield, Maryland (downstream from Dorchester County), was right on the forecast value of 1.5 to 2 feet.

The media provided good coverage. Reporters were deployed to various hot spots for coastal impacts, flood footage, heavy rains, and wind damage. NWS offices provided telephone interviews with newspaper, radio, and television stations throughout the event. Coverage of NWS services was very positive after the storm. Media reports included the steps people took to reduce property damage given the advanced warning—how lives were saved by people not venturing out into the storm and the protective actions taken by the state and local jurisdictions throughout the impacted areas.

An example of how well the NWS services were received during the event came from an editorial in the *Daily News Record* from Harrisonburg, Virginia:

> *"Meteorology and weather forecasting involve a critical blend of science and luck, and through divine graces, the region received the benefits of some pretty good science. Schools closed Friday before the worst of the storm was forecast so buses did not have to hazard across washed out roads. Many offices were never opened or closed early on Friday, providing employees the chance to stay home or make their way home before roads began closing."*

From the *Potomac News*, Woodbridge, Virginia, an editorial stated:

> *"We may not be able to change the course of a hurricane, but weather-tracking has evolved into an amazing science.... Their know-how—human know-how—undoubtedly saved hundreds of lives, a job worth doing."*

Appendix A

Saffir-Simpson Hurricane Scale[*]

Category	Definition—Likely Effects
ONE	**Winds 74-95 mph (65-82 kts.):** No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage.
TWO	**Winds 96-110 mph (83-95 kts.):** Some roofing material, door, and window damage of buildings. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers, and small craft in unprotected anchorages break moorings.
THREE	**Winds 111-130 mph (96-113 kts.):** 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 (114-135 kts.):** More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.
FIVE	**Winds greater than 155 mph (greater than 135 kts.):** Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.

Note: A "major" hurricane is one that is classified as a Category 3 or higher.

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[*] 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 Fran, August 23 - September 8, 1996.

Date/Time	Position		Pressure (mb)	Wind Speed (kt)	Stage
(UTC)	Lat. (°N)	Lon. (°W)			
23/1200	14.0	21.0	1012	25	tropical depression
1800	14.1	22.8	1011	25	“
24/0000	14.2	24.8	1010	25	“
0600	14.2	26.6	1009	30	“
1200	14.1	28.2	1009	30	“
1800	14.1	29.6	1009	30	“
25/0000	14.1	30.8	1009	25	“
0600	14.3	32.0	1009	25	“
1200	14.6	33.4	1009	25	“
1800	14.7	35.1	1009	25	“
26/0000	14.9	37.0	1009	25	“
0600	15.1	38.6	1009	25	“
1200	15.3	40.0	1009	30	“
1800	15.2	41.4	1008	30	“
27/0000	14.9	42.7	1007	30	“
0600	14.7	43.8	1006	30	“
1200	14.6	44.9	1005	35	tropical storm
1800	14.6	46.1	1004	40	“
28/0000	14.6	47.5	1002	45	“
0600	15.0	49.1	1000	50	“
1200	15.5	50.7	995	55	“
1800	15.9	52.3	990	60	“
29/0000	16.4	53.7	987	65	hurricane
0600	17.0	55.0	987	65	“
1200	17.8	56.3	988	65	“
1800	18.6	57.5	988	65	“
30/0000	19.1	58.5	991	65	“
0600	19.4	59.4	991	65	“
1200	19.8	60.1	989	65	“
1800	20.2	60.6	990	60	tropical storm
31/0000	20.5	60.9	988	60	“
0600	20.8	61.2	987	60	“
1200	21.1	61.4	984	65	hurricane
1800	21.5	61.7	983	65	“
01/0000	21.7	62.1	978	65	“
0600	21.9	62.6	982	65	“

Table 1 (continued). Best track, Hurricane Fran, August 23 - September 8, 1996.

