



Natural Disaster Survey Report

THE HALLOWEEN NOR'EASTER OF 1991 **East Coast of the United States...Maine to Florida and** **Puerto Rico**

October 28 to November 1, 1991



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

Cover: Waves crashing into the Massachusetts shore at Nantasket Beach in Hull.
Photograph courtesy of Tom Herde and provided by the BOSTON GLOBE.



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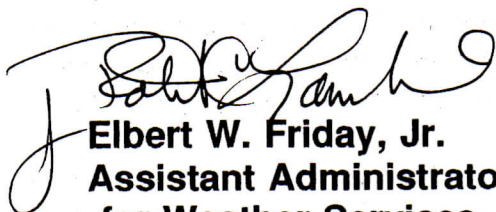
U.S. DEPARTMENT OF COMMERCE
Barbara H. Franklin, Secretary

National Oceanic and Atmospheric Administration
Dr. John A. Knauss, Administrator

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

PREFACE

Nor'easter storms are nothing new to residents along the east coast of the United States. However, the **Halloween Nor'easter of 1991** lasted much longer and impacted an area much larger than what is usually experienced. Due to the efforts of NOAA/National Weather Service meteorologists and meteorological technicians from San Juan, Puerto Rico, to Portland, Maine, the populace of the United States affected by this storm was well served. I congratulate all concerned on their expertise and professionalism in foreseeing this situation and properly responding.



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

July 1992

FOREWORD

The report on the **Halloween Nor'easter of 1991** was prepared by the National Oceanic and Atmospheric Administration Disaster Survey team following on-scene assessments and interviews conducted during the week of November 11, 1991. Such surveys are conducted at the direction of the Assistant Administrator for Weather Services whenever significant storms occur.

National Weather Service employees; Federal, state, and local emergency services and other public officials; media representatives; and members of the general public from North Carolina to Maine were contacted and questioned specifically regarding the meteorological and oceanographic conditions that occurred, the timeliness and accuracy of National Weather Service actions in response to these conditions, and the appropriateness of responses to these actions.

The team is grateful to the many people who helped before, during, and after these visits by gathering information and who took time from other activities to spend time with us.

The Disaster Survey Team

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ACRONYMS AND ABBREVIATIONS

AFOS	Automation of Field Operations and Services
AVN	Aviation Weather Forecast Model
CMAN	Coastal Marine Automated Network
DST	Disaster Survey Team
FEMA	Federal Emergency Management Agency
ft	Feet/Foot
GOES	Geostationary Operational Environmental Satellite
kt	Knots
LFM	Limited-area Fine Mesh Model
MARMON	Marine Monitoring Program
mb	Millibar
MIC	Meteorologist in Charge
MLLW	Mean Lower Low Water
MRPECS	NMC Marine Product, East Coast Storm Surge
NAWAS	National Warning System
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NGM	Nested Grid Model
NGWLMS	Next Generation Water Level Measurement System
NHC	National Hurricane Center
nm	Nautical Miles
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWR	NOAA Weather Radio
NWS	National Weather Service
NWWS	NOAA Weather Wire Services
NYSPIN	New York Statewide Police Information Network
PC	Personal Computer
PNS	Public Information Statements
SDM	Station Duty Manual
SMS	Satellite Marine Section
SOP	Standard Operating Procedure
SWIS	Satellite Weather Information System
USACE	United States Army Corps of Engineers
UTC	Universal Coordinated Time
VAS	VISSR Atmospheric Sounder
VDUC	VAS Data Utilization Center
VISSR	Visible and Infrared Spin Scan Radiometer
WCM	Warning Coordination Meteorologist
WLTS	Water Level Telemetry System
WSFO	Weather Service Forecast Office
WSMO	Weather Service Meteorological Observatory
WSO	Weather Service Office

DISASTER SURVEY TEAM MEMBERS

The **Halloween Nor'easter of 1991** Natural Disaster Survey Team is listed below. To more effectively investigate the storm, the Team Leader split the group in two. One half consisting of Scavia, Waters, Thurm, Coleman, and Viets covered the area from the Canadian border to Manasquan, New Jersey, while the other half with Shaffer, Koehn, Feit, Businger, and Overland researched the area from Manasquan to Cape Hatteras, North Carolina. Dr. Scavia led the northern group, and Dr. Shaffer led the southern group. Additional information on damage in Florida and Puerto Rico was provided by local offices and the Southern Region of the National Weather Service (NWS).

TEAM MEMBERS

Team Leader, **Donald Scavia**, Director, National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program

Team Technical Leader, **Robert Jacobson**, Meteorologist, NWS/Office of Meteorology/Marine and Applied Services Branch

Field Representative, **David Felt**, Chief, NWS/National Meteorological Center (NMC)/Satellite and Marine Section

Field Representative, **Richard Coleman**, Meteorologist in Charge/Area Manager, Weather Service Forecast Office (WSFO) Memphis, Tennessee

Field Representative, **Harvey Thurm**, Regional Marine and Hurricane Program Leader, NWS/Eastern Region

NOAA Public Affairs Specialist, **Patricia Viets**, NWS/Public Affairs Office

Subject Matter Specialist, **Marshall Waters**, Chief, NOAA/Ocean Products Center

Subject Matter Specialist, **Wilson Shaffer**, Chief, NWS/Office of Systems Development/Marine Techniques Branch

Subject Matter Specialist, **Mark Koehn**, Program Leader, NWS/Office of Meteorology/Tsunami and Oceanographic Services Program

Subject Matter Specialist, **James Overland**, Chief, NOAA/Pacific Marine Environmental Research Laboratory/Marine Assessment Research Division

Non-Governmental Expert, **Steven Businger**, Professor, North Carolina State University/Marine, Earth, and Atmospheric Science Department

EXECUTIVE SUMMARY

Beginning on October 28 and lasting until November 1, 1991, a succession of meteorological events combined over the northwest Atlantic Ocean resulting in a series of extraordinary ocean waves and swells. Driven and maintained by persistent, near-hurricane force winds, these waves and swells spread to the south and southwest before crashing onto the North American coast and the northern shores of the islands of the western Atlantic. Although New England, closest to the storm, received the hardest blows, widespread destruction was the rule as far south as Cape Hatteras, North Carolina, while scattered damage occurred to southern Florida and the north coast of Puerto Rico.

During the course of its investigation, the NOAA Disaster Survey Team (DST) traveled along the East Coast from North Carolina to Maine. Overall, the Team found that the system established to develop and disseminate coastal flood watches, warnings, and statements worked well. The several NWS offices involved--national, regional, and local--recognized the threat early and did yeoman work in keeping Federal, state, and local emergency officials; the media; and the public informed with clear, concise, and timely products.

The Team feels, however, that there are some problems that need to be addressed. These are discussed in the pages that follow and are summarized in the findings and recommendations section of this report. In general, there are three areas that require the most attention: data availability, guidance inadequacy, and public response.

Data Availability

All NWS warning products must begin with reliable and timely observations. The Team found that there are not enough water level observation sites along the East Coast. Where these sites do exist, there is not adequate real-time access by the forecasters to the data provided. Further, the Team found a disturbing shortage of basic marine weather observations available. Specifically, there are too few Coastal Marine Automated Network (CMAN) units and buoys along the East Coast. Thus, in many cases, the forecasters are not able to adequately monitor existing conditions.

Guidance Inadequacy

The various numerical models available provided forecasters with very good guidance on open ocean conditions and on the movements and intensity changes of the weather systems affecting the storm. However, the guidance as to coastal conditions was unreliable and, in at least one case, actually inhibited an early warning issuance.

Current development activities on an extratropical coastal storm surge model and a coastal wave prediction system need to be accentuated.

Public Response

Excellent warnings and statements were disseminated by the NWS to state and local emergency service officials and to the media. In general, the response by these groups of people was excellent. The media forwarded this information to the public in a timely fashion. The emergency service personnel were ready ahead of time to take appropriate actions.

In most cases, however, the public either did not respond or they responded improperly. Many people did not perceive this coastal storm as a threat to them. It is apparent to the Team that a public education campaign is needed to make sure people understand the potential of coastal flooding. Such a campaign needs to include the utilization of the NOAA Weather Radio (NWR). The radio's effectiveness in such places as the Outer Banks of North Carolina highlights its potential as a tool for alerting and informing the public.

FINDINGS AND RECOMMENDATIONS

THE EVENT AND ITS IMPACT (CHAPTER I)

Finding 1:

A coastal flood of unusually long duration and intensity occurred during late October 1991, affecting areas along the entire east coast of the United States and Puerto Rico. This storm caused millions of dollars in damage to beaches and man-made beachfront structures, including the seaside home of President George Bush.

DATA ACQUISITION AND AVAILABILITY (CHAPTER III)

Finding 2:

The availability and continuity of an adequate, reliable, and timely data base (consisting of meteorological observations, sea state conditions, and water level measurements) is vital if NWS offices are to provide accurate and timely coastal flood watches and warnings. This includes those areas behind barrier islands, particularly where large rivers or embayments are involved (e.g., Pamlico Sound) so that adequate warning for seiches and coastal flooding can be given.

Recommendation 2-1:

NWS and National Ocean Service (NOS) should implement a system that will ensure that local NWS offices will have real-time, 24-hour access to reliable water level measurements especially from **critical** tide gage stations. This should include those stations behind the various oceanic barriers. The availability of these data is vital to NWS offices responsible for issuing coastal flood watches and warnings.

Recommendation 2-2:

The phaseover from the Water Level Telemetry System (WLTS) to Next Generation Water Level Measurement System (NGWLMS) technology must be accomplished only after all questions and reservations about the new system have been answered and the operational implementation of the new system has been agreed to by both NWS and NOS.

Recommendation 2-3:

The NWS should install an adequate marine observational network that would fill the gaps in the current arrangement and would provide the minimum coverage necessary for the reconfigured forecast areas in the modernized NWS. This network should include shoreline/shallow water wave height measurements.

Finding 3:

A water level value relayed to WSFO Portland, Maine, from a properly operating gage was discounted by forecasters due to past problems with the gage. The coastal flood warning was issued only after electronics technicians verified that the earlier reading was correct, some 3 hours after the threshold value was reached.

Recommendation 3-1:

Water levels should be monitored on a regular basis, either manually or automatically, so that NWS forecasters are aware of possible gage problems and so that water level trends can be observed.

Finding 4:

Marine weather data are not as accessible to NWS forecasters as are land-based data making the use of this information more difficult.

Recommendation 4-1:

The NWS should ensure that marine weather data are integrated into the Automation of Field Operations and Services (AFOS) hourly surface plots for use at local offices having marine responsibility. The Ocean Products Center should seek other ways to bring needed data to the high seas forecasters of the Satellite Marine Section (SMS) at NMC.

Recommendation 4-2:

The NWS should explore adapting the marine monitoring (MARMON) program, developed at WSFO Cleveland and utilized across the Great Lakes, to assist forecasters in monitoring conditions along the East Coast.

PREPAREDNESS (CHAPTER IV)

Finding 5:

On-station standard operating procedures (SOP) varied widely from one station to another. In some cases, guidance materials were not complete or clear enough for a station's most inexperienced members to carry out their duties with the confidence that they had enough information to make the best decisions possible.

Recommendation 5-1:

All local managers should review their Station Duty Manuals (SDM), checklists, emergency procedures, etc., regarding coastal flooding to ensure they are complete, clear, concise, and up to date.

Finding 6:

Station drills on coastal flooding are not common practice at all offices having such responsibility.

Recommendation 6-1:

Drills should be scheduled at all stations with a frequency that will keep coastal flood procedures fresh in the minds of all watchstanders. Actual coastal flood events could be substituted for a drill.

WARNING SERVICES (CHAPTER V)

Finding 7:

NMC and coastal WSFOs and Weather Service Offices (WSO) recognized the potential for a dangerous ocean storm several days before the storm's major impact on the New England and Mid-Atlantic coastlines. Overall, notification of emergency officials and watch/warning lead times were sufficient for effective preparedness actions yielding a remarkably low loss of life.

Recommendation 7-1:

Appropriate recognition is warranted for individuals and organizations who played pivotal roles in ensuring the effective performance of the warning process.

Finding 8:

Overall, the various atmospheric models performed well. However, statistical output from the NMC Marine Product-East Coast Storm Surge (MRPECS) program was consistently too conservative for this storm and may have inhibited warning effectiveness. Also, forecasters were unfamiliar with its usefulness in forecasting wave conditions during long duration storms.

Recommendation 8-1:

NOAA should be encouraged to complete the development of an extratropical storm surge model.

Recommendation 8-2:

NOAA should finalize development of a replacement for the MRPECS program having sufficient resolution and coupling the NMC deep water wave model to the shallow, coastal areas. Further, NWS should ensure that, once developed, the benefits and utilities of this guidance are made known to field personnel.

Finding 9:

In some cases, the public was drawn to the coast to witness the power of the heavy surf. This created traffic problems that may have obstructed emergency actions.

Recommendation 9-1:

NWS offices, working with local emergency managers, are encouraged to develop wording for use in coastal products designed to discourage spectators from going to the coast during coastal flood and high surf episodes.

COORDINATION AND DISSEMINATION (CHAPTER VI)

Finding 10:

Although NAWAS (National Warning System) was used, its fullest capability was not realized because dissemination to local offices was slow or did not occur.

Recommendation 10-1:

NWS managers at all levels should work with their NAWAS system managers to review dissemination procedures and see if these can be strengthened.

Finding 11:

The NOAA Weather Wire Services (NWS) does not appear to be the total answer for disseminating emergency weather information to state and local emergency service managers.

Recommendation 11-1:

The NWS needs to strongly encourage those states subscribing to the NWS to install automatic systems for distributing emergency information to appropriate local officials. Other alternatives for quickly and personally delivering such information to key state and local decision makers, such as the New York Statewide Police Information Network (NYSPIN), need to be explored and developed.

USER RESPONSE (CHAPTER VII)

Finding 12:

Response by the emergency management community and by the various media was generally excellent. Public response to this storm, and to coastal flood watches and warnings in general, was generally poor.

Recommendation 12-1:

The rapport and personal contacts between NWS officials and emergency managers at all levels must be maintained especially during the NWS modernization. This can be accomplished only through frequent visits between NWS personnel and state and local emergency officials. The NWS should look at other ways of coordinating with and informing emergency managers at whatever level is necessary during time-critical events.

Recommendation 12-2:

The NWS should investigate whether some minimum standard of preparedness training should be provided, through briefings or some other mechanism, to high level officials (e.g., mayors and governors) who can play a critical role in responses (e.g., evacuations) to emergency situations.

Finding 13:

Many residents contacted by the DST said that they did not think the storm would be as devastating as it was and took no action to protect their property or to

evacuate. Since this was not a hurricane and, in many locations, was not accompanied by "significant weather," the storm was not perceived as a real danger.

Recommendation 13-1:

The NWS should investigate the feasibility of developing an intensity scale for extratropical storms patterned after the Saffir-Simpson Hurricane Intensity Scale for tropical systems.

Recommendation 13-2:

NWS offices are strongly encouraged to continue the practice of comparing potentially damaging storms with noteworthy storms of the past, thereby increasing the sense of urgency to the general public.

Recommendation 13-3:

NWS should produce a pamphlet dedicated solely to coastal flooding. This needs to be done as part of a systematic public information campaign designed to educate the coastal public on the dangers of coastal storms. This campaign could also include press conferences, now used to increase hurricane awareness, public information statements (PNS), and Public Service Announcements.

Finding 14:

Especially in New England, the NWR is not used by the general public as widely as it could be.

Recommendation 14-1:

The existence of NWR needs to be more highly publicized. In communities where NWR is widely accepted (e.g., the Cape Hatteras area), it is highly successful in keeping both local officials and the general public informed. Local managers should use whatever publicity sources they have available, including Public Service Announcements in the local media to encourage the use of NWR.

CHAPTER I -- THE EVENT AND ITS IMPACT

A series of extraordinary meteorological events during the week of October 27, 1991, set the stage for a major coastal flood and erosion event. Although principally affecting sections of the East Coast from Maine through North Carolina, the impact of the storm was felt south from there to the southernmost reaches of Florida, across much of the Bahamas, and as far south as Puerto Rico. Flooding began early and continued throughout the week. The worst impacts, however, were experienced on October 30 and 31. For this reason, the storm will likely go down in the annals of meteorological history as the "**Halloween Nor'easter of 1991.**"

The event was especially noteworthy for the following reasons.

- a. The storm was of unusually long duration. For example, in North Carolina a heavy surf advisory was in effect for 5.5 days, and a coastal flood warning was in effect for 3.5 days.
- b. With the exception of Cape Cod and the eastern shore of Massachusetts which experienced hurricane force wind gusts and heavy rain, the coastal flooding along the remainder of the East Coast was accompanied by relatively benign weather.
- c. The coastal flooding was generated by three separate and distinct synoptic-scale systems which contributed individually and in combination to produce the damaging high seas.
- d. Coastal flooding was exacerbated when the intense extratropical storm, the third and most potent of the three systems, moved in a very atypical path (i.e., from east to west to south) almost totally opposite the normal storm track, keeping the wave-generating fetch much closer to and pointed directly toward the North American mainland.

An extensive discussion of the meteorology associated with the **Halloween Nor'easter of 1991** is contained in Chapter II. For the purposes of this chapter, the impacts from the interactions of the various weather features will all be considered together under the generic term "storm."

The wind fields generated by the storm covered an extremely large area extending hundreds of miles. This resulted in a tremendous fetch length ranging from south of Labrador to the coast of Florida (figure 1). As the winds persisted, they generated seas over 40 feet (ft) in height. This was somewhat similar to the "Ash Wednesday

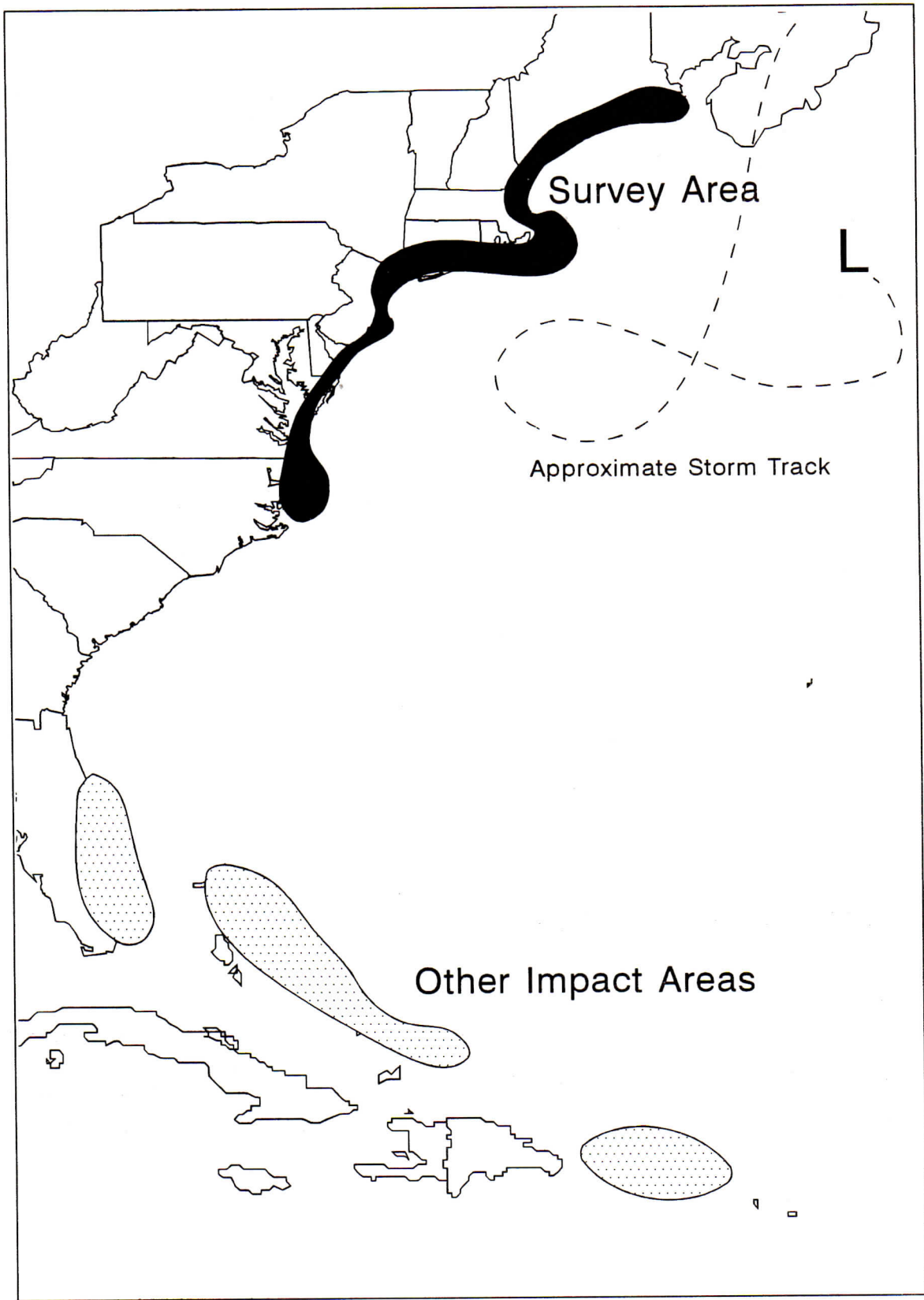


Figure 1. Halloween Nor'easter of 1991...Overview

Storm" of March 1962, in that the long fetch allowed big waves to develop. In areas close to the center of such a tempest, most of the wind energy generally goes into forming shorter-period, wind-driven waves. However, as these waves propagate away from the storm, they are damped much more than are the longer-period waves. What results is called a swell (i.e., the long-period waves that can travel to and impact a coastline thousands of miles away. An excellent example is the swells that crash on the beaches of Oahu, Hawaii. These are often generated by systems halfway across the Pacific and impact Oahu days later.)

Developing after October 27, these swells, traveling unobstructed to the south and southwest, had a clear path to the United States coast bringing abnormally high waves and extreme water levels. Indeed, ocean levels were raised to such an extent that the water acted almost like a dam retarding outward tidal flows and even inhibiting river waters from disgoring into the sea. Flooding in low-lying areas caused by the backup of such flows was seen in such unlikely places as along the Hudson River north to Albany and Troy, New York, and the Potomac River north to metropolitan Washington, D.C. Both of these are over 100 miles from the sea.

Near the coast, the ocean responds to any nor'easter through storm surge as well as through local wave generation. The term "storm surge" is defined as the difference between the observed tide gage water level and the predicted astronomical tide level. Note that this definition excludes waves. These features are damped out by the action of the stilling-well, that part of a tidal gage system holding the water to be measured, and by the longer averaging time of most tide gages.

Tide gages along the East Coast measured storm surges that ranged from just over 5 ft at Boston's gage to roughly 2 ft along North Carolina's Outer Banks. (See tables I and II for water levels measured during this storm and for comparisons with earlier record levels.)

Damage along the coastlines was caused by a combination of relatively high tides, high storm surge levels, and large waves which for several days continuously pounded the shoreline. At low tide, even a fairly large wave will have comparatively little impact on structures. However, when the water level at low tide raises to equal the mean high water mark, the threat from such waves increases. When several feet of storm surge strikes the coastline coincident with high tide, these waves can cause profound damage of the type incurred from this storm.

As experienced during the **Halloween Nor'easter of 1991**, a storm of long duration will impact several tidal cycles. (On the East Coast, one tide cycle is completed about every 12 1/2 hours.) This is in contrast to a fast-moving storm, like a hurricane, where only those tide levels during the few hours of the event are critical.

TABLE I
MAXIMUM STORM SURGE - HALLOWEEN NOR'EASTER OF 1991

<u>Station</u>	<u>Date/Time</u>	<u>Obsvd.</u>	<u>Pred.</u>	<u>Diff.</u>
Eastport, ME	10/30 1048	4.99	2.30	2.69
Cutler, ME	10/30 1000	4.14	1.32	2.82
Portland, ME	10/30 1112	5.13	1.61	3.52
Boston, MA	10/30 2042	8.57	3.46	5.11
Woods Hole, MA	10/30 2318	5.07	0.72	4.35
Nantucket, MA	10/30 1500	7.42	2.82	4.60
Newport, RI	10/31 0106	7.32	3.30	4.02
Providence, RI	10/31 0130	7.95	4.54	3.41
New London, CT	10/31 0312	6.69	2.65	4.04
Montauk, NY	10/31 0218	6.60	2.16	4.44
Bridgeport, CT	10/31 0500	11.50	6.64	4.86
Port Jefferson, NY	10/31 0425	11.63	6.78	4.85
Willetts Point, NY	10/31 0436	12.24	7.15	5.09
The Battery, NY	10/31 0430	8.42	3.48	4.94
Sandy Hook, NJ	10/31 0406	8.38	3.44	4.94
Barnegat Inlet, NJ	10/31 0654	4.49	0.22	4.27
Atlantic City, NJ	10/31 0718	5.31	0.66	4.65
Cape May, NJ	10/31 0800	4.55	0.65	3.90
Philadelphia, PA	10/31 1600	5.27	1.21	4.06
Lewes, DE	10/31 0906	4.56	0.66	3.90
Ocean City, MD	10/31 1848	4.68	0.88	3.80
Cambridge, MD	11/01 0548	2.67	0.46	2.21
Annapolis, MD	11/01 0530	3.18	0.54	2.64
Baltimore, MD	11/01 0712	3.19	0.43	2.76
Washington, DC	11/01 1200	3.75	0.99	2.76
Colonial Beach, VA	11/01 0400	3.07	0.27	2.80
Lewisetta, VA	11/01 0200	3.03	0.41	2.62
Hampton Roads, VA	10/31 1900	4.78	1.85	2.93
Ches.Bay Brdg., VA	10/31 1800	5.08	1.85	3.23
Cape Hatteras, NC	11/01 0600	3.93	1.78	2.15

Notes:

Date/Time shows the month and day and the hour and minute (in EST) of the maximum storm surge.

Observed and Predicted values are listed in feet above Mean Lower Low Water (MLLW).