Date/Time (UTC)	Position Lat. (°N)	Position Lon. (°W)	Pressure (mb)	Wind Speed (kt)	Stage
01/1200	22.2	63.2	982	70	hurricane
1800	22.5	63.9	981	75	“
02/0000	22.9	64.7	978	75	“
0600	23.3	65.7	976	75	“
1200	23.6	66.7	976	75	“
1800	23.9	67.9	976	75	“
03/0000	24.2	69.0	977	75	“
0600	24.4	70.1	975	80	“
1200	24.7	71.2	973	80	“
1800	25.2	72.2	968	85	“
04/0000	25.7	73.1	961	95	“
0600	26.4	73.9	953	100	“
1200	27.0	74.7	956	105	“
1800	27.7	75.5	952	105	“
05/0000	28.6	76.1	946	105	“
0600	29.8	76.7	952	105	“
1200	31.0	77.2	954	100	“
1800	32.3	77.8	952	100	“
06/0000	33.7	78.0	954	100	“
0600	35.2	78.7	970	65	“
1200	36.7	79.0	985	40	tropical storm
1800	38.0	79.4	995	30	tropical depression
07/0000	39.2	79.9	1000	30	“
0600	40.4	80.4	1001	30	“
1200	41.2	80.5	1001	30	“
1800	42.0	80.4	1000	30	“
08/0000	42.8	80.1	999	30	“
0600	43.4	79.9	999	30	“
1200	44.0	79.0	1000	25	“
1800	44.5	77.6	1001	25	“
09/0000	44.9	75.9	1002	25	extratropical
0600	45.4	74.0	1004	20	“
1200	45.7	72.3	1006	15	“
1800	46.0	71.1	1008	15	“
10/0000	46.7	70.0	1010	15	“
0600					absorbed by a front
05/0000	28.6	76.1	946	105	minimum pressure
06/0030	33.9	78.7	954	100	landfall near Cape Fear, NC

Table 2. Ship reports of 34 knots or higher wind speed, associated with Hurricane Fran, August-September 1996.

date/time (UTC)	ship name	latitude (°N)	longitude (°W)	wind dir/ speed (knots)	pressure (mb)
30/0000	**AMAGISAN**	24.7	58.1	090/47	1017.0
30/0600	**AMAGISAN**	23.9	57.1	090/49	1015.0
30/1200	**AMAGISAN**	23.1	55.9	110/35	1015.0
30/1800	**AMAGISAN**	22.1	54.7	090/49	1014.0
31/0000	**AMAGISAN**	21.2	53.5	110/35	1014.5
31/0600	**AMAGISAN**	20.3	52.3	100/39	1014.0
31/1200	**SHIP**	26.7	60.8	110/45	1014.3
03/0600	**SEALAND CRUSADER**	26.8	67.3	150/35	1011.0
04/0000	**ELSX2**	28.4	74.6	060/37	1008.5
05/1200	**KAAPGRACHT**	32.2	79.6	010/66	1006.5
05/1200	**LAVX4**	32.9	76.7	090/45	1001.0
05/1200	**ELRV2**	32.9	77.4	070/40	1004.0
05/1200	**SUNBELT DIXIE**	33.2	77.3	040/58	1004.5
05/1200	**CR MARSEILLE**	33.6	77.1	XXX/60	1006.5
05/1200	**CRISTOFORO COLOMBO**	34.7	74.2	140/40	1013.0
05/1500	**LAVX4**	32.8	76.8	090/53	994.5
05/1500	**ELRV2**	33.2	76.7	060/42	1000.5
05/1800	**LAVX4**	33.0	76.9	100/85	984.0
05/1800	**CR MARSEILLE**	34.5	75.6	090/50	1007.0
05/2100	**CRISTOFORO COLOMBO**	33.0	73.6	130/40	1010.0
05/2100	**ZIM AMERICA**	34.7	74.0	120/45	1010.0
05/2100	**OOCL FIDELITY**	35.8	74.0	110/34	1012.0
06/0000	**COPACABANA**	31.5	72.9	160/36	1013.0
06/0000	**CRISTOFORO COLOMBO**	32.5	74.2	140/38	1010.0
06/0000	**ZIM AMERICA**	34.3	74.1	140/45	1009.0
06/0000	**OOCL FIDELITY**	35.4	74.2	120/38	1010.0
06/0300	**OOCL FIDELITY**	35.0	74.7	110/40	1007.0
06/0600	**LAVX4**	33.3	76.2	200/43	1006.0
06/0600	**CR MARSEILLE**	33.9	73.5	180/40	1013.2
06/0900	**ZIM AMERICA**	33.6	75.4	200/45	1009.0