The Difference between the Observed and Predicted values is defined as the Storm Surge.

TABLE II
MAXIMUM WATER LEVELS - HALLOWEEN NOR'EASTER OF 1991
WITH HISTORICAL COMPARISONS

<u>STATION</u>	<u>Date/Time</u>	<u>Obsvd.</u>	<u>Record Date</u>	<u>Height Elev.</u>
Eastport, ME	10/30 1606	20.24	6/77	24.12
Cutler, ME	10/30 1612	15.18	1/79	17.32
Portland, ME	10/30 1636	12.78	2/78	14.17
Boston, MA	10/30 1654	14.29	2/78	15.25
Woods Hole, MA	10/31 0100	5.22	8/54	10.39
Nantucket, MA	10/30 1730	8.11	1/87	6.58
Newport, RI	10/31 0136	7.34	9/38	13.53
Providence, RI	10/31 0136	7.81	9/38	17.71
New London, CT	10/31 0330	6.65	9/38	10.76
Montauk, NY	10/31 0306	6.57	8/54	8.68
Bridgeport, CT	10/31 0518	11.55	9/38	12.44
Port Jefferson, NY	10/31 0530	11.62	2/78	12.12
Willetts Point, NY	10/31 0524	12.39	9/38	16.90
The Battery, NY	10/31 0324	8.94	9/60	10.23
Sandy Hook, NJ	10/31 0248	8.80	3/62	10.33
Barnegat Inlet, NJ	10/31 0230	5.27	8/76	5.48
Atlantic City, NJ	10/31 0154	8.19	9/44	9.20
Cape May, NJ	10/31 1512	8.43	9/85	9.09
Philadelphia, PA	10/31 2024	9.04	11/50	10.79
Lewes, DE	10/31 1500	7.81	3/62	9.49
Ocean City, MD	10/31 1348	7.16	9/85	7.54
Cambridge, MD	10/31 2318	4.50	9/79	4.87
Baltimore, MD	11/01 0200	4.03	8/33	7.93
Annapolis, MD	11/01 0036	3.85	8/33	6.40
Washington, DC	11/01 0254	5.34	10/42	11.29
Colonial Beach, VA	11/01 0942	4.32	9/79	4.36
Lewisetta, VA	11/01 0818	4.01	3/83	3.62
Hampton Roads, VA	10/31 1618	5.61	8/33	8.39
Ches. Bay Brdg., VA	10/31 1512	5.83	4/78	6.36
Cape Hatteras, NC	10/31 1336	5.64	9/85	5.84

Note:

Date/Time shows the month and day and the hour and minute (in EST) of the highest observed water level.

The highest observed water level is given in feet above Mean Lower Low Water (MLLW).

The Record Height contains the month and year when the highest water level was measured and the height of that measurement in feet above MLLW.

Tables 1 and 2 are derived from NOAA TECHNICAL MEMORANDUM NOS OES, **Effects of the Late October 1991 North Atlantic Extra-Tropical Storm on Water Levels**, dated January, 1992.

This storm came less than one week after spring tides, the highest tides of the month. Had the storm come 5 days earlier, astronomical tides would have been about 1 ft higher along most of the coast--approximately 1 1/2 ft higher at Boston. As a rule, adding the value of the astronomical tide to the storm surge seems to hold. That would imply that water levels at Boston would have been about 1 1/2 ft above the levels they actually experienced, while other locations would have been about a foot above observed levels. This extra 1 1/2 ft might have been enough to flood part of the downtown section of the city.

The closest in-shore wave gage data were observed approximately 2 miles offshore near the U.S. Army Corps of Engineers (USACE) pier at Duck, North Carolina (figure 2). There, wave heights of 14 ft were observed on the afternoon of October 30. The buoy at Diamond Shoals, 12 nautical miles (nm) southeast of Cape Hatteras, North Carolina, observed its highest waves (25-27 ft) at roughly the same time. These waves are clearly swell, indicated by their long (18 second) wave periods. A buoy within sight of Boston (figure 3) measured significant wave heights of over 30 ft-- some of the highest waves ever recorded at that location by the NWS/National Data Buoy Center (NDBC).

In the hardest hit New England communities, seashore homes, roads, sewer/water lines, docks and piers, and coastal protection projects (e.g., seawalls, revetments and groins) were primary targets. Barrier beaches were breached and sand dunes and coastal bluffs eroded. In some cases up to 50 ft of dunes, beaches, or salt marshes vanished. There were some reports of oil spills.

Also hard hit were New England lighthouses. For example, the storm extinguished the light in the Isles of Shoals Lighthouse (figure 4) and destroyed its generator, control huts, boathouse and ramp, and a walkway from the helicopter pad to the house. Its emergency horn and one fuel tank were missing, and two fuel tanks were knocked over.

The most visible casualty of the **Halloween Nor'easter of 1991** was President Bush's house located in Kennebunkport, Maine. The President's home, which has withstood many past storms, suffered severe damage to its ground floor from wave battering. The degree of damage to the President's house and other structures along the coast served to highlight the awesome power of the ocean and the problems faced by an increasing population along the Nation's shorelines.

Without a doubt, the east coast and coincident islands of Massachusetts, being closest to and directly downfetch from the strongest core of the storm, took the most severe pounding. It was locally compared with the Blizzard of February 1978, which has been considered the benchmark nor'easter in this area. Particularly hard hit were parts of Salisbury, Gloucester, Revere, Lynn, Hull, Scituate (especially Peggotty Beach and the Humarock area), Marshfield, Plymouth (Whitehorse Beach), Chatham

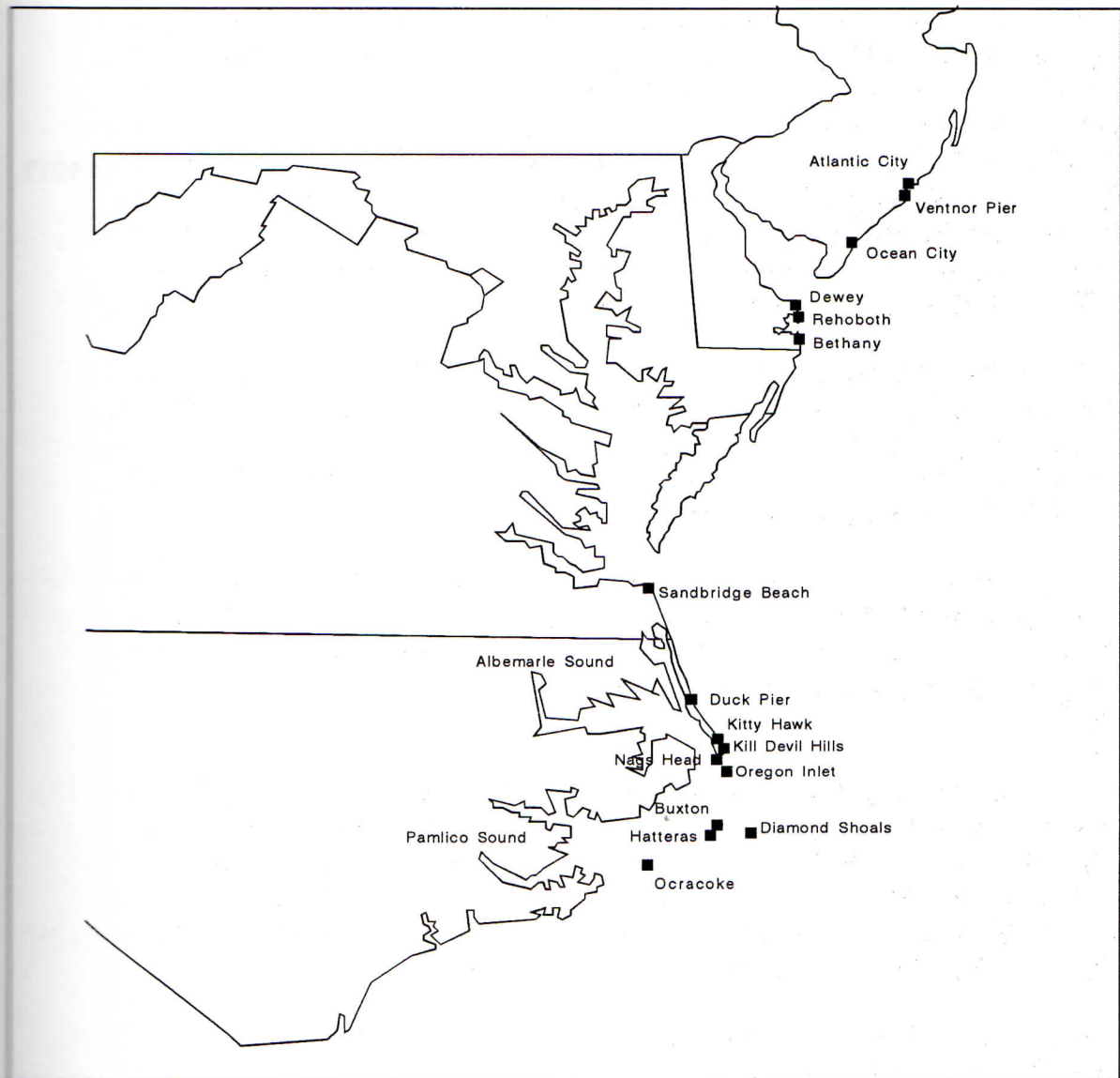


Figure 2. Mid-Atlantic Locations Impacted by the Halloween Nor'easter of 1991.

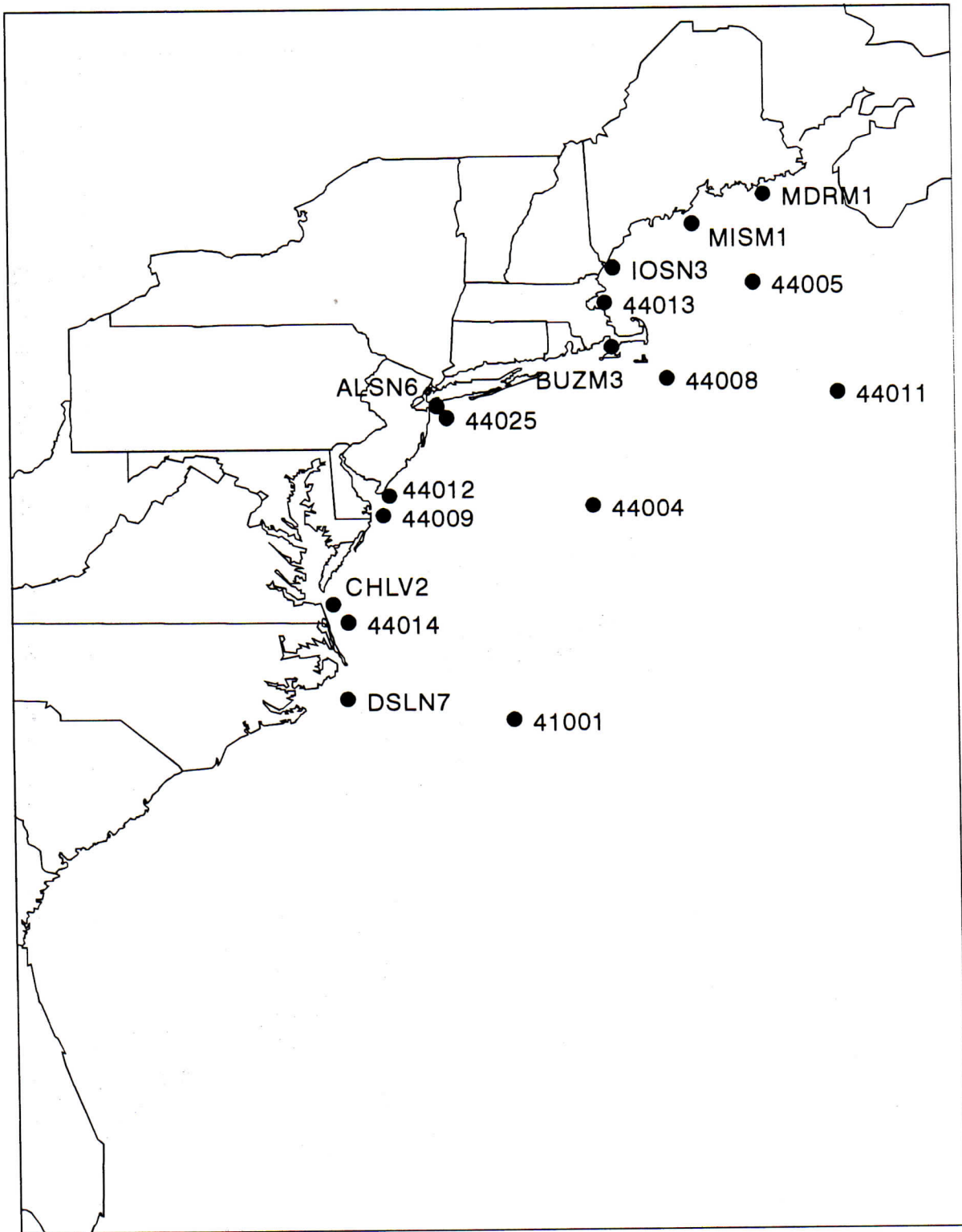


Figure 3. Buoy and C-MAN Stations - Mid-Atlantic and Northeast United States.

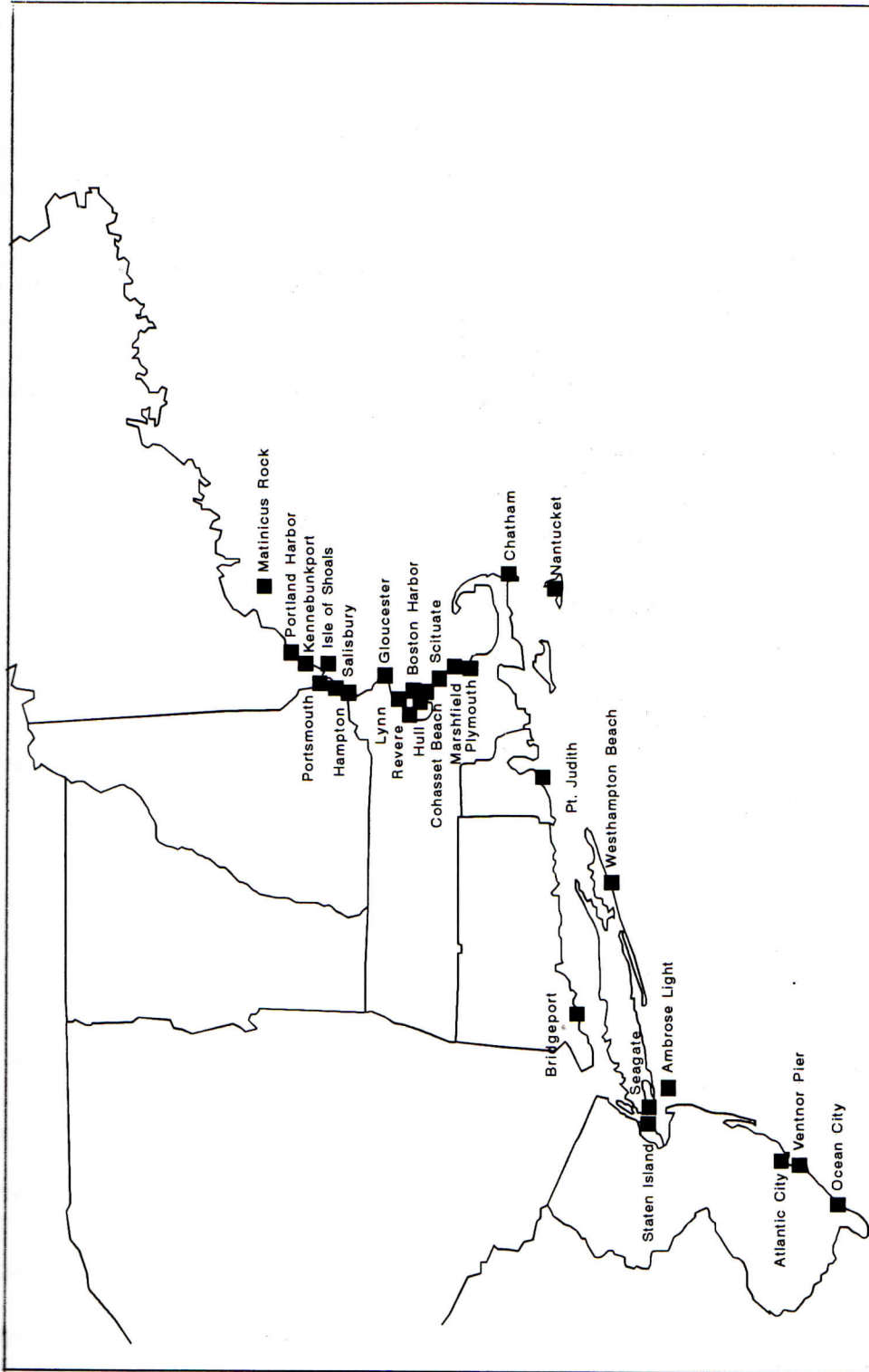


Figure 4. Northeast Locations Impacted by the Halloween Nor'easter of 1991.

(especially North Beach and Morris Island areas), and Nantucket (especially Brant Point). In the town of Scituate alone, according to the American Red Cross, over 1000 single-family dwellings were impacted by the storm with 118 destroyed and 453 suffering major damage.

Besides extensive structural damage to public and private facilities along the Massachusetts coast, considerable boating and fishing gear damage also occurred. The damage to and loss of lobster pots may well have devastating results to people in an industry that has already been experiencing hard economic times.

Relatively few casualties resulted in Massachusetts, however. A 62-year-old man suffered a fatal heart attack in Quincy after tying down his yacht. The Coast Guard is investigating the disappearance of the "Andrea Gail," a deep sea fishing boat with a crew of five out of Gloucester which was reported lost out in the Georges Banks. Two elderly people apparently suffered minor injuries from the wind on Nantucket. A summation of casualties and damages is included in table III.

The coastal flood damage dwarfed the significance of other aspects of the storm. However, because Massachusetts was close enough to the storm's core to receive its full effect, high winds resulted in some direct property damage and caused power outages by downed tree limbs. Additionally, heavy rainfall occurred in some southeastern areas of the state (e.g., 5.57 inches at Blue Hill, Massachusetts, Observatory).

Across coastal sections of Maine and New Hampshire, the most significant damage was limited to those communities which received direct wave battering from the ocean. According to the American Red Cross, 16 single-family dwellings were destroyed while another 51 suffered major damage in York County, Maine. Portsmouth, New Hampshire, suffered a similar blow with 19 single-family dwellings destroyed and 130 reporting major damage. The Hampton area of New Hampshire was also particularly hard hit. In Kennebunkport, outside of the destruction noted to the President's home, fishermen lost an estimated \$1.5 million in gear.

Rhode Island and Connecticut were somewhat protected from the most direct effects of the storm. However, some coastal damage similar to that described above was felt. Also, a fisherman was presumed to have been swept off the rocks and drowned near Pt. Judith.

The coastal regions of New York and New Jersey were impacted to a lesser degree, although extensive coastal flooding and beach erosion occurred (figure 5). Homes (basements and first levels), public buildings, coastal roads, and railroad tracks were flooded. In Suffolk County on Long Island's south shore, more than 40 residences were destroyed and another 35 seriously damaged. Also particularly hard hit was the private community of Seagate located just west of Coney Island in New York City.

**TABLE III
DAMAGE ESTIMATES (MILLIONS OF DOLLARS)**

Damage Estimates (millions of dollars)						
States	Death	Injury	Sum	AIA*	NFIP**	Other#
ME	0	0	3.0	-	1.5	1.5
NH	0	0	.7	-	.7	-
MA	2	2	110.1	40.0	65.6	4.5
RI	1	0	5.0	5.0	-	-
CT	0	0	3.9	3.0	.9	-
NY	4	0	31.2	10.0	16.2	5.0
NJ	0	0	8.4	2.0	5.4	1.0
DE	0	0	-	-	-	-
MD	0	0	-	-	-	-
DC	0	0	-	-	-	-
VA	0	0	.1	-	-	.1
NC	0	0	2.2	-	2.2	-
SC	0	0	-	-	-	-
GA	0	0	-	-	-	-
FL	0	14	3.1	-	-	3.1
PR	0	0	-	-	-	-
OFSHR	5	0	.5	-	-	.5
TOTAL	12	16	168.2	60.0	92.5	15.7

- Derived from statistics provided by the American Insurance Association (AIA). Claims represent losses primarily from wind damage.

- Derived from statistics provided by the National Flood Insurance Program (NFIP). Claims represent losses primarily from water damage.

- Damages were below the insurance organization's threshold, were considered to be too minor for tabulation, or were unreported.

Estimates of other losses were made where possible using existing information. However, millions of dollars in losses due to non-insured "public" items, such as cleanup costs, beach erosion, seawall and pier damage, lighthouse damage, etc., are not included in this list. Also not available are specific tourist dollar losses.

Portions of the boardwalks in Atlantic City and Ocean City, New Jersey, were extensively damaged. Further, the widespread flooding closed off two major roadways into Atlantic City for several hours. The resulting cancellation of buses carrying tourists into the cities' casinos caused a significant economic loss to the area.

The New York and New Jersey coastal regions witnessed at least four storm-related casualties. On October 30 at the height of the storm, an Air National Guard helicopter crashed about 60 miles south of Long Island during a rescue mission. (The helicopter ran out of fuel.) Four of the five-person crew were rescued; the fifth member was never found.

That same night, a man who was fishing alone on a Meadowbrook Parkway drawbridge fell to his death. The specific cause of his death is unknown. On November 2, the body of a teenage boy, believed to be 1 of 2 Staten Island youths who disappeared while fishing during the storm, washed up in the Belford section of Middletown Township. A Coast Guard helicopter unsuccessfully searched the area for the second youth. The Coast Guard did, however, successfully rescue 10 people from the turbulent waters of Long Island Sound during the storm.

Along the Delaware, Maryland, and Virginia coasts, moderate to severe beach erosion occurred primarily on October 30 and 31. In Delaware, damage was most extensive at Bethany, Dewey, and Rehoboth Beaches. Along the Virginia coast, most of the damage occurred along Sandbridge Beach. One bridge access washed out in Hampton Roads. In Maryland, Ocean City officials assessed the damage as "minimal." This may, however, have been the result of a beach renourishment/dune

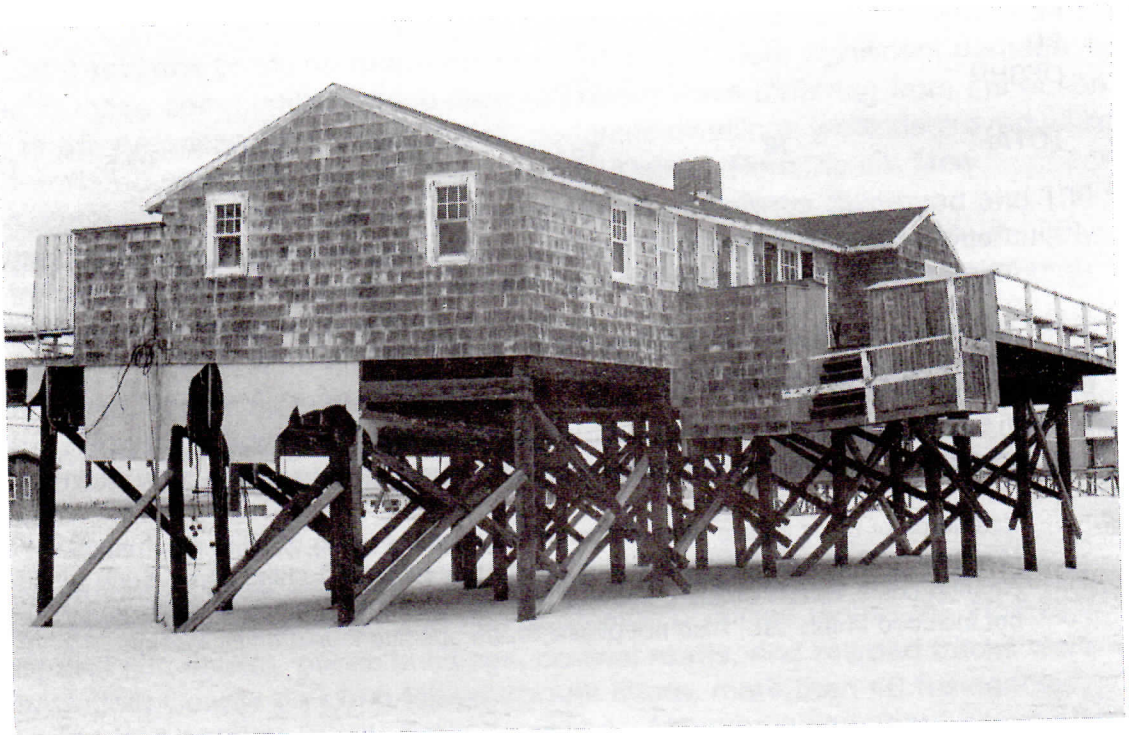


Figure 5. Support pilings, previously buried, have been exposed by severe water action, Westhampton Beach, New York. Photo courtesy of Mark Waters

project completed earlier this year designed specifically to protect the community from storms such as this.

While the Mid-Atlantic coastline of Delaware, Maryland, and Virginia was spared the worst effects of this event, the story was different for portions of the North Carolina shoreline. The extended effects of the storm were most apparent in this region. Sustained winds reached gale force on the Outer Banks, but the weather was characterized by mostly clear skies. Ocean flooding and waves were the only significant sources of destruction. Damage was limited to the ocean beachfront of Currituck and Dare Counties north from Cape Hatteras.

While flooding in North Carolina reached its maximum on October 31, pounding surf attacked and eroded the protective dunes for days before and after that time. Along the Cape Hatteras National Seashore, the dunes were cut in over a dozen places. Sand from the ocean side was washed hundreds of yards inland almost crossing the narrow island. Highway 12 was closed first by water and later by sand deposits up to 4 ft deep. Ferry service to Hatteras Island from Ocracoke was suspended because of flooding near the ferry dock.

The towns of Nags Head, Kitty Hawk, and Kill Devil Hills had flooding for several blocks inland from the beach. Several homes and two or three motels were destroyed or severely damaged by the surf. A total of 76 buildings were condemned in Dare County, North Carolina, alone. Many suffered structural damage while others were condemned because their sewage systems were exposed. The flooding has been called the worst to affect the Outer Banks since the Ash Wednesday Storm of March 1962.

South from North Carolina, damage was less severe and the impacted areas more widely separated. However, effects were reported even along the north coast of Puerto Rico, parts of the U.S. Virgin Islands, and exposed shores of the Bahamas. In Florida, over \$3 million in damage and 14 minor injuries were attributed to the swell generated by the storm. This included the destruction of that portion of the Lake Worth, Florida, pier on which an NOS tide gage and an NWS CMAN unit were located. Again, the wave action, spawned over 1000 nm from where the waves reached shore, was the primary cause of the damage.

Overall casualty and damage estimates from the storm are summarized in table III.

An additional factor should be noted. About a week after this storm, a second coastal flood episode impacted the Mid-Atlantic coast. Weakened by the battering from 7 days earlier, many coastal sand dunes could not provide the protection normally expected. Also, several structures that withstood the earlier assault fell during this second attack. These damages would probably not have occurred without the **Halloween Nor'easter of 1991.**

CHAPTER II -- SCIENTIFIC ANALYSIS OF EVENT

OVERVIEW

As briefly mentioned in Chapter I, three significant meteorological systems contributed to the coastal flooding and wave damage along the east coast of the United States during the week of October 27-November 2, 1991.

System number 1. On October 26, buoy reports indicated an intensifying subtropical low near Bermuda was beginning to generate large oceanic swells. By October 27, this low had evolved first into a tropical storm and then quickly strengthened to become a late season hurricane--Grace. Located about 200 nm southwest of Bermuda, Hurricane Grace was forecast by the National Hurricane Center (NHC) to move northwest, in a general direction toward the North Carolina coast, but to remain well offshore. The winds generated by this storm provided a significant northeast to easterly fetch along the United States east coast south of the Virginia Capes and were the primary cause of heavy surf along the Outer Banks.

System number 2. As Grace was intensifying, a near record 1046 millibar (mb) anticyclone which had been building over northern Quebec began spreading high pressure southward. By October 28, the leading edge of this deep air mass, marked by a strong cold front, had pushed southward through North Carolina east of the Appalachian Mountains and southeastward over the North Atlantic across Nova Scotia and New England. In so doing, it stopped the hurricane's drift toward the coast and forced it to turn northward. The high persisted through midweek dominating the entire Eastern Seaboard.

System number 3. As the cold front moved offshore, a low pressure cell, which had formed on and was traveling northeast along this front, reached the ocean southeast of the Canadian Maritimes. This occurred simultaneously with Grace reaching its maximum potency. Encountering Grace's circulation and moisture, this low stalled and strengthened. Fed by a combination of cold, dry, arctic air from the high and warm, moist, subtropical air from Grace, the low, located near 38°N 60°W, became extremely intense having a central pressure of about 972 mb. The rapidity of the intensification is shown by the fact that beginning at 12 Universal Coordinated Time (UTC), October 29, the central pressure dropped about 15 mb in 12 hours and about 28 mb in 24 hours. By this time, the low had sapped the energy and absorbed the remnants of Hurricane Grace and, as the high weakened, had begun a westward drift toward the upper east coast of the United States.

The combination of these three factors--hurricane, strengthening low south of the Maritimes, and high pressure along the East Coast--produced a nearly 1200 nm fetch of gale and storm force north to northeast winds from Newfoundland to the Florida coast which was to continue for days.

DAILY SYNOPSES

SATURDAY, October 26, 1991

At 06 UTC, satellite imagery and data buoy reports suggested that a surface subtropical low, centered at 27°N 66°W, was strengthening. In its high seas forecast, the NHC was carrying a gale warning in association with this system. At the same time the imagery hinted of some amplification of an inverted upper air trough to the northeast of this low.

The 00 UTC run of the NMC aviation weather forecast (AVN) model supported the continued amplification of the inverted trough by tightening the gradient north of 35°N during the next 48 hours. Such amplification generally indicates that the low will continue to intensify.

At this same time, a weak wave appeared in the lower Midwest, on a cold front extending northeast into Canada. This front denoted the leading edge of a deep, strong anticyclone that had formed over the Northwest Territories and intensified over Quebec.

Figures 6 through 17 contain extracts from the NMC surface analyses from October 27 through November 1. Figures 18 through 25 contain infrared (18-21) and water vapor (22-25) satellite photographs for this same period.

SUNDAY, October 27, 1991

At 16 UTC, the subtropical low, now located at 30.4°N 66.6°W, had intensified and reached tropical storm status. NHC named it Grace. Satellite imagery indicated it had a slow westward movement. Storm force winds extended out to 350 nm from Grace's center over its northern semicircle while winds to 30 knots (kt) continued out another 130 nm. By 22 UTC, Grace, continuing to strengthen, was upgraded to hurricane status.

Coincidentally, a strong short-wave trough aloft, associated with the Canadian cold front, moved along the U.S.-Canadian border throughout the day. During the night, the cold front passed through New England toward the south and southeast. The wave, now a low but still weak, was centered over eastern Lake Ontario and was forecast by the AVN model to move east-southeast to roughly 43°N 58°W. At this same time, the high, continuing to build, was forecast to follow along moving from just east of Hudson Bay to the east-southeast. The result of all this would be a greatly increased pressure gradient along the east coast of the U.S. during the next 36 hours.

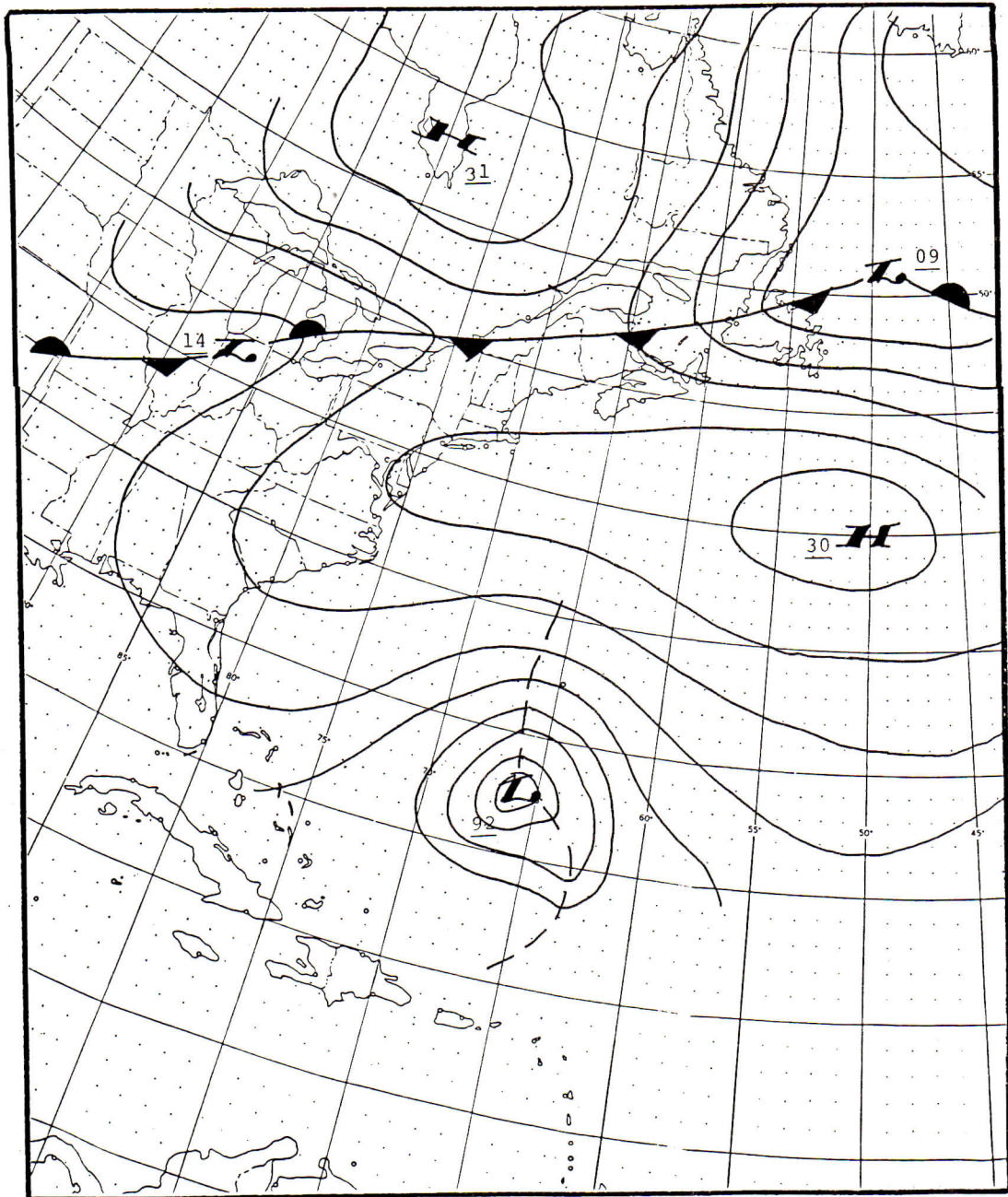
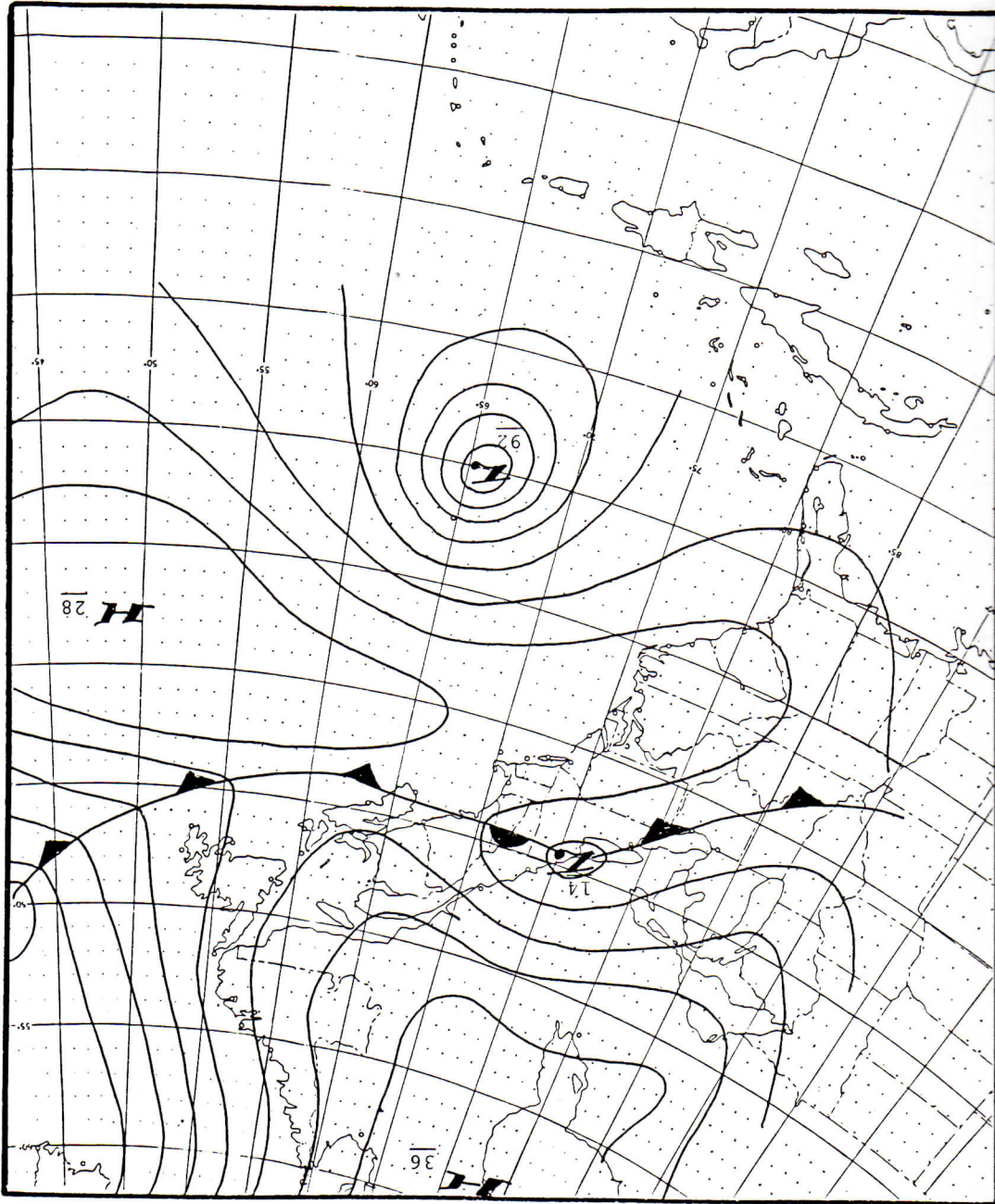


Figure 6. 0000 UTC Surface Analysis - 27 October 1991.

Figure 7. 1200 UTC Surface Analysis - 27 October 1991.



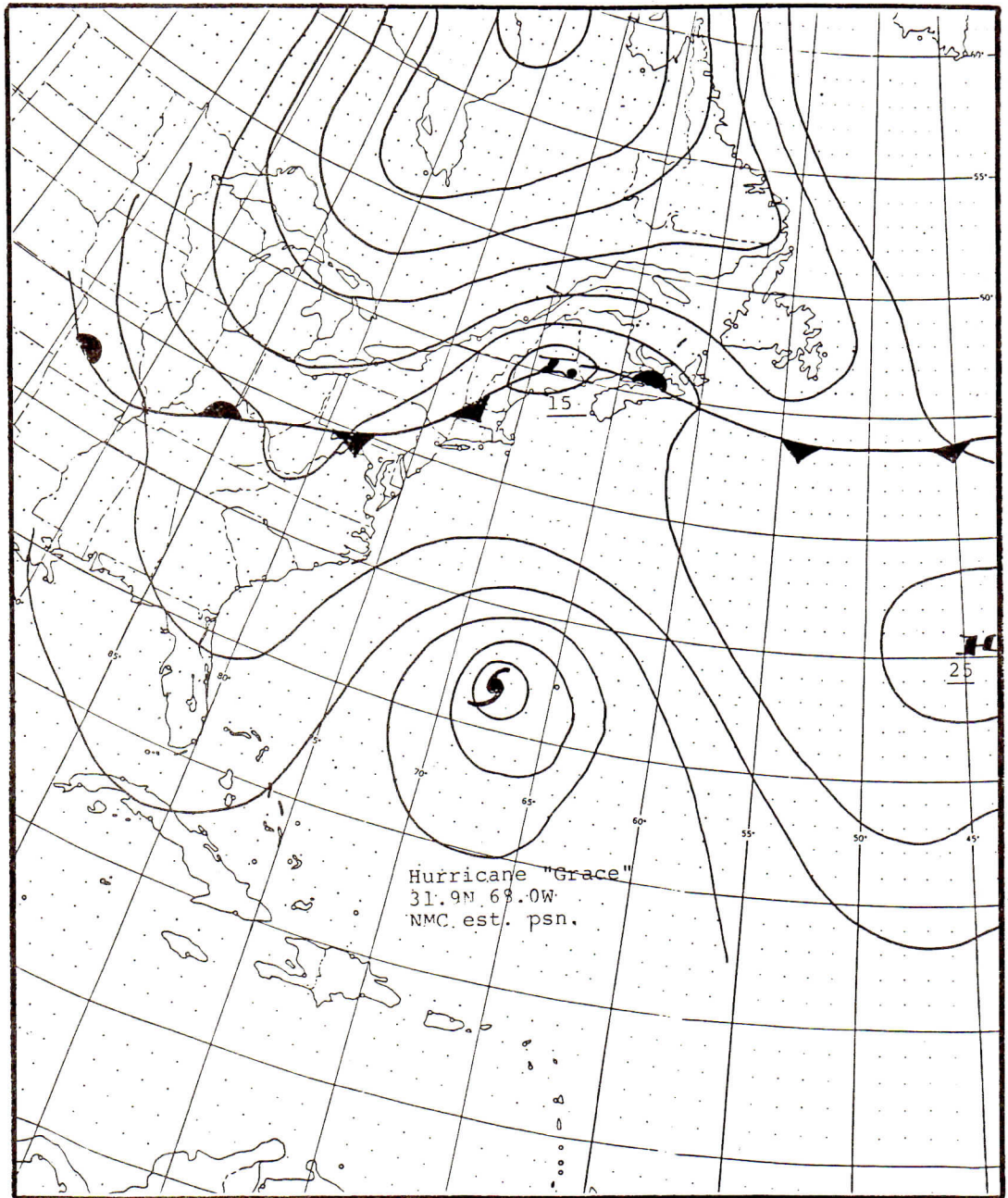


Figure 8. 0000 UTC Surface Analysis - 28 October 1991.

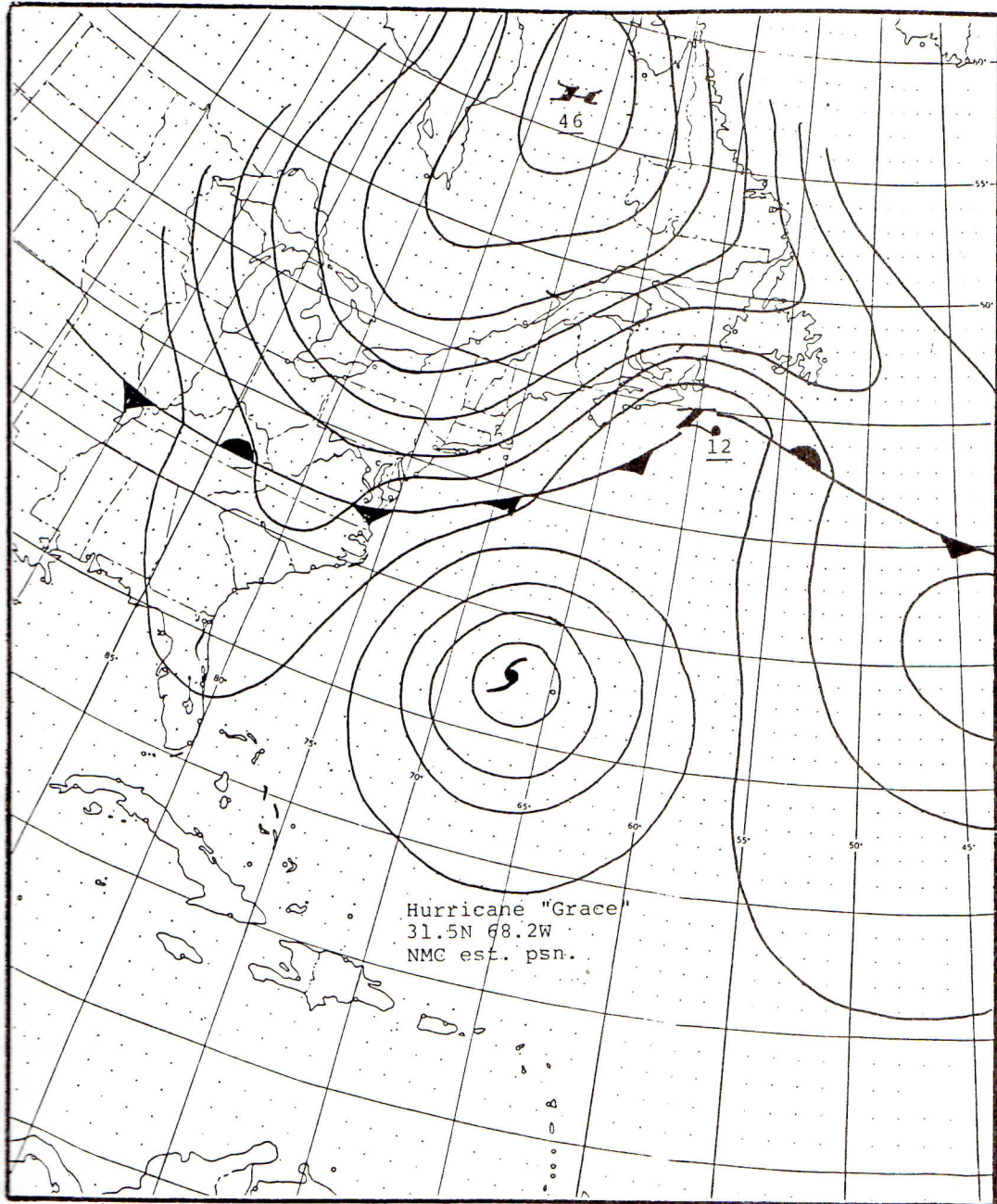


Figure 9. 1200 UTC Surface Analysis - 28 October 1991.

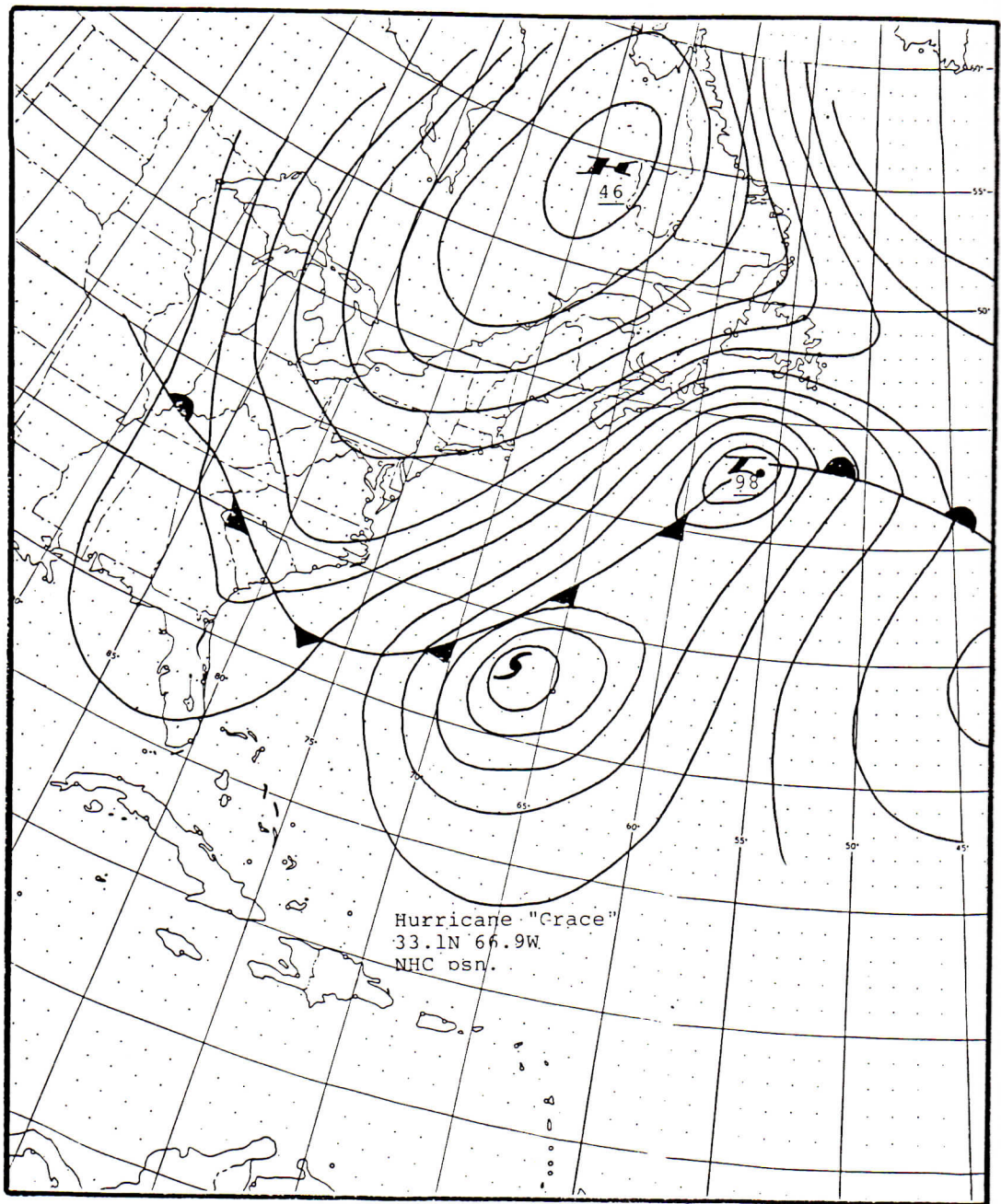


Figure 10. 0000 UTC Surface Analysis - 29 October 1991.