Table 3. Hurricane Fran selected surface observations, September 1996.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts)[a]	Peak gust (kts)	Date /time (UTC)[b]	Storm surge (ft)[c]	Storm tide (ft)[d]	total rain (in)
South Carolina								
Charleston (CHS)	998.0	05/2234	27	36	05/2330			1.10
Charleston City Office			29	41	05/1850	1.1		0.87
Cheraw	992.2			56	06/0315			1.32
Cherry Grove Pier				67	05/2215			8.36
Conway				48				5.02
Dillon								4.62
Florence			30 [M]	56[M]	06/0250			2.21
Garden City Pier				64	05/2215			6.91
Loris				47				5.14
Marion								3.01
Mullins								3.98
Myrtle Beach Pavilion				66	05/2215			7.01
MB Springmaid Pier				65	05/2215	3.6		
North Carolina								
Apex (South RDU)								6.06
Atlantic Beach				87				
Butner								6.21
Cherry Point MCA (NKT)[M]	993.9	06/0255	51	66	06/0244			
Duck Pier	1006.9	06/0800	41	51	06/0900	1.5		
Duke Marine Lab (Beaufort)				80		5.4		
Elizabeth City CG (ECG)	1005.1	06/1147	37	48	06/1255			
Fayetteville (FAY)	971.6	06/0430	55	69	06/0430			
Figure Eight Island							10-12 [e]	
Fort Bragg (FBG)	972.3	06/0246	38	64	06/0431			4.70
Graham								6.65
Greensboro (GSO)	984.4	06/0900	30	42	06/0537			3.91
Greenville				87				
Hatteras Pier (NOS)	1004.4	06/0600	36	51	06/0600			
Hatteras ASOS (HSE)			38	49	06/0300			
Holden Beach				60	05/2300			
New River	982.0	05/0230	58	82	06/0156			7.05
Newport								3.24
North Topsail Beach			65		05/0045		8-9 [e]	
Oregon Inlet						2.3		
Pope AFB (POB)	977.6	06/0455	43	58	06/0418			6.72
Raleigh-Durham (RDU)	977.6	06/0653	39	69	06/0453			8.80
Rocky Mount (RWI) *	980.7	06/0200	17	39	06/0445			3.68
Rougemount (Durham Co)								6.02
Seymour Johnson (GSB)	981.0	06/0555	55	70	06/0555			6.38
Southport State Pilot Office				91				
Wilmington (ILM)	961.4	06/0036	58	75	05/2349			
Wilmington Tide Gauge						5.5		
Wrightsville Beach							10-11 [e]	
NOAA Ship Whiting [f]	959.9	05/2135						