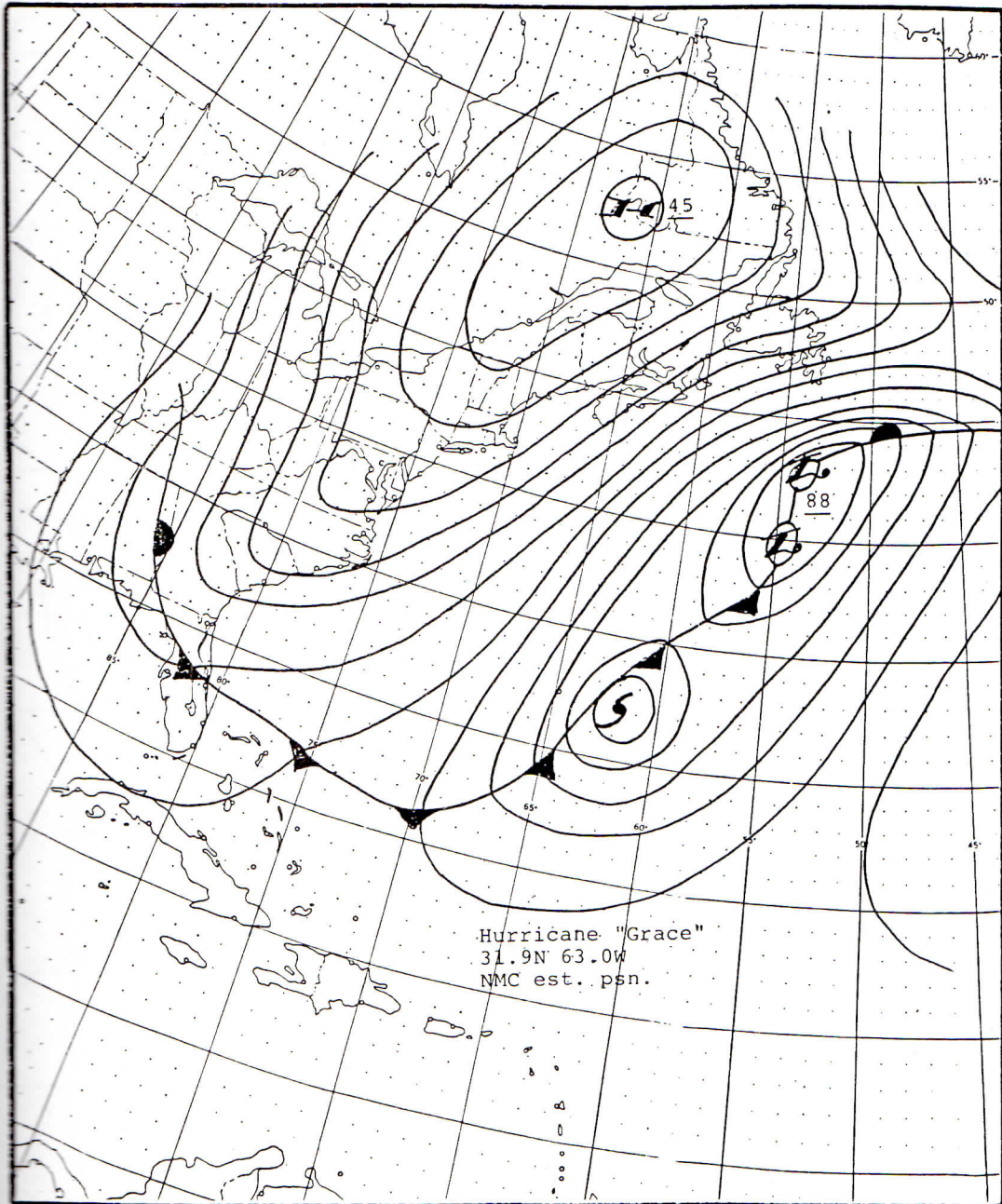


Figure 11. 1200 UTC Surface Analysis - 29 October 1991.

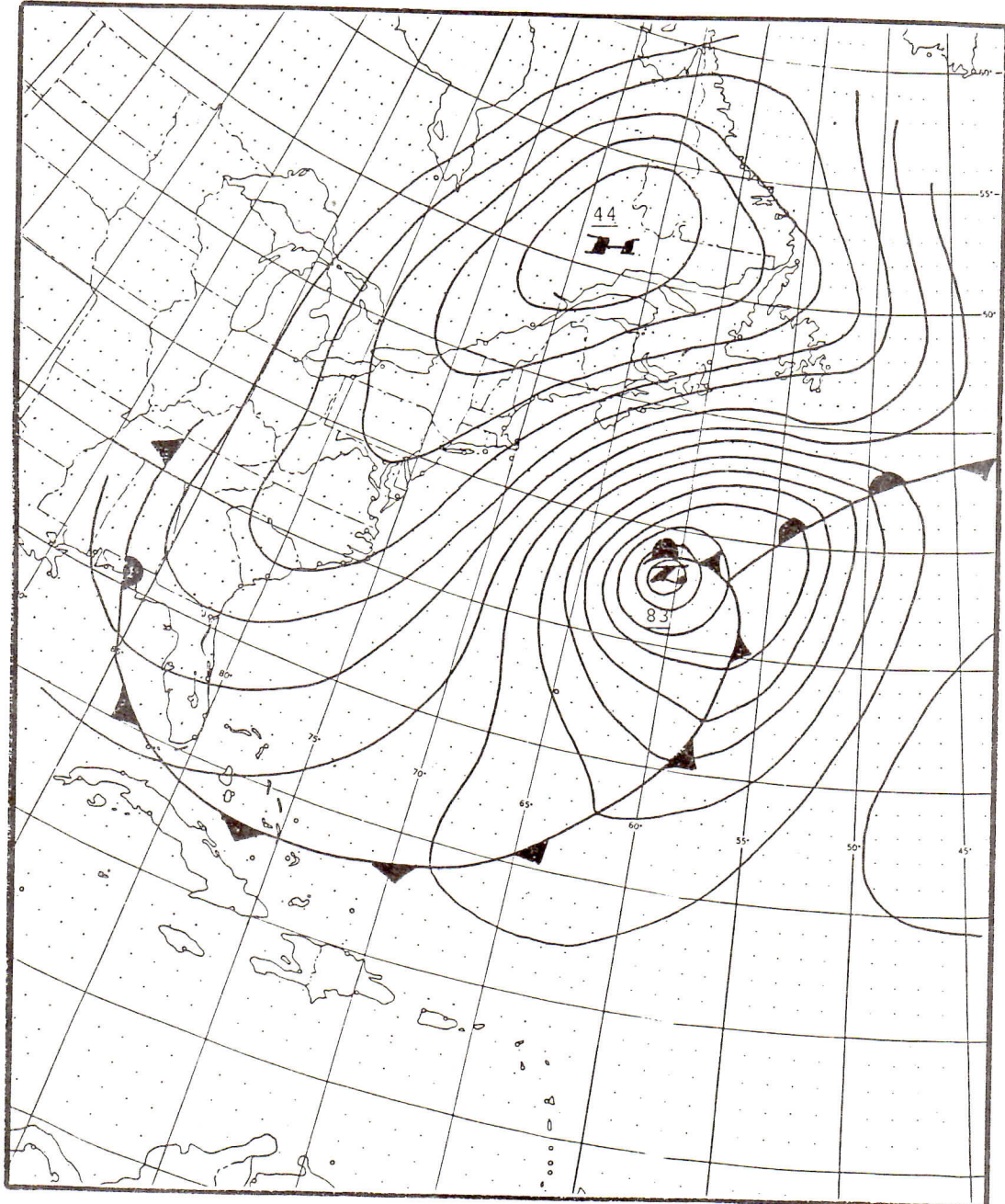


Figure 12. 0000 UTC Surface Analysis - 30 October 1991.

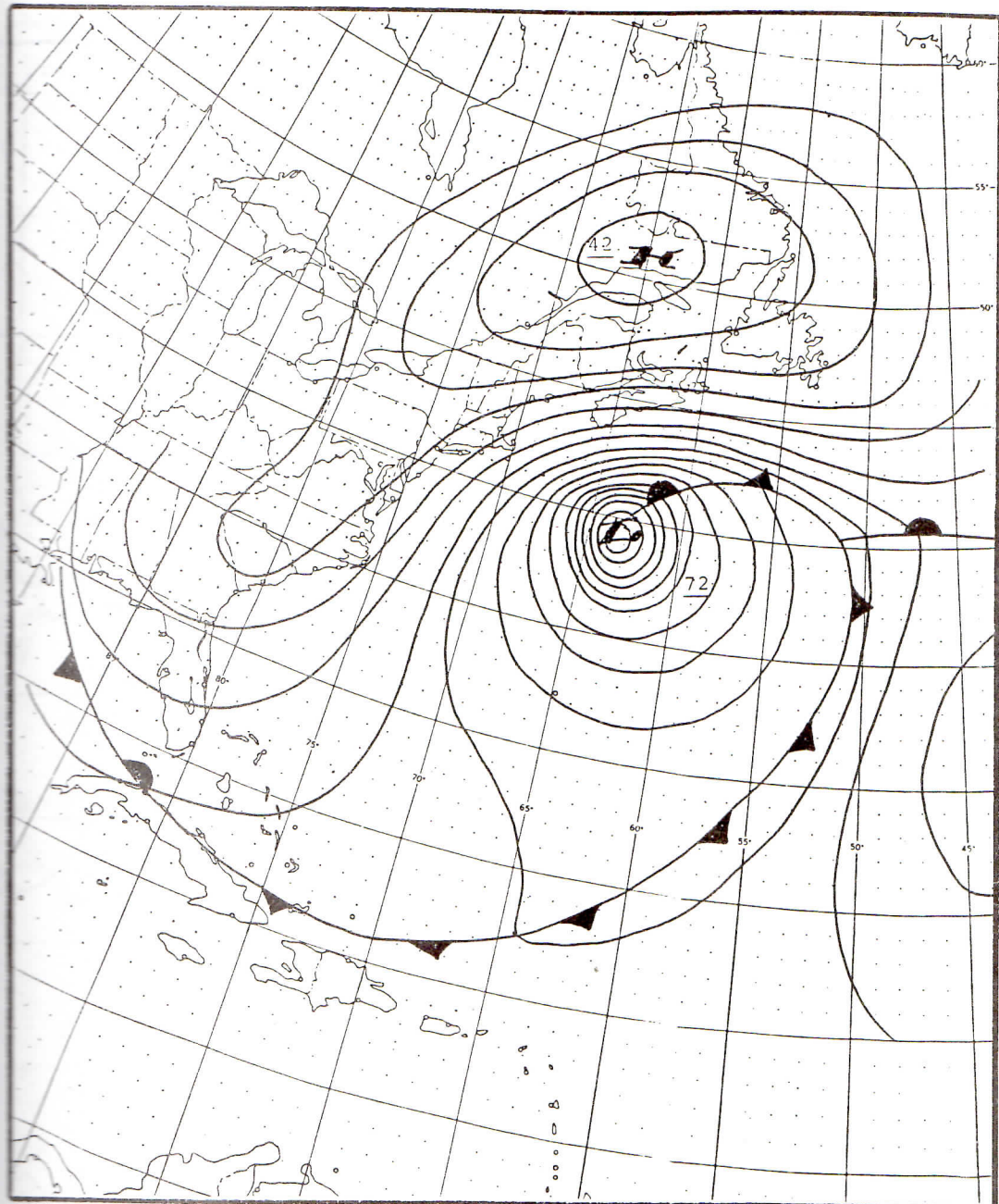


Figure 13. 1200 UTC Surface Analysis - 30 October 1991.

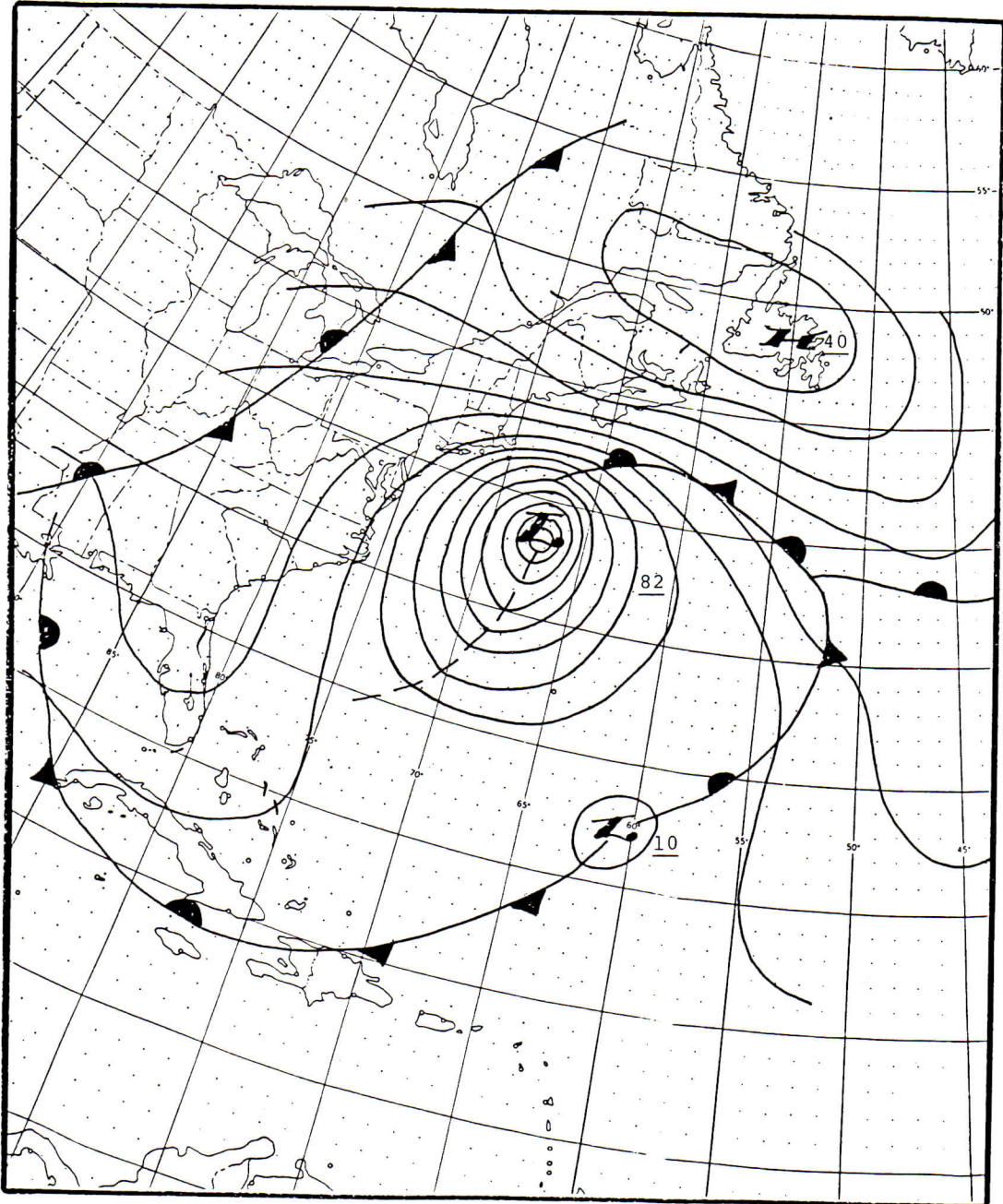


Figure 14. 0000 UTC Surface Analysis - 31 October 1991.

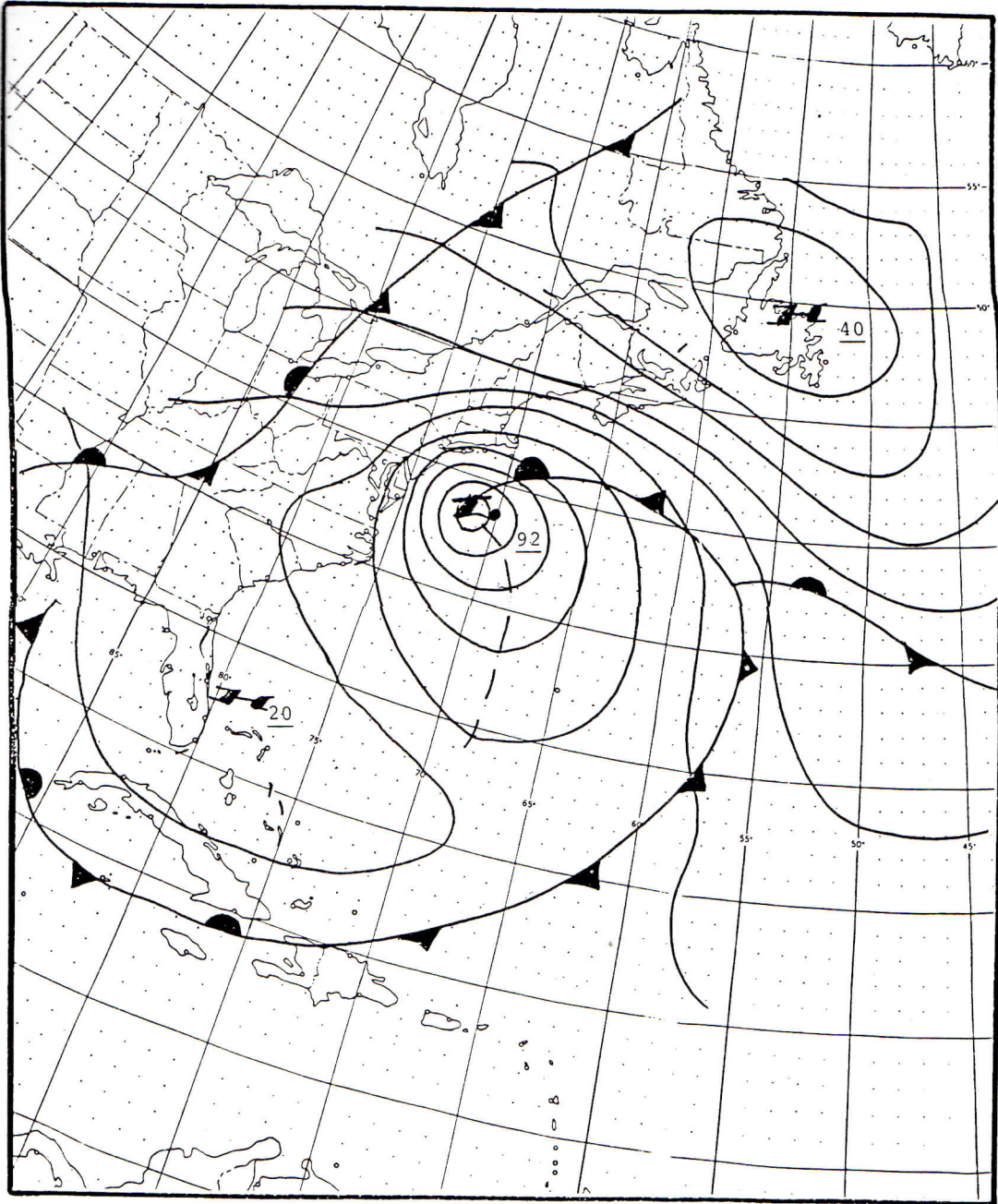


Figure 15. 1200 UTC Surface Analysis - 31 October 1991.

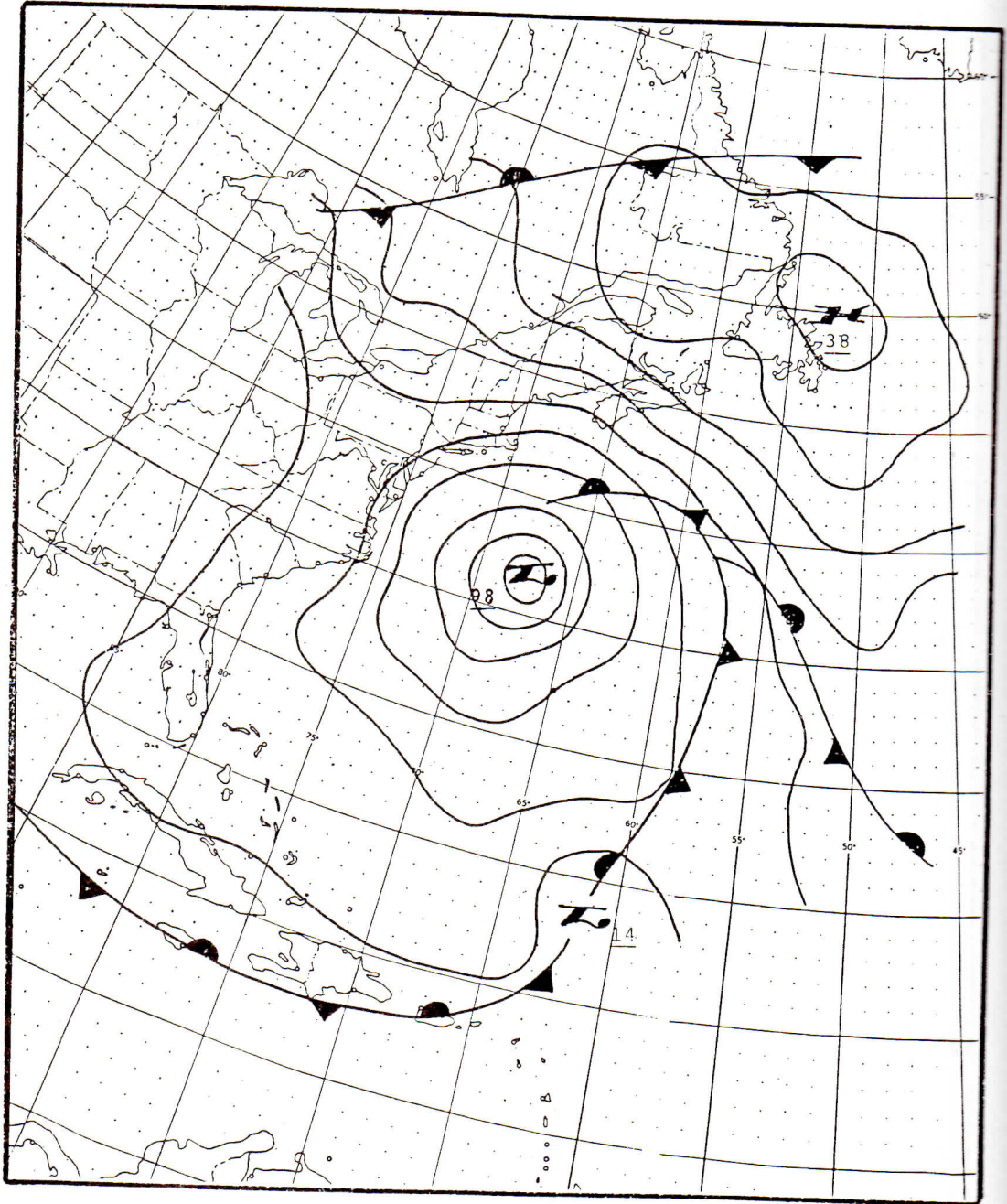


Figure 16. 0000 UTC Surface Analysis - 1 November 1991.

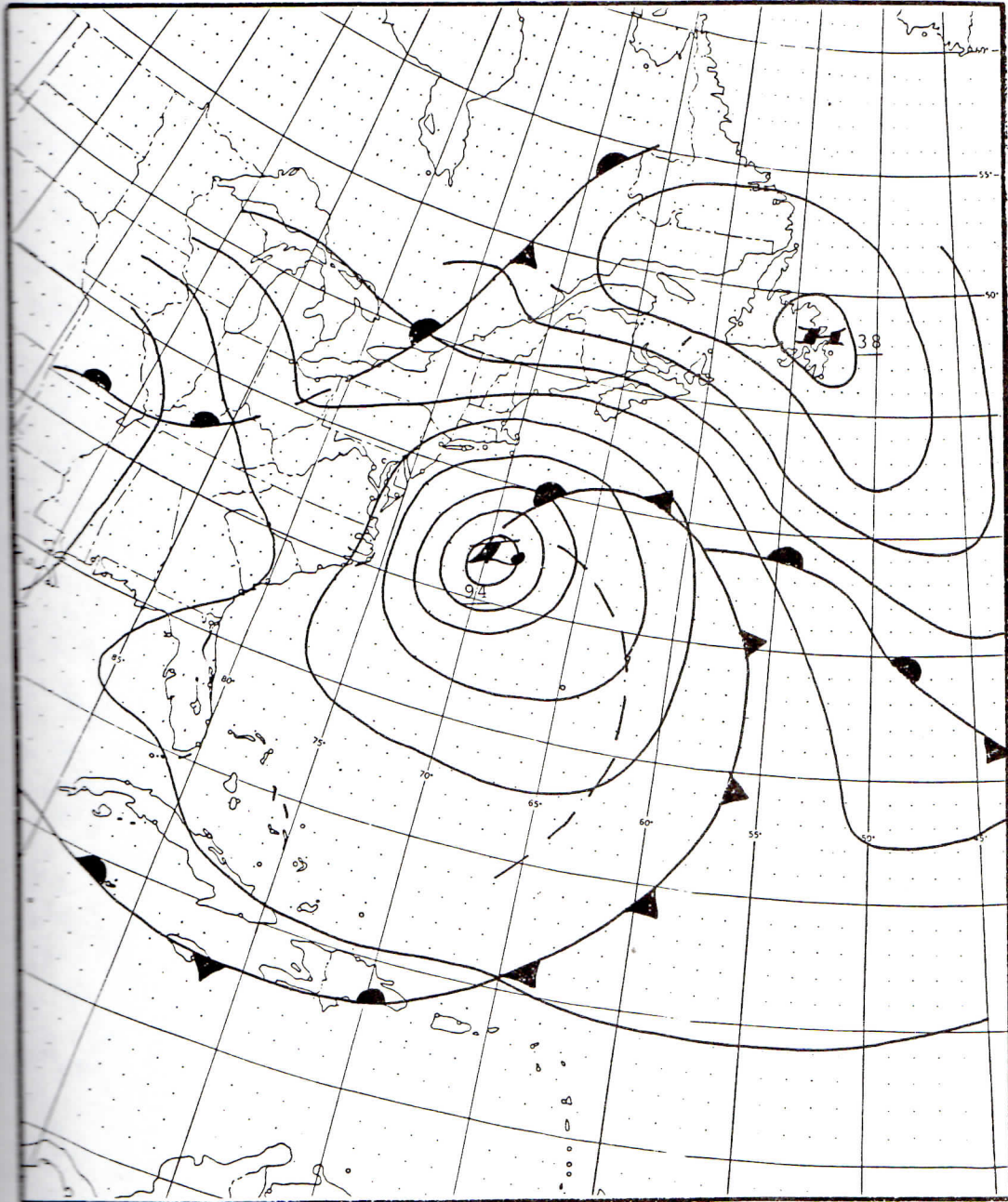


Figure 17. 1200 UTC Surface Analysis - 1 November 1991.

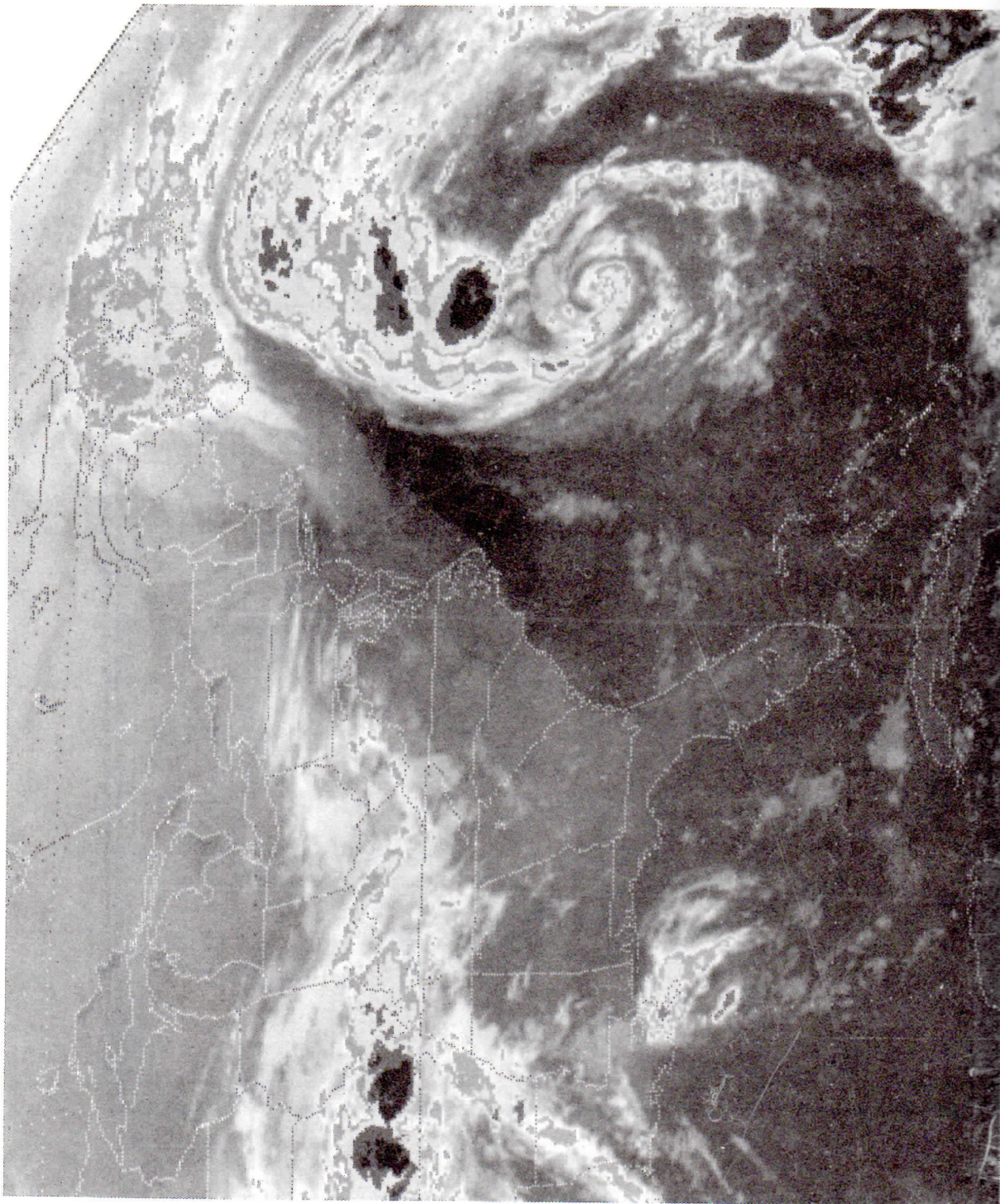


Figure 18. 1201 UTC 28 October 1991 GOES Infrared Image - Hurricane Grace near Bermuda/Developing Low east of Maine

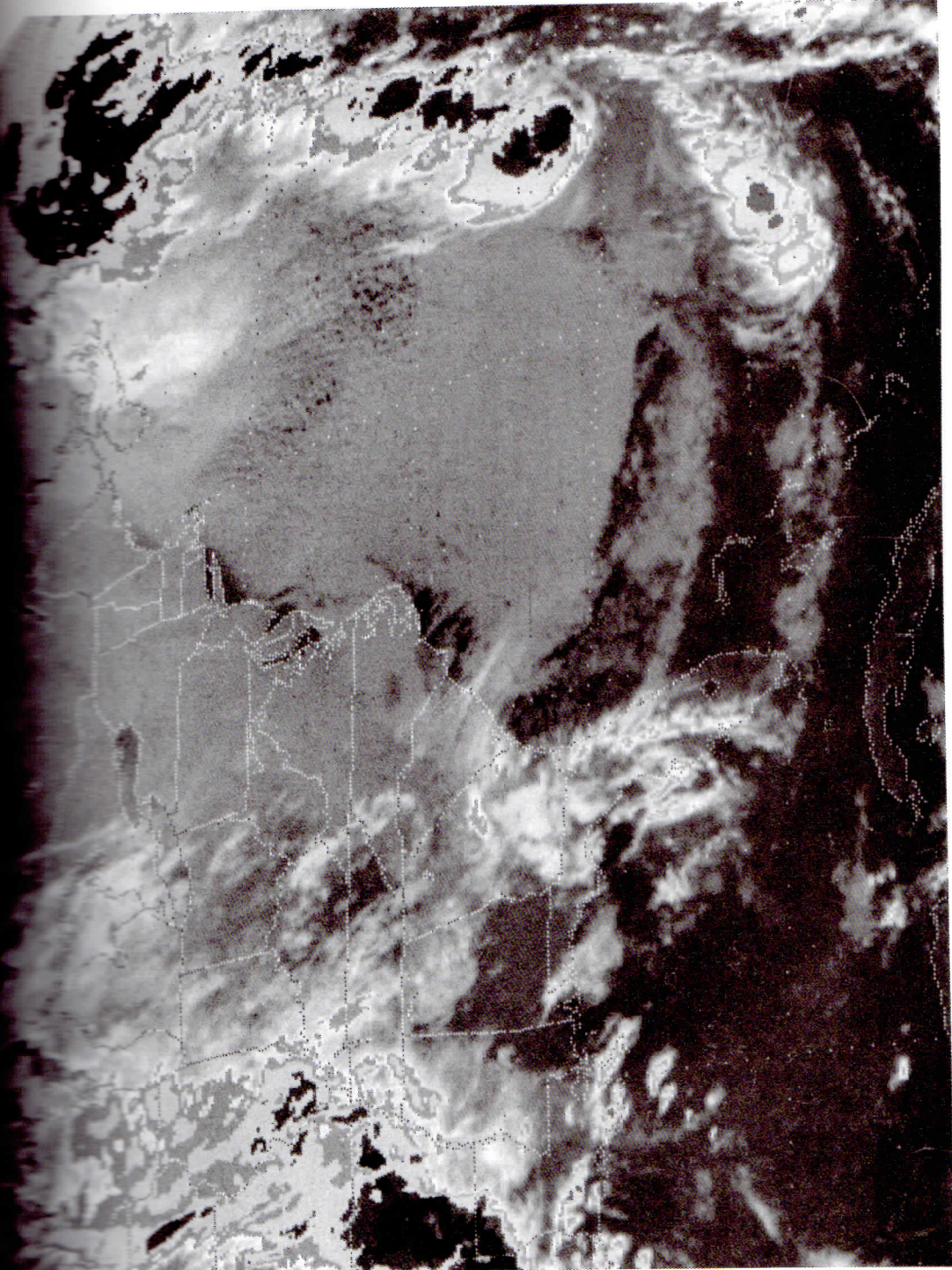


Figure 19. 1201 UTC 29 October 1991 GOES Infrared Image - Cold front from North Atlantic Low is nearing Grace.

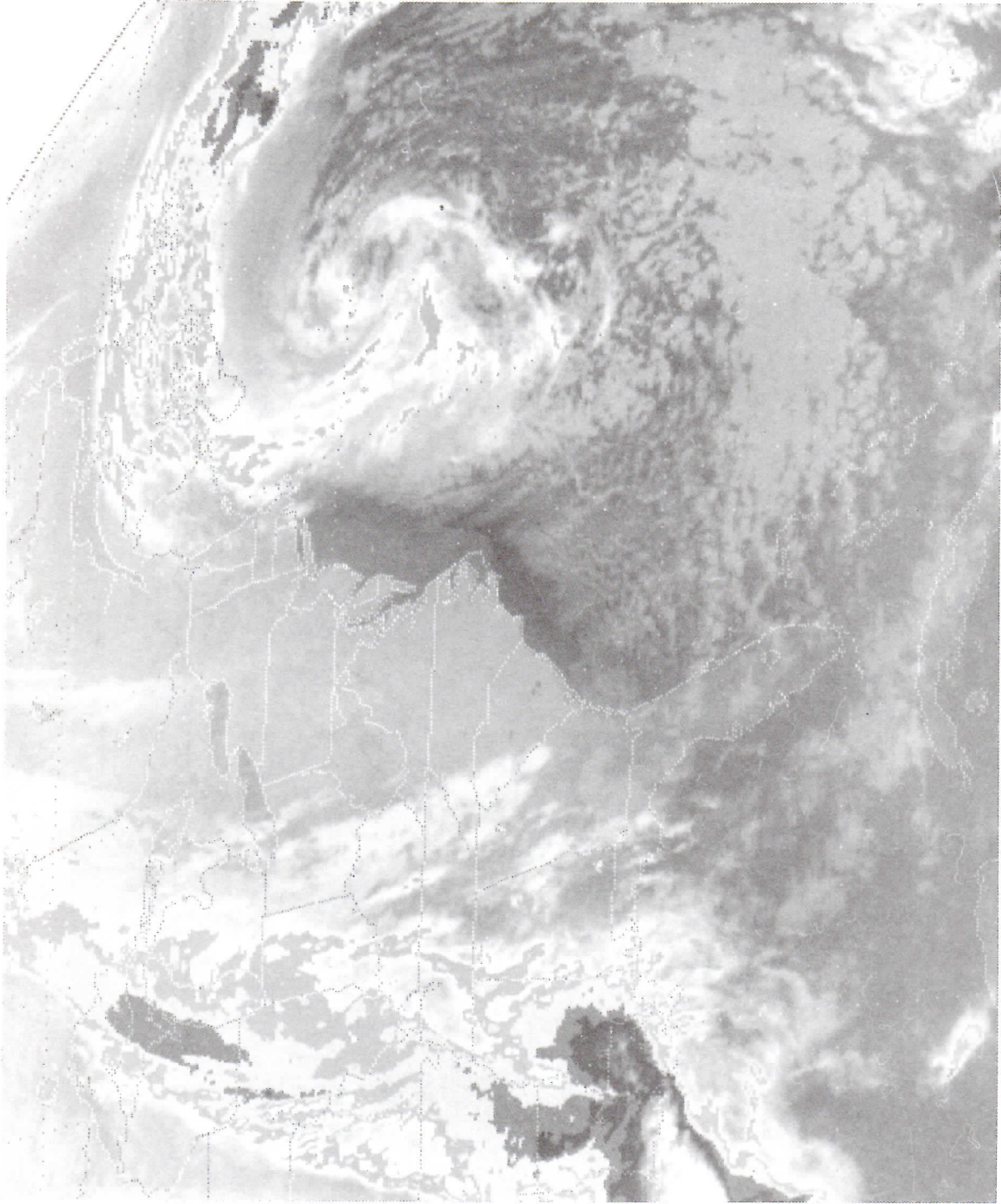


Figure 20. 1201 UTC 30 October 1991 GOES infrared Image - North Atlantic Low at its most intense.

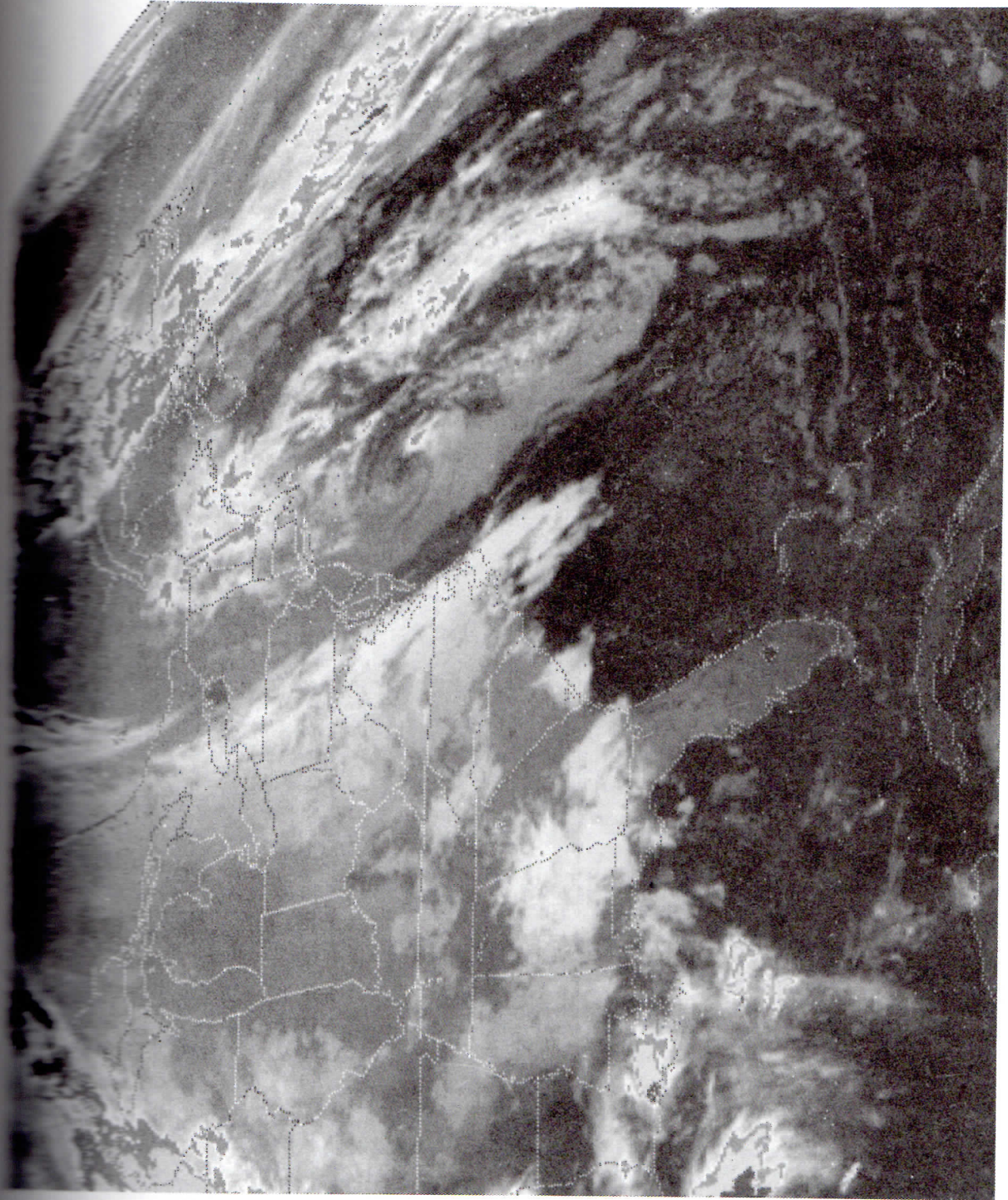


Figure 21. 1201 UTC 31 October 1991 GOES Infrared Image - North Atlantic Low weakening off mid-Atlantic coast.

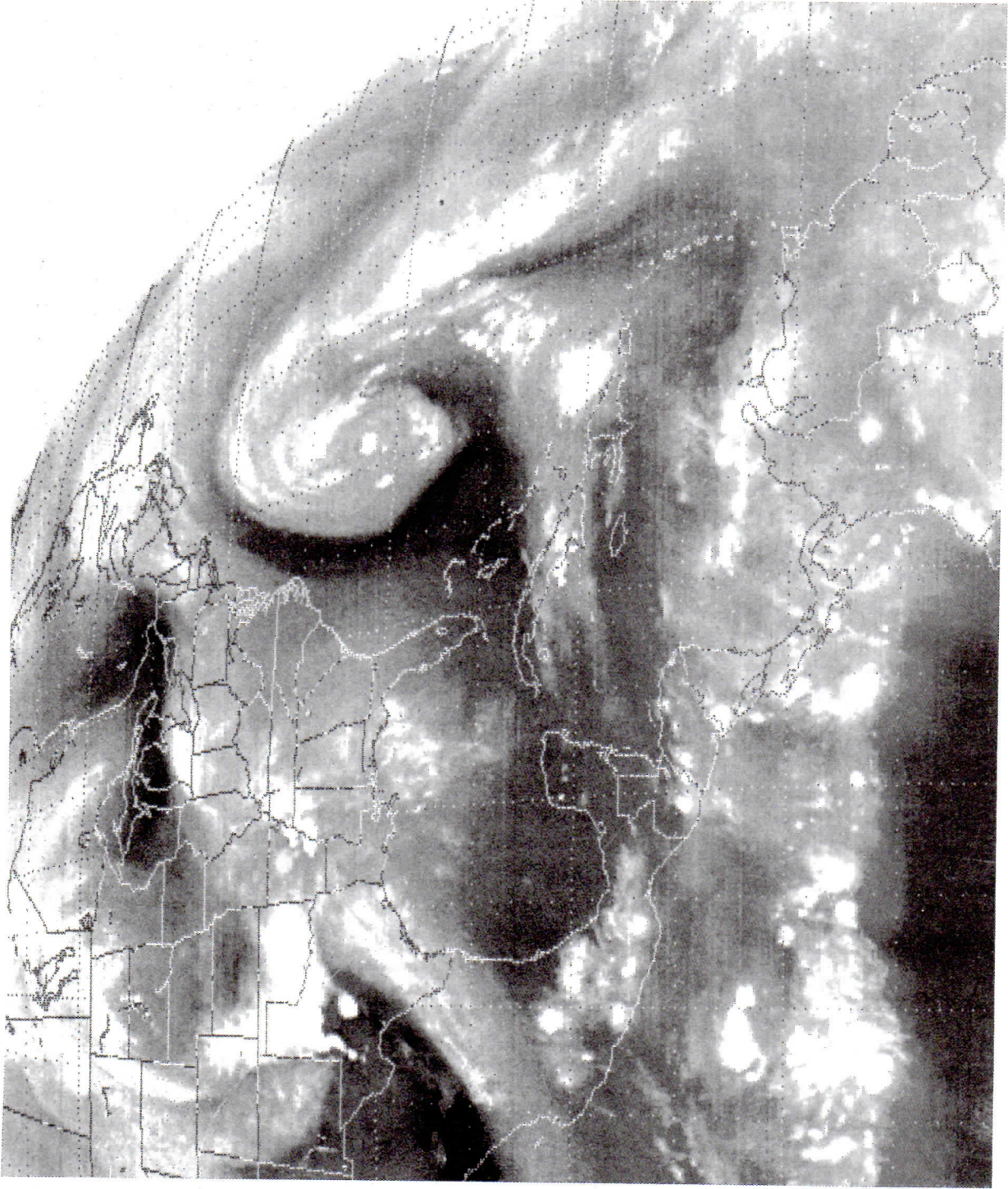


Figure 22. 0301 UTC 28 October 1991 GOES Water Vapor Image - Grace off Bermuda. Dry Canadian High north of New York.

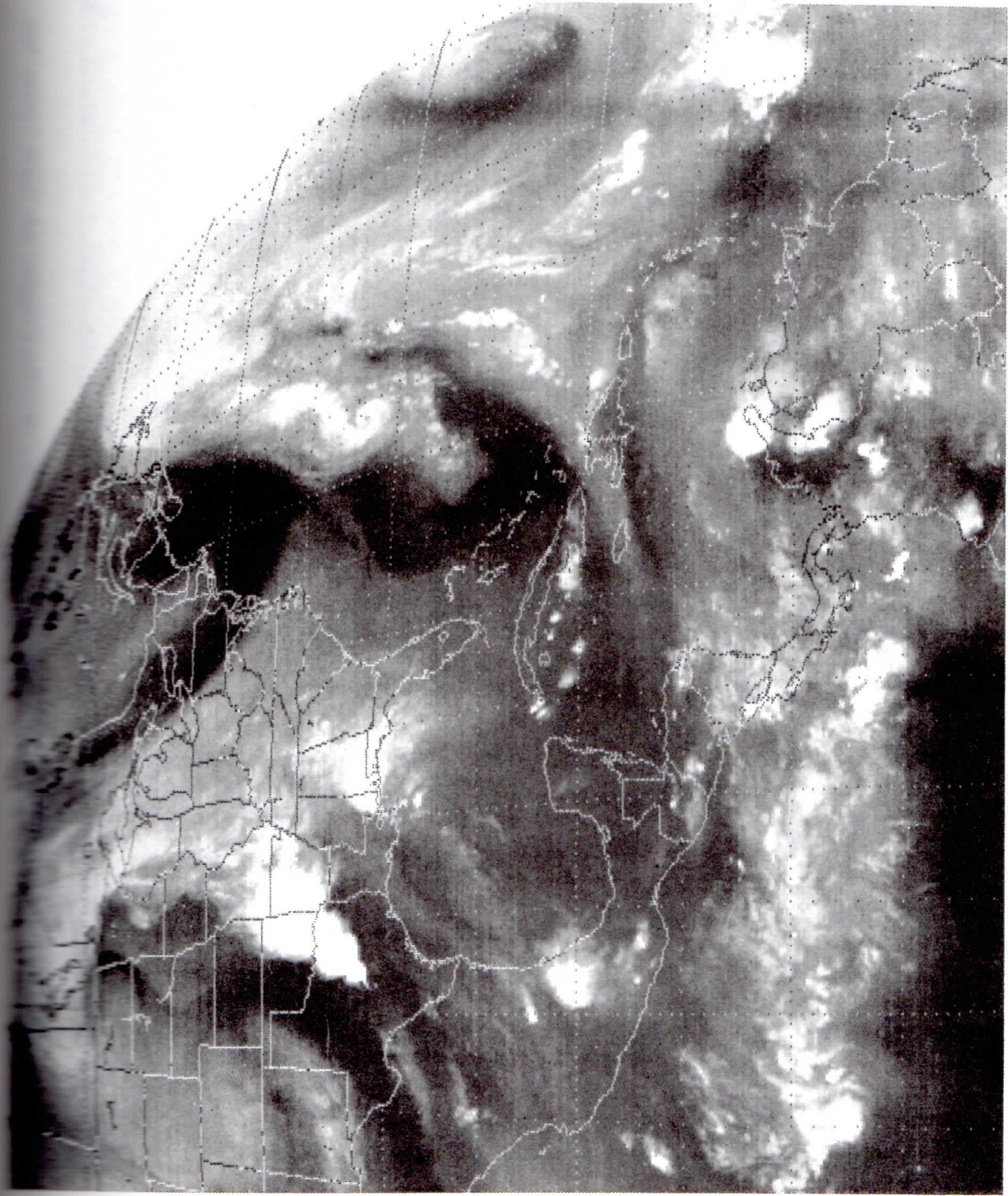


Figure 23. 0301 UTC 29 October 1991 GOES Water Vapor Image - Weak eye of Grace still visible. Dry Air over Northeast U.S.

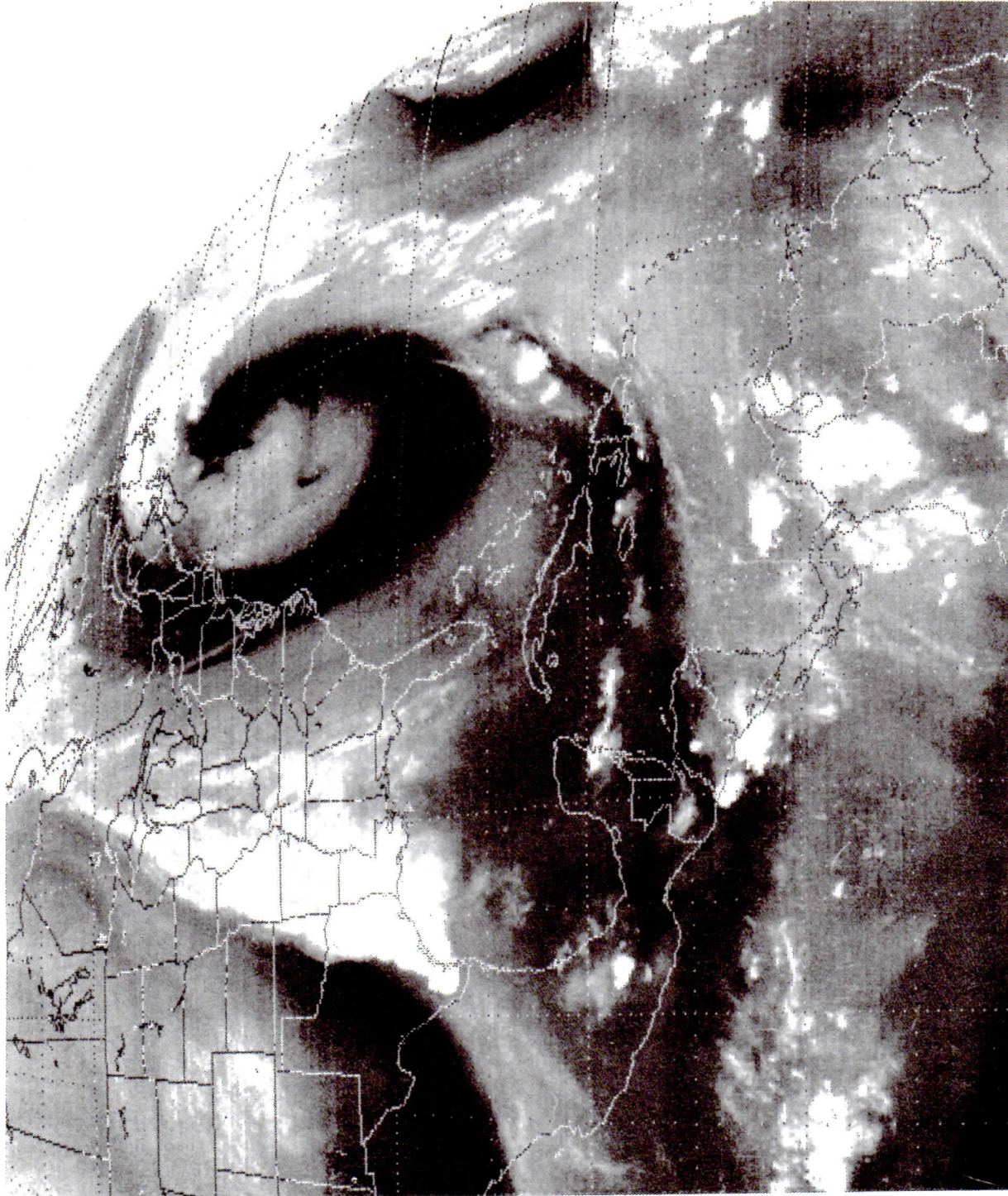


Figure 24. 0701 UTC 30 October 1991 GOES Water Vapor Image - Dry air being wrapped into North Atlantic low.