Table 3 (continued). Hurricane Fran selected surface observations, September 1996.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts)[a]	Peak gust (kts)	Date/ time (UTC)[b]	Storm surge (ft)[c]	Storm tide (ft)[d]	total rain (in)
Virginia								
Charlottesville (CHO) [M]	998.6	06/1645	22	38	06/1045			
Danville (DAN) [M]	987.5	06/1151	34	46	06/0449			
Hot Springs (HSP) [M]	1002.4	06/1400	29	48	06/1540			
Lynchburg (LYH) [M]	990.6	06/1454	18	38	06/1243			
Norfolk NAS (NGU)	1004.6	06/0855	36	55	06/0805	2.6		
Richmond (RIC)	1000.8	06/1141	32	46	06/1141			
Roanoke (ROA) [M]	994.7	06/1254	33	44	06/0954			
Staunton (SHD) [M]	997.6	06/1840	25	43	06/1120			
Washington D.C. [g]						5.6/7.3		
CMAN Stations								
Frying Pan Shoals (FPSN7)	960.6	05/2300	79	108	05/2100			
Diamond Shoals (DSLN7)	1006.6	06/0500	58	65	06/0400			
Cape Lookout (CLKN7)	996.9	06/0100	56	71	06/0300			
Folly Island (FBIS1)	997.6	05/2200	24	41	05/1900			
Chesapeake Light (CHLV2)	1007.1	06/0900	40	47	06/1000			
Savannah Light (SVLS1)	1002.8	05/2000	30	36	05/1900			
Buoys								
41004	988.7	05/1900	48	64	05/1900			

[a] NWS standard averaging period is 1 min; ASOS and C-MAN are 2 min; buoys are 8 min.
[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] Estimated.
[f] Docked at Wilmington State Pier.
[*] Station not reporting from 0200-1000 UTC 06 Sept.
[M] Taken directly from METAR reports.
[g] The 5.6 ft value occurred on 06 Sept at 1700 UTC and was the actual storm surge, the 7.3 ft value occurred as a much broader peak on 09 Sept at 0418 UTC from freshwater runoff.

Table 4. Watch and warning summary, Hurricane Fran, August - September 1996.

Date/time (UTC)	Action	Location
29/0300	hurricane watch	Northeastern Leeward Islands from Antigua through St. Maartin
29/2100	hurricane watch discontinued	Northeastern Leeward Islands from Antigua through St. Maartin
02/2100	hurricane watch	Central Bahamas
02/2100	tropical storm warning	Central Bahamas
03/0900	hurricane watch	Northwestern Bahamas
03/1800	hurricane warning	Northwestern Bahamas
04/0300	hurricane watch	north of Sebastien Inlet, FL to Little River Inlet, SC
04/0900	watches and warnings discontinued	Central Bahamas
04/1500	hurricane watch extended northward	Little River Inlet, SC to Oregon Inlet, NC including Pamlico Sound
04/1800	hurricane warning downgraded to tropical storm warning	Northwestern Bahama Islands of Andros and New Providence
04/2100	hurricane warning	north of Brunswick, GA to Cape Lookout, NC
04/2100	hurricane watch	north of Cape Lookout, NC to Currituck Beach Light, NC including Pamlico and Albemarle Sounds
04/2100	tropical storm warning	Flagler Beach, FL to Brunswick, GA
04/2100	hurricane watch discontinued	south of Cape Lookout, NC
05/0300	hurricane warning extended northward	north of Cape Lookout, NC to NC/VA border including the Pamlico and Albemarle Sounds
05/0300	hurricane watch	north of NC/VA border to Chincoteague, VA including the Greater Hampton Roads area

Table 4 (continued). Watch and warning summary, Hurricane Fran, August-September 1996.

Date/time (UTC)	Action	Location
05/0300	hurricane warning downgraded to tropical storm warning	northwestern Bahama Islands of Abaco and Grand Bahama
05/0300	hurricane warning discontinued	northwestern Bahama Islands
05/0300	tropical storm warning discontinued	Andros and New Providence Islands
05/0900	tropical storm warning discontinued	Flagler Beach, FL to Brunswick, GA
05/0900	tropical storm warning discontinued	northwestern Bahama Islands of Abaco and Grand Bahama
05/1500	tropical storm warning	north of the NC/VA border to Chincoteague, VA including the Greater Hampton Roads area
05/1500	tropical storm warning	lower Chesapeake Bay
05/1500	hurricane warning downgraded to tropical storm warning	north of Brunswick, GA to just south of Edisto Beach, SC
06/0100	hurricane and tropical storm warnings discontinued	Cape Romain, SC southward
06/0300	hurricane warnings discontinued	south of Cape Fear, NC
06/0300	hurricane watch discontinued	north of the NC/SC border to Chincoteague, VA including the Greater Hampton Roads area
06/0900	hurricane warning discontinued	remainder of NC coast
06/1800	tropical storm warning discontinued	remainder of U.S. east coast