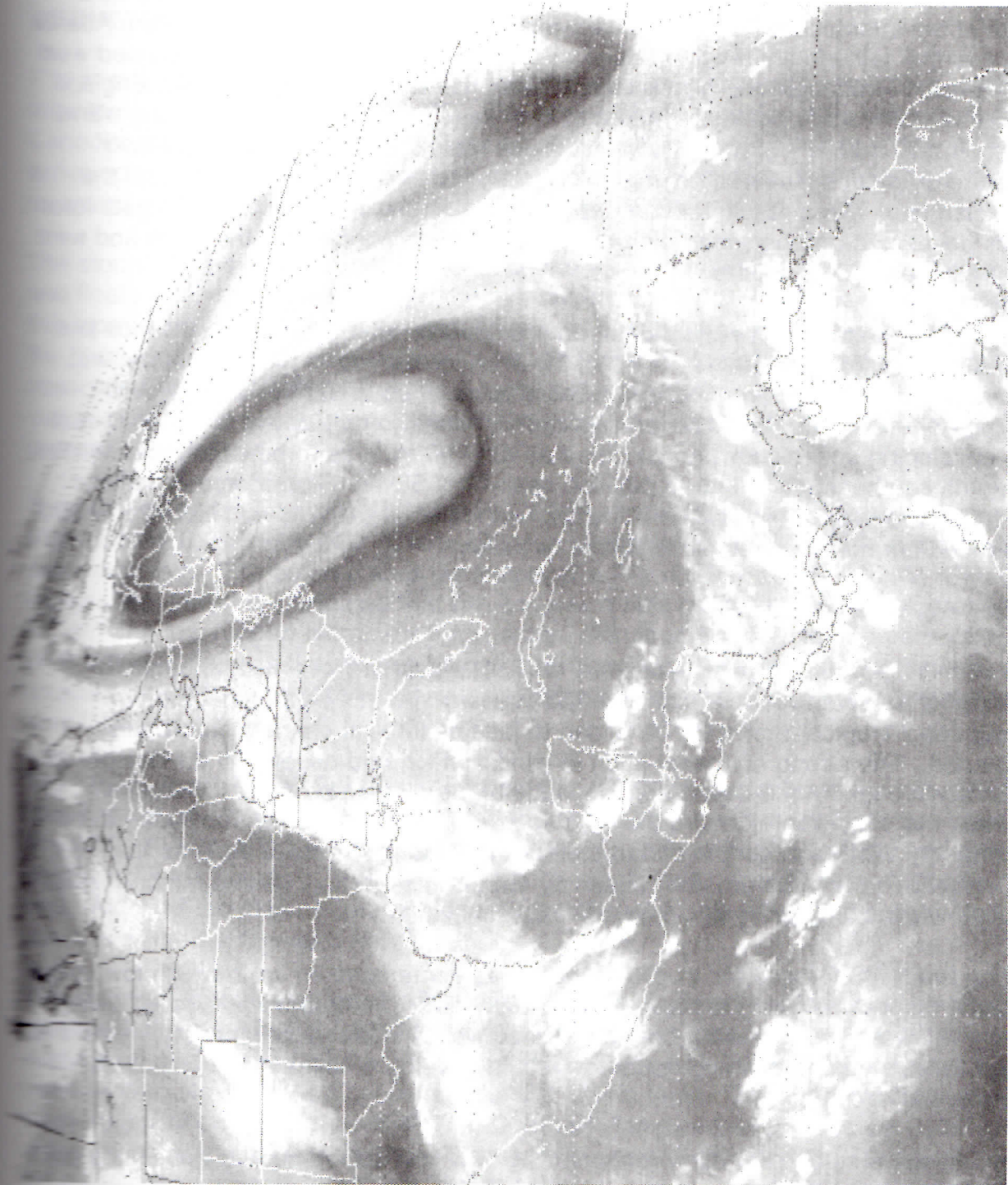


Figure 25. 0301 UTC 31 October 1991 GOES Water Vapor Image - Dry air has wrapped 1 1/2 times around North Atlantic Low.

MONDAY, October 28, 1991

On October 28, a strong surface low pressure system had developed southeast of Nova Scotia from what was originally the weak midwestern wave. This came as a result of the interaction of the now quasi-stationary upper low over the western Atlantic with a higher latitude short-wave trough. Further, Hurricane Grace, now situated west of Bermuda, and the strong high pressure area, now centered north of New England and at its near record peak strength, added to this intensification by supplying warm, moist air and cold, dry air, respectively. These events led to a greatly tightened pressure gradient between the surface low, the now dissipating hurricane, and the Canadian high. As a result, late on October 28, a strong northeast fetch of gale force winds developed and persisted over the oceanic area especially to the north and west of the deepening low near Nova Scotia.

The 00 UTC, October 28, AVN model run dramatically strengthened the surface low. By early morning, the extreme nature of the situation, hinted at the day before, was apparent. At the same time (16 UTC) Grace, positioned at 32.7°N 68.3°W, was moving north at 5 kt. The NHC forecast the hurricane to drift slowly to the northeast. The developing oceanic low, now located at 43°N 60°W, was forecast to move toward the south-southeast at 10 kt to a position near 40°N 58°W. Storm-force conditions were forecast to exist by 00 UTC Tuesday. Winds of 50 to 75 kt with seas 25 to 36 ft within 400 nm northwest semicircle were forecast.

TUESDAY, October 29, 1991

The oceanic storm, previously stationary well southeast of Nova Scotia, began to develop to the southwest and continued to intensify. At this same time, the now downgraded Tropical Storm Grace began to lose its tropical characteristics and weakened. The strong northeast fetch of winds, which had developed on October 28, persisted throughout the day, a consequence of the surface pressure differential between the Canadian high and the Atlantic low. The swell activity continuing to be spawned by this storm contributed to the start of beach erosion as early as the night of October 28, while the erosion caused by Grace was abating. Some minor coastal flooding was also reported at Chatham, Massachusetts.

Among the NWS forecasters involved, there was some concern as to which low center the AVN model was trying to move to the southwest. The model was strengthening an upper low and suggested a drift to the southwest. The satellite imagery seemed to indicate that the strengthening upper low would develop a new surface low center which would intensify.

The dangerous storm previously forecast was now fact. Movement to the southwest at 10 kt was indicated. Lists of observed ship data confirmed the degree of intensity associated with the wind and swell conditions. Two ships just east of Georges Bank,

for example, reported 40 and 43 ft combined seas. In the forecast, initial conditions were listed as winds 50 to 75 kt and seas 35 to 50 ft within 400 nm over the northwest semicircle.

WEDNESDAY, October 30, 1991

The strong northeast fetch of gale and storm force winds persisted over the ocean area through the night of October 30. The strong pressure differential between the Canadian high and the Atlantic low was maintained throughout the day. This extratropical storm continued moving west, entrained the tropical moisture from the remnants of Tropical Storm Grace, and intensified further.

The storm continued west-northwest during the afternoon before turning southwest and finally beginning to weaken on the night of October 30. Since the movement of this storm was northeast to southwest, it arrived along the coastal United States via the "back door." As a consequence, the normal experience of increasing cloudiness associated with nor'easters at most of these coastal locations did not occur. The majority of people along the Eastern Seaboard awoke Wednesday morning to generally clear skies.

The NMC surface plot at 12 UTC showed a 977 mb pressure measurement from a ship located at 39.5°N 63°W. The associated winds were given as 40 kt out of the east-southeast. The surface analysis indicated a 972 mb low at 39°N 64°W. Satellite image data, however, indicated that the low was a little farther north centering at 40°N 64°W. The low had an extremely tight center. Winds of 55 to 70 kt and seas of 35 to 50 ft within 300 nm of the storm's northern semicircle and western quadrant were forecast by SMS. This placed the western edge of the area of strongest winds directly over Cape Cod.

The Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) Data Utilization Center (VDUC) indicated the speed of the low to be 20 kt due west. The NMC AVN and Nested Grid Model (NGM) were slow with the feature, had positioned it too far south, and showed it to be significantly weaker than it actually was. Much of the major damage along the southeastern New England coast was to occur over the next several hours.

The duration, length, and areal extent of the fetch associated with this oceanic storm produced offshore seas reported to be 40 to 78 ft high. Closer to shore over the continental shelf, seas built up as high as 25 to 40 ft. Gale force winds along the southeastern New England coast increased to storm force. The Weather Service Meteorological Observatory (WSMO) in Chatham, Massachusetts, recorded wind gusts greater than 60 mph for more than 15 straight hours and greater than 70 mph for 6 hours. Compounding the problem, the strongest winds occurred near or shortly before the afternoon high tide.

The most severe coastal flood damage was reported along the Massachusetts coast in conjunction with the high tide. In Boston, this came at 4:33 pm while in Chatham at 5:05 pm. Tides were estimated to be 3 to 4 ft above the normal high tide along the entire Massachusetts coast. At Boston, the peak tide during this storm was 14 feet above Mean Lower Low Water (MLLW). The timing of the strongest winds with the incoming high tide resulted in a tremendous build-up of seas just offshore and produced destructive wave action.

THURSDAY, October 31, 1991

The low was now at 38°N 71.5°W. Unlike most extratropical lows, it had formed and maintained a well defined "eye." One ship reported winds of 55 kt within 60 nm to the west of the storm's center. However, removed from its cold air source, the high pressure air mass was becoming modified and the low, no longer able to feed off its previous energy sources, was filling. All NMC models now showed that by Friday the storm would rapidly weaken and move to the northeast.

Although weakening, the system still generated a significant northeast wind and continued to cause tides to be well above normal. However, the damage caused by towering coastal waves did diminish. By this time, some of the more protected areas had been affected. For example, Bridgeport, Connecticut's, Sikorsky Airport, at the western end of Long Island Sound, experienced runway flooding Thursday morning forcing a temporary closing of the airport.

FRIDAY, November 1, 1991

During the day, wind and sea conditions diminished considerably along the coast as the large-scale pressure gradients abated. However, as the low pressure center continued eastward, it moved over the warm Gulf Stream. The infusion of new energy from this source reintensified the storm, again generated storm force winds and, as seen on satellite photographs, produced an eyelike center surrounded by convection. This development was confirmed by NHC-ordered aircraft reconnaissance.

Although NHC considered classifying this as a hurricane, NMC, NHC, and NWS Headquarters decided against this to avoid unnecessarily confusing and alarming the public.

SATURDAY, November 2, 1991

Continuing northward toward Nova Scotia, the storm left the Gulf Stream and again crossed over the cold North Atlantic. Early on the morning of November 2, the now rapidly weakening storm made landfall just west of Halifax, Nova Scotia, terminating the event.

SUMMARY

Overall, the NMC computer models did a good job giving adequate lead time for warning purposes on the Atlantic High Seas. However, the development, strength, and rapid westward motion of the surface low on the afternoon and evening of Wednesday, October 30 was not handled well by the models. The surface low moved much further west than prescribed by either the NGM or AVN and did so along 40°N and not 38°N as per model guidance. This rapid westward motion and the fact that the low made it to 71°W before turning southwest away from the New England shore contributed greatly to the coastal flooding and subsequent wave damage along the New England Coast.

CHAPTER III - DATA ACQUISITION AND AVAILABILITY

COASTAL MARINE DATA SOURCES AND AVAILABILITY

Sea surface and marine weather observations utilized routinely by NWS forecasters during coastal and high seas storm events come from several sources: (1) data buoys deployed in both nearshore and offshore locations, (2) remote CMAN platforms, (3) voluntary observing ships, (4) drifting buoys, and (5) NOS-maintained water level gages. The buoys and the CMAN units are operated and maintained by the NDBC.

NDBC Systems

Moored buoys and CMAN stations maintained by the NDBC rely on the Geostationary Operational Environmental Satellite (GOES) system to telemeter hourly observations from the observing platforms through the satellite and the National Environmental Satellite, Data, and Information Service (NESDIS) Wallops Island facility to the NWS central and field offices. Observations are transmitted from the platforms hourly and arrive at NWS field stations over the AFOS Network.

Although most of the network was operational, recent activity, specifically damage caused by Hurricane Bob in August 1991, had depleted the available systems somewhat. The Gulf of Maine data buoy, designated number 44005, was set adrift by Bob and was retrieved by the Coast Guard later that month. Buoy 44004, located at the former Ocean Station 'Hotel' near 38.5°N 70.6°W, failed in early August, was reported adrift in September, and was subsequently retrieved. All other NDBC buoys were on station and reported throughout the storm.

With respect to CMAN units, the sea temperature sensor at Diamond Shoals Light, North Carolina (DSLN7), was inoperative during this event as a result of Hurricane Bob in August. All other CMAN stations were providing reliable data at the beginning of the event. However, damage to several of these stations occurred during the storm.

According to weekly NDBC status reports, CMAN stations at Matinicus Rock, Maine (MISM1), and Ambrose Light, New York (ALSN6), suffered some degradation of reliability during the storm. For the period October 24 - 31, the report showed 95 percent and 98 percent data availability from these two stations, respectively. However, for the period October 31 - November 7, only 83 percent and 90 percent of all observations from these two sites were available due to intermittent transmission problems and parity errors. Elsewhere, the station at Lake Worth, Florida (LKWF1),

was destroyed on October 31 when the pier on which it was mounted gave way during the high waves that reached Florida.

National Ocean Service (NOS) Water Level Information

Water level information is provided to forecasters primarily from the NOS-maintained WLTTS network in place at many United States coastal sites. This network of gages is maintained by NOS primarily to record long- and short-term variations in water levels. For these tasks, real-time data are not an NOS requirement. The NWS, because it does have a requirement for real-time water level information during potential coastal flooding and tsunami events, and the NOS have modified selected NOS gage installations to allow for such real-time access.

Two methods of providing this access are now in use: (1) Handar, developed by NWS as an offshoot of similar technology used on river gages, and (2) TIDES_ABC, an NOS-developed software package designed to plot water level readings from the past 24 hours against predicted tide heights.

Handar technology, maintained by NWS, incorporates a programmable unit that transmits the NOS water level gage data via commercial telephone line to a computer or dumb terminal remotely located in an NWS field office. Either the field office can initiate the call for a reading or the gage itself can initiate a call to a field office at a certain time interval or whenever the gage height reaches a pre-set critical level. Multiple readings each hour can be obtained by this system which also has the capability to store several weeks' worth of data.

In the TIDES_ABC system, a tide gage and an NWS office computer are again connected through a telephone line. The TIDES_ABC software at a local NWS office initiates a phone call to one of several remote gages available to a particular office. Water level observations for up to the past 24 hours are displayed graphically on the computer screen along with the predicted water levels for the same period. In this way, trends are readily apparent, and departures from tidal predictions can be seen at a glance.

A disadvantage of TIDES_ABC is that it is more cumbersome and time-consuming to use than a simple interrogation of a Handar-equipped gage. Especially in routine situations where no departure from predicted values is expected, NWS forecasters seem to prefer accessing the Handar equipment at locations where both methods of real-time access are available.

As with Handar units, only selected gages are equipped to be accessed via TIDES_ABC. A summary of water level data available during this event to the various field offices involved is shown in table IV. Overall, tide gages along the East Coast performed well throughout this event. However, some discrepancies were noted as follows.

<u>Station</u>	<u>Tide Gage Site</u>	<u>Maintained By</u>	<u>Method of Data Access</u>
WSFO PWM	Portland Harbor, ME	NOS	Dial-up access via NWS Handar unit; gage calls WSFO if level reaches 11.0 ft
WSFO BOS	Boston Harbor, MA Charles R. Dam Tender Buzzard's Bay, MA New Bedford, MA Sandwich, MA Wing's Neck, MA Nantucket, MA Woods Hole, MA Oceanographic Institute (WHOI)	NOS USACE USACE USACE USACE Steamship WHOI	Dial-up access via NWS Handar unit; TIDES_ABC, dial-up access via NWS Handar unit Tender reads gage Remote dial-up access Remote dial-up access Remote dial-up access Remote dial-up access Staff reading Staff reading
WSO BDR	Stamford, CT	USACE	Remote dial-up access
WSFO NYC	Providence, RI	USACE	Remote dial-up access
	Bridgeport Hbr., CT	NOS	Dial-up access via NWS Handar
	Willetts Point, NY	NOS	TIDES_ABC
	The Battery, NY	NOS	TIDES_ABC
	Bergen Point, NJ	NOS	TIDES_ABC
	Sandy Hook, NY	NOS	TIDES_ABC
WSO ACY	Ventnor City Pier, NJ	NOS	Gage with NWS Handar unit calls ACY hourly and when water level reaches 5.8 ft MLLW
WSO ILG	Cape May, NJ	NOS	TIDES_ABC
	Sandy Hook, NJ	NOS	TIDES_ABC
	Ocean City, MD	NOS	Dial-up access via NWS Handar unit
	Ocean City, MD	NOS	Dial-up access via NWS Handar unit
	Hampton Roads, VA (Sewell's Pt)	NOS	Dial-up access via NWS Handar unit; gage calls ORF if level reaches 4.0 ft MLLW
	Ches. Bay Bridge, VA (South Is.)	NOS	TIDES_ABC; dial-up access via NWS Handar unit; gage calls ORF if level reaches 4.0 ft MLLW
WSO HAT	Windmill Point, VA	NOS	TIDES_ABC
	Lewisetta, VA	NOS	TIDES_ABC
	Cape Hatteras, NC (Frisco)	NOS	Gage with NWS Handar unit calls HAT hourly; prints to Silent 700
	Duck, NC	USACE	Dial-up access every hourly

TABLE IV. REAL-TIME WATER LEVEL INFORMATION AVAILABLE TO NWS FIELD OFFICES NORTH OF CAPE HATTERAS

(1) The NGWLMS gage at Atlantic City, New Jersey, which at the time of the storm was undergoing pre-operational testing, reported water levels 0.9 ft lower than the WLTS gage collocated with it and 1.4 ft lower than the WLTS gage at nearby Ventnor Pier. Atlantic City data from the NGWLMS gage were not available to NWS forecasters in real-time. Report of the discrepancy was made by the USACE to the Official in Charge of WSO Atlantic City after the fact.

(2) The Ocean City, Maryland, WLTS gage was demolished by this storm and will not be returned to service. The NGWLMS gage operating at this location is not presently accessible by NWS field offices in real-time.

(3) The NOS gage collocated with the CMAN station at Lake Worth, Florida, was destroyed when the outer 200 ft of the Lake Worth Pier was destroyed by the high waves associated with this storm.

(4) Gages at Duck, North Carolina, and Boston, Massachusetts, were also affected by the storm but have now been repaired and returned to service.

In addition to the problems noted above, the tide gage at Portland Harbor, Maine, is programmed to call forecasters at WFSO Portland when the water level reaches 11.0 ft above MLLW. At 4 am, EST, October 30, the gage called and reported such a reading. The forecasters felt the reported 11.1 ft above MLLW was excessive since the winds along the Maine and New Hampshire coasts were blowing from the northeast, parallel to most of the coastline. Experience had shown that most coastal flooding on this portion of the coast occurred with strong southeast onshore winds. Finally, this interpretation of the data seemed to be supported by the MRPECS statistical storm surge prediction of only 1.7 ft above normal tide.

Forecasters also mentioned that a couple of days earlier, the gage had malfunctioned. This undermined their confidence in the readings since there was some question whether or not the gage had been repaired by NOS maintenance technicians. In the absence of other interrogatable tide gages in that area, with no other method to verify the reading, and without the Gulf of Maine buoy (44005) to monitor existing sea conditions, the forecasters in Portland were reluctant to rely solely on these data. They filed an A-23 Equipment Outage Form on the NOS tide gage. The station electronics technician visited the gage at 9 am, EST, and confirmed that it was operating correctly and that the 11.1 ft value was undoubtedly accurate.

Upon learning this, a coastal flood warning was issued at 10 am, EST, 4 hours before the onset of significant coastal flooding along the Maine and New Hampshire coasts. Forecasters felt that had they known that the gage was reading correctly, they would have probably issued a coastal flood watch or, perhaps, a warning at 4 am, EST.

The NOS is presently modernizing its network of water level gages throughout the United States. At many locations, NGWLMS instruments are installed but are not yet in an operational mode. This new system is designed to make use of a GOES link to transmit routine data to field offices. This system, as currently envisioned, will transmit data every 3 hours via GOES satellite. Following quality checks by NOS, this data will be released to the NWS field offices via AFOS.

Much concern was raised by NWS local officials throughout the survey area regarding the reliability and access to real-time water level information on an as-needed basis. For the long term, concern was raised by the local officials throughout the affected area about the availability and reliability of the NGWLMS data. For non-storm periods, the three-hourly data dump will likely be satisfactory. But, in the event of a storm or coastal flooding episode, frequent access to real-time water level information is critical. NOS has installed telephone lines from each system for quality control and maintenance, and it would appear reasonable for NOS to permit access to NWS forecasters during coastal flooding episodes for monitoring water levels in real-time. This issue must be resolved before the NGWLMS network is declared operational and the existing WLTS network decommissioned.

There was a need expressed by several NWS managers for water level information from estuarine areas (i.e., sounds and embayments behind barrier islands) to alert forecasters of seiches and flooding from back bays. During extended periods of onshore winds, water from back bay areas cannot escape to sea as efficiently as during light or offshore wind situations. With each subsequent high tide, the departure from predicted water levels increases. For example, WSO Atlantic City reports that after four or five tidal cycles when strong northeast (onshore) winds are involved, back bay water levels can be as much as 1.5 ft higher than simultaneous oceanfront readings. Several offices get reports from local officials and/or private citizens on water level conditions in these areas. However, data from most of these must be directly read by a human observer. As such, requests for information from the volunteer observers at these sites are made sparingly to maintain cooperation.

SATELLITE DATA SOURCES AND AVAILABILITY

Satellite data, in the form of images and/or image animation, are utilized by NWS forecasters centrally at NMC and NHC and at the various field sites. These data may be the single most important source of information available to all marine forecasters. GOES data are available in visible, infrared, and water vapor formats at both NMC and NWS field offices from NESDIS/Satellite Services Division. In the field, the GOES image data are available via the Satellite Weather Information System (SWIS) and the microSWIS (personal computer [PC] based image display/animation system) as images and/or image animation. In addition, NMC forecasters have satellite information available from the VDUC that is not available to NWS field offices.

OTHER DATA ACCESS AND AVAILABILITY LIMITATIONS

Other than those items noted above, the DST found that the forecasters generally had access to the available tools.

The DST did become aware of a data access problem that seemed to impact the operation during the **Halloween Nor'easter of 1991**. According to NMC SMS staff, the current procedure of having the NOS Ocean Products Branch meteorologist, located at NMC, provide a list of current synoptic observations to the SMS High Seas forecaster is too labor-intensive. They suggest that a plot containing wind speed and direction, combined sea and swell height and direction, visibility, pressure, pressure tendency, and past or present weather would be all that is needed. They did note, however, that several ship reports on the NOS list of October 29 showing seas of over 40 ft just east of Georges Bank did indeed help verify forecast conditions. (Single observations of this type illustrate how important real-time in-situ data are to the forecaster.)

On a related topic, a lead forecaster in Boston recommended that the MARMON program now in use throughout the Great Lakes be adapted for use along the East Coast. This program compares existing forecasts with current observations and alerts the appropriate forecaster when discrepancies arise.

For this to be effective, however, an adequate observational network needs to be in place. The current network available is consistently denigrated by NWS marine forecasters. The sparsity of actual on-water observation points is a major hinderance in accurately specifying wave heights and wind speeds existent over the waters offshore the United States. Visual wave observations, in particular those taken from land-based observers, are prone to have large errors. This is a major problem and needs to be addressed.

CHAPTER IV - PREPAREDNESS

Disaster preparedness activities at NWS offices have a dual focus. The first is internal preparedness dealing with internal station management activities (e.g., drills, checklists, SDMs, and staff awareness). The other focus is external preparedness, whereby NWS officials meet with state and local officials to learn their requirements (as they apply to NWS functions), participate in emergency planning and emergency drills, and take part in post-storm analyses of emergency actions to identify refinements and improvements.

INTERNAL PREPAREDNESS ACTIVITIES

Weather Service forecasters must be ready to respond to all weather-related events in a timely manner to ensure that adequate warnings are delivered to the public. This is accomplished by developing and maintaining detailed, readily available, and easily understood instructions and procedures. Of course, these procedures are useless unless forecasters are aware of their existence and are able to apply them to whatever situation might arise. This familiarization can either be gained through actual practice or through station drills.

The DST found that established SOPs were generally in place at all stations visited. Samples of the on-station guidance are included in appendix A to this report. The type and quality of the guidance varied from station to station. It ranged from fully developed SDM chapters on coastal flooding, with references to historical tide heights and estimated return periods and procedures for backup access to tide gages, etc., to a short one pager with a brief checklist and telephone listing.

The success of SOPs lies in whether or not those who must use them can readily find the information they need to successfully handle the situation at hand. The DST identified no major instances where on-station guidance was incorrect or lacking in the most critical areas. Some stations, however, could include more background information, historical data, and examples. Several minor discrepancies were noted and are, presumably, being corrected.

Station drills focusing on coastal flooding or high surf events were found to have been conducted at Portland, Maine (June and October-November 1991); Boston, Massachusetts (October 1990 and October/November 1991--in progress at the time of the storm); and Norfolk, Virginia (November 1990, June 1991, and November 1991). No other drills had been documented. However, at other offices--Atlantic City, for instance--minor coastal flooding is a common enough occurrence that the local

manager believes that proficiency is maintained in real-time without requiring formal drills.

EXTERNAL PREPAREDNESS ACTIVITIES

Preparing state and local officials, the media, and the general public for the eventuality of coastal flooding (or any other weather-related event) is equally important to preparing station personnel for these events. It appears to the DST that NWS officials throughout the area investigated had spent and continue to spend considerable effort in attempting to do this. The responses from the emergency service community and the media were generally, although not uniformly, good. The responses from the public were, in general, poor.

Perception by emergency managers and the public of the potential danger from a particular weather-related event seems to be critical in developing public cooperation and response. Local NWS managers must become actively involved in meeting with emergency managers to develop a common understanding as to the potential of various weather events, participate in planning activities, and conduct post mortem reviews to identify deficiencies and improve the warning system. Although the effort was there, the message, at least as far as most of the public along the Mid-Atlantic and New England Coasts is concerned, has not gotten through for this type of coastal flooding event.

The reality is that each NWS office still has different requirements for meeting this educational responsibility. In places like Cape Hatteras on the Outer Banks of North Carolina, the populace, from the state emergency managers to the hotel operators and wind surfers, is very weather-conscious. The frequency of storms and the potential for destruction they possess makes this apparent even to the most casual observer.

At the other extreme, problems were found in New Hampshire and New Jersey in getting local emergency officials and the public to believe in the power of the approaching storm. These are noted in Chapter VII. In Atlantic City, coastal flood warnings were largely ignored in spite of the local NWS manager's active involvement with emergency managers throughout southern New Jersey in educating the public and developing emergency plans. This, again, was due mainly to a lack of appreciation for the potential of this event.

In Norfolk, Virginia, the DST met with the WSO Meteorologist in Charge (MIC), the Director and Deputy Director of Norfolk Emergency Services, and the City of Virginia Beach Fire Department - Emergency Management Division. In this meeting, all three emergency managers emphasized that their contact with WSO Norfolk is frequent, due, in part, to the particular problems of the Hampton Roads area in evacuation planning. Because tunnels and highways susceptible to flooding are major parts of evacuation plans for the Norfolk-Virginia Beach-Chesapeake areas (average elevation

above mean sea level of Virginia Beach and Norfolk is around 13 ft), emergency managers are extremely weather-conscious. All agreed that at least monthly meetings and weekly phone calls take place to discuss various weather-related matters.

The hurricane threat along the Atlantic coast has prompted emergency managers to foster active disaster preparedness programs in all coastal areas. Hurricane preparedness activities and associated drills ensure that necessary weather information can be passed on to state and local emergency managers in the shortest amount of time. A comprehensive hurricane simulation drill is planned for early 1992 in FEMA Region III. "Hurricane Zelda" is intended to involve all levels of emergency management as well as FEMA, NWS, United States Coast Guard, and other agencies to strengthen hurricane plans currently in force. Since coastal flooding can account for a significant part of the damage caused by a hurricane, these preparedness efforts have a carryover effect to other coastal flood episodes as well.

The perception among NWS personnel and emergency managers throughout the survey area was that personal visits and communications are absolutely essential in maintaining the high state of readiness of the warning and preparedness program. Reduced travel budgets have prevented NWS personnel from conducting as many disaster awareness tours. If this continues, everyone (NWS and emergency managers) interviewed indicated that the warning and preparedness efforts invested up to this time will gradually be lost.

Particularly in the restructured NWS, many coastal areas will be without a direct and immediate NWS presence. In these cases, it is imperative that the Warning Coordination Meteorologist (WCM) and the MIC keep actively acquainted with various emergency management personnel in the new Weather Forecast Office area of responsibility. This will require a sufficient and reliable travel budget and enough time to perform this task.

At the DST meeting in Atlantic City, the time-intensiveness of this preparedness task was made clear. The State of New Jersey uses the "home-rule" approach to emergency services. Emergency management is run at a municipality level with local governments having the authority to conduct evacuations and produce their own emergency plans. This situation can cause problems for NWS personnel in conducting Warning and Preparedness programs due to the number of agencies involved in emergency management. Problems arise, as well, in the execution of emergency management plans. In one case during this storm, a municipality ordered an evacuation without coordinating with other municipalities as to where the evacuees were to be sheltered.

In the modernized NWS, the plan currently calls for the Philadelphia office to be responsible for Delaware, southern New Jersey, and eastern Pennsylvania. This totals some 60 counties. Even with WCMs dedicated solely to preparedness activities.

they will have a difficult time dealing with all aspects of the warning preparedness in states where individual municipalities direct their own emergency management functions with little centralized coordination or oversight.



**Figure 26. The remains of Sandy Beach, Scituate, Massachusetts.
Photo courtesy of Pat Vlets.**

CHAPTER V - WARNING SERVICES

The meteorological scenario that unfolded over the New England and Mid-Atlantic states in late October presented some unique and formidable challenges to the NWS warning and forecast system. While these meteorological details are described elsewhere in this survey report, several points are worthy of reiteration.

Unlike the typical nor'easter that develops off the North Carolina Outer Banks during the winter months and moves north and east along the New England coast, this major ocean storm moved west and then southwest toward the United States coast from its area of origin south of Nova Scotia. This "back door" approach precluded the normal precursory environmental clues so familiar to persons who have often experienced coastal winter storms in the northeast. Such was the case, for example, in Maine during the height of the coastal flooding on October 30. One resident observed, "It was a rather typical autumn day in New England unless you were on the coast."

The formation of Hurricane Grace several days earlier and its subsequent absorption into what was to be an ocean storm of historic proportions was a complicating factor for forecasters in formulating forecasts and statements.

The interaction between the intense extratropical storm and a near record high pressure system over the Canadian Maritimes strengthened the wind field over vast areas of the ocean resulting in a long fetch toward the New England coastline.

Forecasters at NMC SMS and in WSFOs with coastal responsibility recognized the devastating potential for a coastal storm several days in advance of its onslaught. (See selected state forecast discussions [SFDs] in appendix B.) In addition to NHC advisories on Hurricane Grace, SMS's high seas forecasts (appendix C) indicated storm development as early as 22 UTC on October 27 and advertised a dangerous storm in the high seas forecast issued at 10 UTC, October 28. Subsequently, SMS's high seas forecasts and WSFOs' coastal and offshore forecasts highlighted the developing threat to marine interests with gale and storm warnings.

Forecasters at several offices mentioned to the DST the importance of numerical weather prediction and statistical computer guidance from various atmospheric models. Boston issued a coastal flood watch at 3 am, EST, October 29, based, in part, on the Limited-area Fine Mesh (LFM) coastal wind forecast of 46 kt at Nantucket. According to a Boston forecaster, "It looked like the Blizzard of '78 without the snow!" Another Boston forecaster said the 3000 ft wind forecasts were superb! He used, as a rule of thumb, 80 percent of the 3000 ft winds to estimate surface winds.

This forecast guidance, together with forecaster experience in dealing with coastal storms, resulted in a suite of timely, state of the science warning and forecast products and services to a host of users, including government, public safety, and emergency management officials, private sector interests, the media, and the public. (Appendix C contains copies of selected warning and forecast products issued by various NWS offices having marine responsibilities.)

Not all computer guidance was helpful, however. Several comments were received indicating that the output from the MRPECS was consistently too conservative for this storm scenario. One forecaster in Boston stated that he would have issued more strongly worded statements, comparing this storm in terms of its destructive potential with the Blizzard of '78, had it not been for the surge model output.

In defense of the MRPECS, it should be noted that this guidance is statistical in nature. Most storms in this part of the Atlantic are moving away from the United States. In all likelihood, few, if any, storms moving toward the coast, like the **Halloween Nor'easter of 1991**, were in the database used to derive the original statistical regression equations. In such situations, the statistical guidance can't be expected to give good guidance.

Also, at the time of the storm, MRPECS was run using wind and pressure inputs based on the LFM model. Since then, it has been converted so that it now uses inputs from the newer NGM model. However, even though this model provides better offshore wind and pressure predictions, the MRPECS will still be of limited value during unusual storms such as this one.

A common theme reiterated at coastal offices was the need for more real-time tide gage and buoy data. As discussed in Chapter III, members of the staff at WSFO Portland lost confidence in the accuracy of a tide gage reading, and the absence of nearby gages for comparative purposes may have caused the delay in the issuance of a coastal flood watch or coastal flood warning.

WSFO Portland did issue a special weather statement at 4:30 am, EST, on October 30, highlighting heavy surf and beach erosion. However, the forecasters are convinced that the loss of data from the Gulf of Maine buoy that had been torn from its moorings during Hurricane Bob inhibited their ability to gauge the arrival time and magnitude of heavy surf along the coast.

WSFOs and WSOs placed emphasis on different hazardous aspects of the storm, *depending upon the orientation of the storm's circulation relative to exposed northeast- and east-facing coastal margins*. For example, heavy surf advisories were issued from the North Carolina Outer Banks northward along the Mid-Atlantic coast to Long Island and Cape Cod highlighting the dangers of high surf and the destructive effect of moderate to severe beach erosion. In the early stages of this event, these advisories

emphasized the impact of heavy swells radiating from Hurricane Grace while it was approximately 300 miles east of the North Carolina coast. Later, the focus shifted to the effects of the rapidly intensifying extratropical storm as Hurricane Grace fell apart and its energy absorbed into the larger circulation.

At the same time, WSFO Boston issued high wind warnings for eastern Massachusetts, including Cape Cod, which bore the brunt of the storm due to its closer proximity to the center. Winds gusted near or above hurricane force for several hours during the afternoon and evening of October 30.

In addition to marine warnings (gale and storm), coastal flood warnings stretched along the entire northeast coastline highlighting the severe flooding associated with storm surges 3 to 5 ft above normal. As can be seen by a review of selected issuances found in appendix C, WSFOs and WSOs provided excellent, site-specific advice for affected areas, many times incorporating information provided by emergency management, law enforcement, and government officials.

While coastal flood watches did not precede coastal flood warnings in every case, there is good evidence of intensive coordination within the NWS field structure as offices braced to handle this critical weather event. Perhaps as importantly, a recurring theme from the DST's interviews on the scene was the appreciation expressed by emergency managers and other groups external to the NWS for the early and frequent contact with NWS officials and field personnel as the storm approached.

Several NWS statements emphasized the hazardous nature of the high waves attendant to this storm, but the mention of heavy surf may have had the reverse effect on a segment of the population. Many sightseers were drawn into beach areas putting themselves at risk and inhibiting the actions of local officials. One person in Massachusetts lost his life apparently while surfing.

CHAPTER VI - COORDINATION AND DISSEMINATION

The flow of information from the NWS offices was timely, strongly and clearly worded, and accurate. Coordination between NWS and emergency services personnel was in some cases initiated over 72 hours before the storm reached its peak. For example, NWS Eastern Region Headquarters began a close liaison with FEMA Regions I, II, III, and IV beginning on October 28. In many instances, however, this flow required a great deal of effort on the part of one or more persons, usually the local NWS office manager. Although NWS, NWR, and NAWAS were used, telephone contact between local offices and local emergency managers was extensive.

WSFO PORTLAND, MAINE

Two NWS offices in WSFO Portland's area of responsibility were involved with the storm. These include WSFO Portland itself and WSO Concord, New Hampshire. The MIC of the WSFO maintained almost continuous telephone contact with emergency managers from that state and from New Hampshire throughout the period. Also, as part of this communication effort, the staff at the WSFO issued a special one-time product, a hazardous weather outlook, aimed at the emergency managers and containing alerting information.

The WSFO is equipped with a facsimile machine used to transmit hard copies of warnings and statements. Similar systems were also used at other offices visited by the DST. The labor intensiveness required of such contacts can be overwhelming. If this process is to be continued, the NWS should try to automate it where possible.

In general, the system in place throughout this area requires that the state emergency managers receive warnings and watches and pass them down to their county managers. These officials, in turn, forward the alerts to local managers. Both Maine and New Hampshire emergency managers were contacted by the DST and noted that they have access to the NWS. (In Maine, this access is through the State Police headquarters. The Maine Emergency Management Agency is attempting to get its own NWS drop.) Further, the NAWAS already in place at the WSFO, at the WSO, and at various other spots around both states ensured that the state managers were notified. Additionally, both states noted that they are introducing NWR to their local and county emergency managers to diminish the telephone traffic and quicken the local alerting time.

As a backup, the Portland WSFO disseminates messages to the Associated Press via the Family of Services. This allows emergency managers to receive information

through the various media outlets across both states should those managers not have immediate access to their NWWs.

WSFO Portland has responsibility for a special location: the home of President George Bush in Kennebunkport, Maine. A Secret Service unit is at that location but was not directly notified by the WSFO. SOPs, as noted in the SDM, did not mandate this. However, the SOPs and SDM have been changed to ensure that this is done whenever a watch or warning affecting the area is issued.

WSFO BOSTON, MASSACHUSETTS

WSFO Boston; WSO Providence, Rhode Island; WSO Hartford, Connecticut; WSMO Chatham, Massachusetts; and WSO Bridgeport, Connecticut; all took part in overseeing the **Halloween Nor'easter of 1991**. Information was disseminated from WSFO Boston directly to the Massachusetts Emergency Management Agency over NAWAS and the NWWs which, in turn, funneled it through the area directors to the local emergency managers in the jurisdictions involved. The staff at Boston contacted appropriate emergency managers and began issuing media alerts and PNSs on October 27, notifying them of the impending conditions.

In this area, a close relationship between personnel at WSFO Boston and the Massachusetts emergency managers resulted in a timely and accurate dissemination of weather material. Those managers interviewed by the DST said that the Boston office did a superb job in providing advanced warning and in keeping them up to date during the run of the storm.

A similar story can be told in Rhode Island and Connecticut. Even though the damage and impact were less severe, WSO managers kept in close contact with their respective state and local emergency officials. WSO Providence, Rhode Island, supplied information to state officials from 07 UTC, October 30, until the storm ended through its connection with the Rhode Island Law Enforcement Telecommunications System. Emergency managers also were serviced by NWWs and by hourly telephone contacts with the WSO.

Connecticut emergency service managers had access to all products issued by the area NWS offices through NWWs. They also maintained telephone contact with WSO Bridgeport for the storm's duration.

WSFO NEW YORK, NEW YORK

The only involved office in this area was the WSFO itself. The state of New York is extremely well organized as far as the emergency services program is concerned. Information flows to the state headquarters through NAWAS or the NWWs and is

disseminated downward through the NYSPIN communication's circuitry. The local officials had ample lead time to implement preparedness actions.

One problem was noted in New York. NYSPIN was established to automatically distribute emergency products throughout the state. However, coastal flood messages were not included in this system. This required the New York WSFO to reissue products with a special weather statement communication's header. NYSPIN has been changed to rectify this problem.

WSFO PHILADELPHIA, PENNSYLVANIA

WSO Atlantic City, New Jersey, bore the brunt of the weather in this WSFO's area of responsibility. In New Jersey, the DST met with 18 people, including emergency managers from the state, county, and local governments and local media personnel. The flow of information in New Jersey is more diffuse than in the other states surveyed in that the NWS contacts local officials directly without going through a state organization. These contacts are usually handled over the telephone.

Because of the structure of the emergency service organization in New Jersey, local contacts at the county level are a must. The NWS does not seem to be a viable alternative in this state. A suggestion was made that an automatic facsimile machine (see discussion noted in the Portland, Maine, area above) be installed at WSO Atlantic City. This would allow the station to automatically call and forward to the concerned county and local officials hard copies of necessary information at the touch of a button.

WSFO WASHINGTON, DC

WSOs in Baltimore, Maryland, and Wilmington, Delaware, were active during this storm. However, WSO Norfolk, Virginia, was the office in the WSFO Washington area most affected by the **Halloween Nor'easter of 1991**, although the WSFO did issue several warnings, forecasts, and statements and retained overall responsibility for the coast. Also, the WSFO used NAWAS frequently to brief both state and local emergency managers and to pass coastal information on to the Virginia State Emergency Operations Center.

The Norfolk MIC and local area emergency managers talked often--four or five times a day--over the telephone through the duration of the storm. This is a normal procedure during such events. The MIC notified officials early in the week of the developing system and of its potential and followed up with the telephone and with facsimiles. Coordination, although labor intensive, was very satisfactory.

WSFO RALEIGH, NORTH CAROLINA

In North Carolina, WSFO Raleigh staff maintained close telephone contact with the State Division of Emergency Management. At the local level, WSO Cape Hatteras, the office responsible for the area impacted, maintained close telephone contact with county and local emergency managers.

These local managers also relied heavily on NWR broadcasts and used this forum for disseminating their own emergency messages to the general public (example in appendix C). This was the only office visited by the DST at which this was done. The extreme reliance placed on the NWR system in this weather-sensitive area was striking.

Conversations with officials from the North Carolina Division of Emergency Management (Area A), from the Dare County Emergency Management Office, and with the Dare County Sheriff all indicated that NWR is utilized extensively. It is used to disseminate timely weather information and to advise the public of weather-related road closures, etc. Local radio stations are not as likely to remain on the air during poor weather as is the Hatteras NWR station. Discussions with individuals and local officials substantiated the emergency managers' claims that NWR enjoys a broad listener base and, in fact, becomes THE source of weather and weather-related emergency information for the citizens of Dare County and the Outer Banks. The local emergency officials relied on and acted on the information provided by the NWS. Those managers debriefed by the DST were very satisfied with the service provided by both offices. They also expressed concern about closing the Hatteras office when the NWS modernizes.

Emergency managers and NWS officials in all locations stressed the value of reliable communications links between NWS offices and emergency managers, primarily as a real-time tool for sharing information and disseminating warnings. In particular, location of facsimile machines at NWS offices was viewed as very desirable for rapidly sending warnings and statements to emergency managers.

Few local emergency management officials rely on NWS for receiving timely warnings. Instead, they rely on private sector weather companies, NWR, The Weather Channel, or the local media for their information. Most believe that the local NWS office sending the word out in a personal manner (albeit via facsimile) makes the warning more apt to be received and acted upon in a timely manner. The difficulty with facsimile transmissions is that, if there is a long list of addressees, the product being disseminated becomes less and less timely to addressees at the end of the list and the workload is very labor intensive.

The emergency managers in Norfolk, Virginia, suggested that the availability of a rapid conference calling capability would be useful for alerting all emergency managers

involved in the large Hampton Roads area as to the onset of hazardous weather conditions.

At WSO Cape Hatteras, where a facsimile machine is currently in place (compliments of local emergency management agencies), a facsimile card for an existing PC was suggested. This machine, used as the station AFOS backup terminal, could be dedicated to sending NWS products to local officials. This would free the existing facsimile machine for receiving reports from these same agencies. Some difficulties arose during the Halloween storm when local phone switches were not properly aligned. This resulted in non-receipt of some reports from local emergency managers.

Finally, NAWAS was successfully utilized to deliver coastal flood warnings to those agencies tied in to the system. However, it was noted that, in almost all cases, the system does not extend to the local emergency management level. To reach these people, other methods (telephone, NWR, facsimile, etc.) had to be used.



**Figure 27. A house moved off its foundation in Scituate, Massachusetts.
Photo courtesy of Pat Viets.**

CHAPTER VII -- USER RESPONSE

EMERGENCY MANAGEMENT RESPONSE

The overall response by most members of the emergency management community was outstanding. Warnings and watches issued by the NWS were used as a basis to alert local communities about the storm. Most officials with whom the DST talked said they had ample warning. They all noted that they communicate regularly with NWS meteorologists and have come to respect the judgment of the forecasters.

The MIC at WSFO Boston reported that, from an NWS perspective, the emergency management response in southern New England, the hardest hit area, was effective. Numerous preparations were made by state and local officials hours before the crucial Wednesday afternoon high tides. For example, Massachusetts personnel started to implement that state's emergency action plan at 9 am, EST, Wednesday morning, coastal evacuations were recommended before the brunt of the storm struck, and people and equipment needed for immediate recovery efforts were, in many areas, pre-positioned by noon. The city of Chatham made plans Wednesday morning to dismiss school early.

State emergency managers in New Hampshire realized that a warning for a high tide 5 ft above normal would be significant, and they passed the word to their county managers by radio or telephone. However, they told the DST that it was difficult trying to convince officials in the coastal communities of the tide's significance.

Some local officials were very responsive in acting on the warnings received. In the town of Scituate, Massachusetts, for example, the emergency services director received word of the storm and drove to the coastal areas to pass the word. (See figures 26 and 27 for damage in that community.) In general, the emergency managers in Massachusetts related weather information to the Blizzard of '78, a storm considered to be a baseline for nor'easters in this part of the country, and realized the potential power the storm packed.

The responses uncovered by the DST in New Jersey, however, were not so positive. The probability of a coastal flooding episode was broadcast over NWR and via NWS starting on Monday, October 28. By October 31, when the worst flooding occurred (well preceded by a coastal flood warning issued by the WSO), little action was found to have been taken. The local officials (together with the media and the public), although notified, did not seem to grasp the significance of the event even though terms like "historic levels" included in the warnings and statements made it clear that a

significant flooding event was imminent. The general manager of the radio station that has Emergency Broadcast System responsibility in the local area told the DST that he read the warning as it scrolled by on The Weather Channel but did not grasp the significance of the words. The wind and rain that normally heightens the public's awareness of coastal storms was absent.

Many of the local officials and media representatives in attendance at a meeting called for the DST in Atlantic City agreed that they saw the warnings and that the message they contained was clear. Still they did not react. There were several reasons given for this apparent unconcern. However, the underlying basis for the lack of action was: Since the skies were fair and there was no strong wind, what could happen?

MEDIA RESPONSE

Overall response by the media was on target. Radio and television stations and newspapers along the East Coast carried all of the warnings and watches issued by the NWS, urged residents of the coastal communities to take shelter, and warned them against watching the storm. The Weather Channel did its usual fine job on reporting this system.

The print media, while lacking the immediacy of the electronic media, published numerous articles all along the affected areas to increase public awareness of storms. Again, the DST received general praise for the flow of information from the NWS. A representative from the Portland Press-Herald, for example, said that he had no trouble getting information from the WSFO and, in fact, was planning to write more weather-related articles to increase public awareness of weather hazards.

The media all expressed satisfaction in receiving timely and accurate forecasts. A reporter from Channel 8 in Portland, Maine, advised the DST that he needs to establish a link with the WSFO and intends to do so. Channel 8 downlinks its information via satellite from WSI Corporation.

One possible problem was mentioned to the DST in this area. Although several of the media listened to the NWR, the consensus was that the warnings on NWR in that area were not updated frequently enough.

PUBLIC RESPONSE

Overall, the public response fell short of the response by emergency managers and the media. The storm was a unique event and was so advertised. However, it was generally not accompanied by what the public perceives as significant weather. Also, like all non-hurricane storms, it was not named.

These two factors seem to have played a significant role in the public's apparent lack of concern about the potential power of the storm. Also, NWS forecasters and emergency managers speculated that the general belief among the populace that October is not the time of year that a destructive nor'easter is likely to occur added to this apathy. Whatever the reason, the public generally disregarded the warnings.

In researching the lack of response by the public, the DST learned from various sources that the public tends not to understand the significance of coastal flood watches and warnings. Coastal residents without previous first-hand experience had no frame of reference. Faced with sunny skies and the lack of significant weather, many residents did not perceive the potential threat.

In the Portland, Maine, area coastal residents said they realized that the storm could potentially be dangerous, but they underestimated its power. Emergency managers said they realized the potential power of the storm but had difficulty convincing coastal communities of the storm's potential power.

In Massachusetts, although a state of emergency was declared, no mandatory orders were given to evacuate. This contrasts with Hurricane Bob when at least two of these orders were issued.

Information about Bob was provided by the NHC. In the case of the **Halloween Nor'easter of 1991**, local offices handled dissemination. In some cases, the lack of hurricane status and the lack of a central information point were related to the public's misconception about the storm's potential impact. This was true even though the statements issued by NWS offices were clearly worded and stressed the extreme dangers inherent with the storm.

The response of some individuals along the Maine coast can best summarize a typical reaction of many other coastal residents. They knew they were in trouble when the water failed to recede after the morning high tide on October 30. Waves were crashing over the seawall at least 2 hours before the next high tide which was set for 4:22 pm, EST, that day. Instead of moving, however, they watched the storm and even videotaped much of it. They moved out of the storm's way only when it became absolutely necessary.

In the Boston area and along southern Long Island, the wave battering was the key to the destruction of property. The coastal residents realized that low tide was considerably higher than normal but did little to protect their property.

The weather awareness of the populace in the Outer Banks area of North Carolina and the reliance they have on the NWR for their emergency weather information was a notable exception to this trend. (Figures 28 and 29 show examples of the result of

the storm in this area.) In general, the DST discovered that the use of this medium outside of North Carolina was much less than they expected.

Finally, officials from FEMA also told the team that, in general, people do not respect and understand the power of the ocean. Additionally, they reported that some of the television meteorologists were tending to overreact. This resulted in skepticism and even increased curiosity by the residents. In several areas along the coast, there was considerable traffic by sightseers into threatened areas. Such traffic could have seriously hampered preparedness efforts and needlessly jeopardized lives. The WSFO Boston MIC reported that in Cohasset, people who drove by the beach to view the storm had to be rescued.



Figure 28. Sand buried motel in Buxton, North Carolina. Photo courtesy of Mark Koehn.



Figure 29. Sand buried beach house in Buxton, North Carolina. Photo courtesy of Mark Koehn.

APPENDIX A - SELECTED OFFICE COASTAL FLOOD INSTRUCTIONS

WSFO BOSTON, MASSACHUSETTS:

WINTER STORM WATCH/WARNING ACTION SHEET DATE: _____

circle type:	WINTER STORM WATCH	WINTER STORM WARNING
	COASTAL FLOOD WATCH	COASTAL FLOOD WARNING
	HIGH WIND WARNING	BLIZZARD WARNING

COORDINATION: Before issuing a watch or warning, coordinate with the appropriate WSO's and WSFO's by phone or by an early SFD.