Appendix C

Summary of Fatalities

Date	State	County	Details
9/5	NC	Onslow	Male drove off bridge at North Topsail beach
9/5	NC	Bladen	Man had heart attack, rescue workers could not reach him
9/5	SC	Horry	Woman swerved to avoid tree and drove into ditch
9/5	SC	Williamsburg	Male driving car hit tree that fell on road
9/5	NC	Wake	Male drowned in Crabtree Creek
9/5	NC	Durham	Male fire fighter was killed when tree fell on his truck
9/5	NC	Alamance	Male died when tree fell on home
9/5	NC	Johnston	Male died when tree fell on home
9/5	NC	Wake	1 Male/1 Female died when car ran into fallen tree
9/5	NC	Wayne	Male killed when car ran into fallen tree
9/5	NC	Pender	Female died from exposure and hyperthermia
9/5	NC	Pender	Male cause unknown
9/5	NC	Pitt	Male killed when car ran into fallen tree
9/5	NC	Duplin	Female killed when a chimney collapsed on her house
9/5	NC	Onslow	Female killed when tree fell on her
9/5	MD	Montgomery	1 Male/1 Female swept away in car by flooded waters
9/5	VA	Pittsylvania	1 Male drowned when he attempted to drive across a flooded roadway
9/6	VA	Augusta	2 Males drowned when swept away while trying to cross a bridge
9/6	VA	Highland	Female drowned when crossing flooded area
9/6	WV	Pendleton	Male drowned when he drove car into flooded waters
9/6	WV	Grant	Male drowned when he drove tractor into flooded waters
9/6	PA	Cumberland	Female drowned when car swept away by flood waters
9/6	PA	Perry	Female drowned near home due to flash flood

Appendix D

Initial Public Issuances by Hydrologic Product Category

Office	ESF	FFA	FFW	FLW
NWSO Wilmington, NC+	see Raleigh, NC	see Raleigh, NC & Columbia, SC	9/5 4:50pm	9/6 12:30pm
NWSO Morehead City, NC+	see Raleigh, NC	see Raleigh, NC	9/5 5:03pm	9/6 3:22pm
NWSFO Raleigh, NC	9/3 12:30pm	9/4 4:40pm	9/5 7:39pm	9/6 12:40am (FLS) 6:45am (FLW)
NWSO Wakefield, VA+	9/4 2:22pm	see Sterling, VA & Raleigh, NC		9/6 3:00am
NWSO Roanoke, VA+	9/4 4:50pm	see Charleston, WV & Sterling, VA	9/6 12:02am	9/6 6:45am
NWSFO Sterling, VA		9/4 4:04pm (life-threatening)	9/6 5:36am	9/6 7:53am
NWSFO Charleston,WV	9/4 3:15pm	9/5 5:31am	9/6 1:30pm	
NWSFO Pittsburgh, PA	9/5 9:00am	9/5 10:15pm 9/6 11:05am (river)	9/6 11:52am	9/6 5:00pm
NWSO Central Pennsylvania+	9/5 10:35am	see Philadelphia & Pittsburgh, PA	9/6 4:08pm	9/6 10:09pm
NWSFO Cleveland, OH		9/6 3:22pm	9/7 5:30am	9/7 9:00am
NWSFO Philadelphia, PA+		9/6 4:20am		
NWSFO Charleston, WV+		9/5 5:15am		

ESF - Flood Potential Statement
FFA - Flood/Flash Flood Watch
FFW - Flood/Flash Flood Warning
FLW - River Flood Warning
FLS - Flood Statement

+ During the current stage of the modernization and restructuring (MAR) of the NWS, some offices have not yet assumed full responsibility for issuing all products for the areas they serve. Once the MAR is completed, these offices will assume full responsibility for issuing all hydrologic products.