Note: East Coast Coordination on Hurricane Hotline may be necessary (see Instructions in WINTER STORM MANUAL)

Read watch/warning information on NWR _____ and NAWAS _____. Disseminate watch/warning via Special Weather Statement.

If strong winds and/or high tides may cause coastal flooding, beach erosion, etc., put message on the Coast Guard Circuit _____ (use ACOMMS:XMIT 0) and notify Corp of Engineers with special reference to Stamford, CT. Corp of Engineers _____ FTS 839-7630 (or 7629) or #87 (FTS 81-617-647-8630) (see Coastal Flood SDM for home numbers).

Phone call list:

_____ MEMA Ops 8a-5p #95 (8-1-508-820-2016)*; 5PM-8am call #96 (81-508-820-2000)* (switch board) ask that receipt of this message be confirmed by MEMA Comms. Director's number 81-508-820-2010 (2011 for secretary). Additional number 1-800-982-6846.

* MA Fiscal crises forces auto transfer of telcon to answering svc between midnight-7am, 7 days/week and also 4pm-midnight sat/sun. The answering svc will ask you if this is an emergency. Say YES and ask them to notify the person on call to give us a call to relay pertinent info. When MEMA calls you, you may wish to coordinate further calls the remainder of the shift.

_____ City of Boston, Highway Dept. - 482-5300 ext. 169.

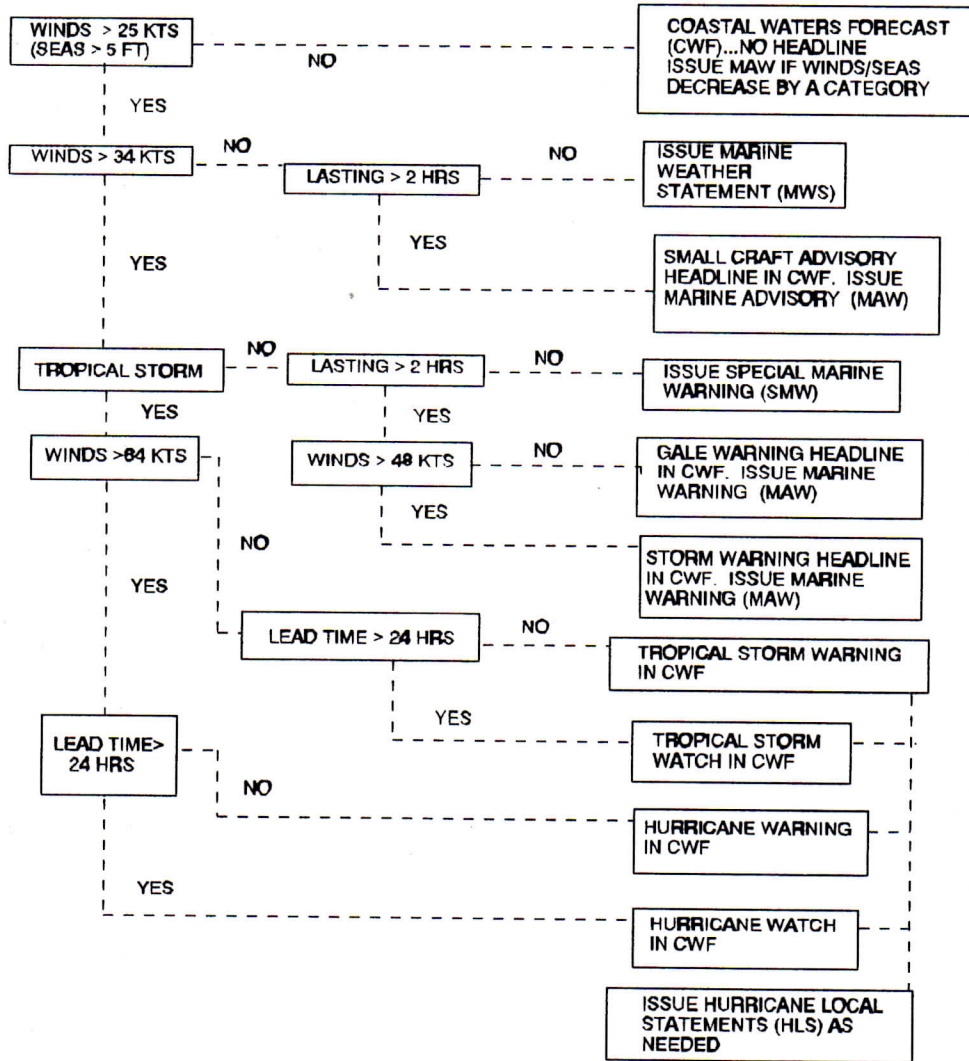
_____ Red Cross - #94 (1-800-462-2705 then dial 911. Upon answer: day shift ask for Duty Officer; 430 pm-830am give info to a recording).

_____ Nantucket Police (when included in watch/warning area) 81-508-228-1212.

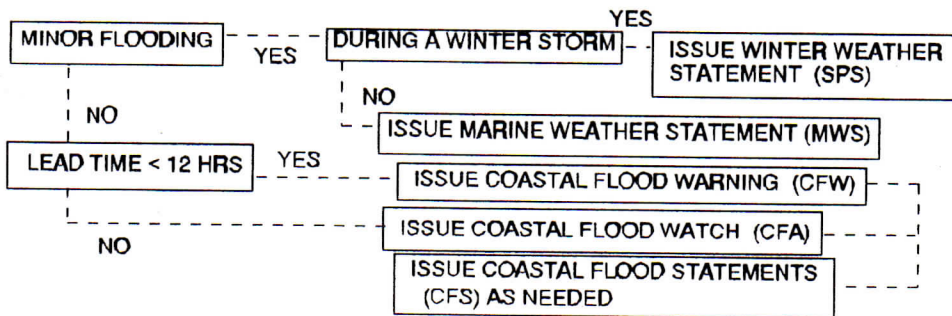
_____ FEMA - #93 (81-233-9540) (if calling after hours, on weekends, or holidays, ask the answering service to have Duty Officer call us).

- 1) Review the staffing situation.
- 2) Special Weather Statements should be issued every three hours during the on-going storms. Include the time of the next issuance...and meet the deadline.
- 3) Put snowfall reports for Massachusetts into OPUBOS.
- 4) For ocean storms...initiate hourly buoy plots.
- 5) File Non-Routine Board.

Coastal Waters Forecast Decision Tree



COASTAL FLOODING DECISION TREE



WSFO PORTLAND, MAINE:

JULY 1, 1986

TO: ALL
FROM: FRED
SUBJ: TIDE READINGS FROM PORTLAND HARBOR

THE WAY THE TIDE READINGS ARE OBTAINED FOR PORTLAND HARBOR HAS BEEN CHANGED. THE READINGS ARE MADE BY COMPUTER AND THE READINGS MUST BE OBTAINED FROM THE COMPUTER. THE PROCEDURE IS NOT SIMPLE LIKE IT USED TO BE AS THERE IS NO DIRECT READOUT IN THIS OFFICE.

TIDE READINGS ARE STILL AVAILABLE. THEY ARE JUST NOT AS EASY TO OBTAIN. THIS CHANGE IS PART OF A NATIONAL CHANGE TAKING PLACE AS A RESULT OF HURRICANE GLORIA. MANY TIDE GAGE READINGS (INCLUDING OURS) WERE UNAVAILABLE AT THE TIME THEY WERE NEEDED MOST BECAUSE OF POWER FAILURES. THIS SYSTEM WILL STILL PROVIDE A READING AS LONG AS A TELEPHONE LINE IS AVAILABLE.

THE TIDE READINGS CAN BE OBTAINED BY ONE OF TWO METHODS. CALL THE COMPUTER AND GET A VOICE READING. OR CALL THE COMPUTER ON THE TRS-80 AND GET A PRINTOUT OF READINGS AT 15 MINUTE INTERVALS.

THE COMPUTER IS ALARMED TO CALL US ON 780-3552 WHENEVER THE TIDE GOES ABOVE 11 FEET. THE CALL WILL BE A COMPUTER GENERATED VOICE THAT SOUNDS A LITTLE UNUSUAL. IF YOU A FUNNY SOUNDING CALL ON THE FITS LINE, IT MAY BE THE TIDE GAGE CALLING TO ALERT US OF A TIDE READING ABOVE 11 FEET.

TO FIND OUT WHAT THE COMPUTER GENERATED VOICE SOUNDS LIKE, CALL FOR A READING. THE TELEPHONE NUMBER IS 9-871-7215. YOU WILL GET THE IDENTIFIER (ID001). THE TIDE READING, A READING OF BATTERY VOLTAGE, AND A REPEAT OF THE IDENTIFIER. THIS IS THE SAME PROCEDURE FOR OBTAINING A READING.

Separator line of asterisks

SUBJ: TIDE READINGS FROM PORTLAND HARBOR

TO OBTAIN A READING USING THE TRS-80 IS A LITTLE MORE INVOLVED. IT REQUIRES A NUMBER OF COMMANDS TO RESET THE TRS-80 TO THE PROPER PARITY AND THEN RETURN IT FOR HYDRO USE ONCE YOU ARE FINISHED. THE PROPER COMMANDS ARE:

- 1. STRIKE "BREAK" KEY.
2. TYPE "S" AND ENTER.
3. TYPE "SETCOM A=OFF" AND ENTER.
4. TYPE "S" AND ENTER.
5. TYPE "SETCOM A=)" AND ENTER.
6. TYPE "T" AND ENTER.
7. TYPE "ATDT9,8717215" AND ENTER.
8. AFTER CONNECTION STRIKE "CONTROL S".
9. COMPUTER WILL PRINT THREE LINES OF DATA.
10. AFTER READINGS ARE COMPLETE, STRIKE "CONTROL S" TO OBTAIN PRINTOUT OF OLD DATA.
11. COMPUTER WILL ASK FOR DUMP DATE. SELECT JULIAN DATE FOR WHICH PRINTOUT IS TO BEGIN AND ENTER. (IN

- SELECTING JULIAN DATE TERMINAL WILL DOUBLE PRINT. THIS IS NORMAL).
12. COMPUTER WILL ASK FOR DUMP TIME. SELECT TIME IN EST FOR WHICH PRINTOUT IS TO BEGIN AND ENTER. (IN SELECTING TIME TERMINAL WILL DOUBLE PRINT. THIS IS NORMAL).
13. READINGS WILL BE GIVEN AT 15 MINUTE INTERVALS FROM DUMP DATE AND TIME TO PRESENT. (TIDE AND BATTERY READINGS).
14. AFTER PRINTOUT HAS FINISHED, COMPUTER WILL ASK FOR ANOTHER DUMP DATE. MAKE NO ENTRIES FOR A LEAST ONE MINUTE. THIS ALLOWS COMPUTER TO DISCONNECT.
15. ONCE DISCONNECT OCCURS, STRIKE "BREAK" KEY.
16. TYPE "S" AND ENTER.
17. TYPE "SETCOM A=OFF" AND ENTER.
18. TYPE "S" AND ENTER.
19. TYPE "DO MODEM300" AND ENTER.
20. TYPE "T" AND ENTER.

Separator line of asterisks

V. COASTAL FLOOD WATCHES/WARNINGS/STATEMENTS
WSOM C-43

Coastal Flooding is defined as being from 2 causes, storm surge and heavy surf. If a MWS is issued for surf conditions, it should headline "HEAVY SURF ADVISORY IN EFFECT".

COASTAL FLOOD WATCHES/WARNINGS and HEAVY SURF ADVISORIES shall be headlined in appropriate coastal zones, local, and marine forecasts.

If coastal flooding is expected due to a winter storm on which we are issuing WINTER WEATHER STATEMENTS (SPS), we can include any coastal flood watch/warning or heavy surf advisory information in the WINTER WEATHER STATEMENT. At other times we will have to feat them as a separate event.

COASTAL FLOOD WATCH..AFOS heading..CFAPWM
A COASTAL FLOOD WATCH should be issued for possible coastal flooding within the next 12 to 36 hours.

COASTAL FLOOD WARNING..AFOS heading..CFWPWM
A COASTAL FLOOD WARNING shall be issued for coastal flooding expected within the next 12 hours.

COASTAL FLOOD STATEMENT..AFOS heading..CFSPWM
A COASTAL FLOOD STATEMENT is used to revise, extend, cancel, or update COASTAL FLOOD WATCHES/WARNINGS.

A MARINE WEATHER STATEMENT (MWS) is used in lieu of the above products during minor coastal flooding episodes or when the severity and extent of coastal flooding are uncertain.

When referring to a forecast or occurrence of tidal heights above normal in any statement, watch, or warning concerning coastal flooding, it shall be referenced to the heights above mean low water MLW at Portland as well. (Use NOS tide tables for values). The statement, "To convert mean low water MLW to mean sea level MSL subtract 4.6 feet from the MLW value." shall be included. (from ERH Memo May 6, 1988).

EXAMPLE: The combination of very strong onshore winds and an astronomical high tide early in the afternoon will produce tides 2 to 3 feet above normal at the time of high tide. In Portland, the tide will reach 12.5 to 13.5 feet above mean low water MLW between 1230 PM and 130 PM. To convert mean low water MLW to mean sea level MSL subtract 4.6 feet from the MLW value.

Do not use references to MLW, MSL or exact tidal times in the CFWPWM.

APPENDIX B - SELECTED STATE FORECAST DISCUSSIONS

STATE FORECAST DISCUSSION
NATIONAL WEATHER SERVICE RALEIGH/DURHAM, NC
244 PM EDT SAT OCT 26 1991

GENLY SAME FCST AS PAST SVRL WITH A COUPLE OF WRINKLES. FIRST SL MENTION PATCHY DENSE FOG IN MUCH OF CNTRL AND NEARLY SUN MORNING SINE HAD LOTS OF LOG THIS MORNING..AND BECAUSE NGM BNDRY RH FCST NR 100 PCR OVERNIGHT AND LO LVL THICKENS CHART THIS MRNG SHOWD WEAK WEDGE OVR PIEDMT. HAVE CONTD TO TRACK BAND OF WDLY SCT SHOWERS OVER OPEN WATERS MOVG WWD TWD NC CST. SINCE FEW MOVED INLAND LAST NIGHT..WL MENTION 20 PCT CHC RW FOR CSTL ZNS..BUT WL RESTRICT ANY OTHERS TO CSTL WTRS SUN/SUN NGT. TRMW PTLY CLOUDY WITH LTL TEMP CHANGE .. THINK GUID TEMPS AGAIN TOO LOW.

MAIN WX FTR TO CONCRND WITH IS MNLY A MARINE PROBLEM..FOR NOW UPR LO WHICH HAS NOW WORKED ITS WAY DOWN TO SFC NR 28N 66W IS FCST BY MIA TO MOVE NW TO 30N70W (PER HIGH SEAS FCST) WITH 360 NM OF GALE FORCE WINDS IN NRN SEMICRCL. THIS PUTS GALE FORCE WINDS WITHIN 60 MILE OF HAT BY LATE SUN. SAT PIX SHOWS SYSTEM IN GULF MEX MOVG EWD AND ITS OUTFLOW IS WRAPPING AROUND SYSTEM OF CONCERN.. AND ITS OUTFLOW HAS BULGED BACK WNWWD IN RESPONSE. AVN MODEL AND MOST OTHER MDLS INCLUDING EUROPEAN MODELS TAK SYSTEM ON N..NOT NW OR W. BUT NGM HAS BEEN CONSISTENT IN PAST 2 TUNS IN CXSTS CLOSD SFC LO CNTR NT 28W 75W..AND LOOP OF NGM BNDRY WINDS SHOWS WATCHG.FOR NOT WL UP WNDTS TO 25 TO 30 KTS FOR CSTL WATERS BY SUN NGT..BUT TOO FAR AWAY IN TIME TO ISSUE SCA.

VERY DEEP WRN U.S. TROF FCST TO DEVELOP NEXT 36-48 HRS WITH RDG AMPLIFY IN E. UPR TRO OFF NE U.S. CST DEEPENS A LTL LATE IN PD AND NGM/AVN BOTH HINT AT SUBTLE PSBL BACKDOOR FROPA INTO NERN NC ON MON AFTERNOON. WL SHADE TEMPS DOWNWARD THERE ON CAUTIOUS SIDE..NC...NONE GAF

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FORECAST DISCUSSION OF SOUTHERN NEW ENGLAND
NATIONAL WEATHER SERVICE BOSTON MA
320 AM EST SUN OCT 27 1991

AREAS OF FOG ONCE AGAIN EARLY AM. ALTHO A REPEAT OF THE PAST 2 OR 3 MORNINGS..WL PROBABLY ISSUE SPS.

MODELS RELATIVELY CONSISTENT IN HANDLING OF S/W TROF TO PASS THRU NE US TNGT. MOST ENERGY PASSES N OF FCST AREA SO HAVE KEPT POPS IN CHC CAT. ALTHO INCRSG MID/HI CLDNS...SOME SUN AND MILD TEMPS SHOULD PREVAIL TDA ONCE FOG THIS OUT. BASED ON CUR TRENDS...HAVE RESTRICTED ANY CHC SHWRS TDA TO JUST WRN ZNS. CHC TSTM THIS EVE MAY BE LTL HEIR W THAN INDCTC ON FPC BUT STILL NOT VRY LKLY GIVEN ORIENTATION OF INSTBLTY AXIS AND DYNAMICS.

IMPRESSIVE CAA MON BHND S/W TROF WITH INCRSG N TO NE FLOW. GRADIENT IN CAA PATTERN CUD SUPPORT GALES OVR MUCH OF MARINE AREA MON. HYBRID LO PRES SYSTEM SW OF BERMUDA BEARS WATCHING..SPECY FOR INCRSG SWELLS IN A COUPLE OF DAYS..BUT WL PROBABLY REMAIN WELL S AND E OF AREA.

HI AMPLITUDE PATTERN TO CONTINUE AS INDCTD BY LTST AVN RUN OUT TO 72 HRS. THUS CANNOT REACH THE ONSET OF THE WARMER RETURN FLOW IN THE EFP.

WRKZFP AVBL FOR YOUR REVIEW/COMMENTS.
.MA...NONE. GALES MAY BE REQUIRED MON MAZ501-502 AND OFFSHORE.
.RI...NONE. SCA MAY BE REQUIRED MON FOR RIZ501.
.CT...NONE.
REFER TO NYCCWFNYC FOR MARINE ADVYS/WRNGS.

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STATE FORECAST DISCUSSION
NATIONAL WEATHER SERVICE NEW YORK NY
230 PM EST SUN OCT 27 1991

DISC: INTERESTING FCST.

FIRST FCST PROB IS FOG. 18Z USCG STATIONS REPORTED VSBY FM 0 TO 1 MI IN FOG. USCG AT SANDY HOOK AND ROCKAWAY REPORTED 0 MI IN FOG AND FIRE ISLAND REPORTED 1/2 MI IN FOG. WITH SFC COLD FNT JUST MVG INTO EXTREME WRN NY AND PA...THERE IS NO MECHANISM TO IMMEDIATELY LIFT FOG. WILL ISSUE DENSE FOR ADVISORY FOR ALL COASTAL AREAS TNGT. FOG WILL LIFT WITH PASSAGE OF FNT LATE TNGT.

SECOND FCST PROB IS CHC OF WHWRS TNGT. LEADING EDGE OF LGT SHWRS IS CVER WRN NY AND PA. SHWRS MVG NE BETWEEN 20 AND 25 KTS. BEST CHC OF SHWRS WILL FCST FOR NW NJ..ZONE 1 AND ROCKLAND AND WESTCHESTER COUNTIES..NY ZONE 14. WILL IGNORE FWC PERCENT PROG POPS OF 20 PERCENT IN FOURTH PD. ATTM..SEE NO JUSTIFICATION FOR THESE POPS.

THIRD FCST PROB IS WINDS. SFC LOW NORTH OF NY INTENSIFIES AS IS MVS EAST..THEN COMBINES WITH THE CIRCULATION OF TROPICAL STORM GRACE WLL OFFSHORE DURING MON. SFC WIND GRAD BETWEEN STORM LOW PRES SYSTEMS OFFSHORE AND HIGH PRES SYS OVR SE CANADA INCREASES SIGNIFICANTLY OVER AREA MON. ATTM. WILL ISSUE GALE WARNINGS FOR COASTAL WATER INCLUDING LI SOUNDS AND SCA FOR NY HARBOR.

GET READY FOR SIG CHILL. AUTUMN RETURNS TO THE AREA.

.NY...SERN...DENSE FOR ADVY TNGT Z14>17
...GALE WARNINGS FOR COASTAL WATERS AND LI SOUND
...SCA FOR NY HARBOR
.NJ...NRN...DENSE FOR ADVY TNGT Z05-07-15
...GALE WARNINGS FOR COASTAL WATERS

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STATE FORECAST DISCUSSION
NATIONAL WEATHER SERVICE / RALEIGH, DURHAM, NC
222 AM EST WED OCT 30 1991

WILL MAKE SOME ADJUSTS TO CSTL WRNG AND ADVSY. WILL DROP GALES BACK TO SCA S OF CAPE LOOKOUT...KEEPING GALE AND CSTL FLOOD WRNGS CAPE LOOKOUT N. ALSO HEAVY SURF ADVSY ALG OUTER BANKS TDA. MODELS CONF TO POINT TO WNDTS GRDLY BCMG MORE NE AFT TDA AS LARGE SFC LO PRES MEADERS ARND OFFSHR OF MID-ATLC RING. ALTHO WNDTS STILL BE RESPECTABLE ALG UPR CST TDA AND ON INTO THU...LOOKS AS THO THEY MAY DMSHG SOME AS THEY COME MORE FROM OFF LAND. THIS DOES PRESENT A PRBLM WITH SOME SOUND SIDE FLOODING ALG OUTER BANKS TNGT AND THU AND WILL MENTION THAT IN OUTER BANKS FCST. OTRW BLOCKING PATN ALF WILL KEEP THINGS MOVING ALG RATHER SLOWLY BUT BEGINNING TO SEE THE OMEGA BLOCK WEAKENING SOME WITH TIME. MAY BEGIN TO SEE SOME CLDS CREEPING INTO W TNGT AND THU AND THIS IS REFLECTED IN CURRENT FCST. GENTLY OTHER ASPECTS OF FCST LOOK OK AND WILL ONLY MAKE AN MINOR ADJUST CAPE LOOKOUT N
.NC...GALE WARNINGS CSTL WATERS HERE AND THERE.
...HEAVY SURF ADVISORY ZONE 1.
...CSTL FLOOD WARNING S OF VA BEACH TO CAPE LOOKOUT.
...SCA S OF CAPE LOOKOUT AND ON ALBEMARLE AND PAMLICO SOUNDS.

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FORECAST DISCUSSION FOR SOUTHERN NEW ENGLAND
NATIONAL WEATHER SERVICE BOSTON MA
140 PM EST WED OCT 30 1991

OCEAN STORM SHOULD BE WEAKENING AND FOLLOWING NGM TRENDS PER OCCLUSION. CHH MAY BE SEEING CENTER OF STORM ON RADAR. HEAVY STORM DAMAGE AS WE ARE MOVING THRU HI TIDE COASTAL FLOODING NOW. BELIEVED THE WORST OF TIDAL FLOODING NOW WILL CONTINUE CFW THRU THUS AS PREV BUT WORD THAT WORST MAY HAVE OCCURRED THIS AFTN. CT COASTAL FLOOD THREAT UNKNOWN ATTN BUT TIDES THIS AM WERE 2-3 FT ABV NORMAL AND EXPECT TO RUN 3-4 FT ABV NORMAL AT TIME OF HI TIDE THIS AFTN. MAYBE THIS TIDAL FLOODING PBLM CAN BE TERMINATED ON THE 4 AM THURSDAY PKG. WEAKENING SFC PPP MAY ALLOW SLOWLY LOWERING SURGE W HUGE SWELL EVER SO SLOWLY DAMPENING OUT NEXT 72 HRS.

HEAVY RAIN BANDS PROBABLE AND ASSTD STREET FLOODING DUE TO LEAF CLOGGED DRAINS. SWISS IMAGERY SHWG STORM MOTION 1016 SINCE 12Z....WHEN WILL IT LOOP S? WIL THERE B A 50 KT LOW LVL WIND FIELD 200 MI OUT FM CENTER EVEN TOMORROW DESPITE THE WKNG OCCLUDED CENTER.

HAVE SEEN SVRL 80KT SHIP REPORTS W WAVES OF 50 TO 71 FT.

HWW PROBABLY MAY BE TERMINATED IN PART ON THE 9 PM PKG...WORST IS OR SHUD HAVE OCCURRED BY 00Z/31 PER FD (1,2,3) FA1 3 K WINDS AT BOS/ACK.

FOR THE RECORD HAD 3 REPORTS OF SLEET TDY...WOBURN...NEWTON CTR AND OSTERVILLE (EVAP COOLING PER NGM T3/T5 PREDICTORS)

GRASS FIRES ETC REPORTED IN SOME AREAS WHERE IT WAS PARCHED TDY W STG WIND. (BURNING LEAVES?)

1815Z SCATTERED REPORT PWR OUT AND TREES DOWN RI/E MA. FLOODING ALREADY OCCURRING BRANT PT.

. MA...HWW MAZ001>004-007>009 FOR THIS EVE. ENTIRE CST THRU STORM ALL CWF.

.RI...STORM R1Z501. CFW ENTIRE CST THRU THUS. HWW ALL RI.

.CT...CFW ENTIRE CT CST FOR THRU THU.

REFER TO NYCCWFNYC FOR MARINE ADVYS/WRNGS.
DRAG

APPENDIX C - SELECTED FORECASTS AND STATEMENTS

HIGH SEAS FORECASTS NATIONAL WEATHER SERVICE,
WASHINGTON, DC
2200 UTC SUN OCT 27 1991

NORTH ATLANTIC NORTH 32N TO 65N WEST OF 35W
.FORECAST VALID 0600 UTC TUE OCT 29 1991

WARNINGS.

SEE S OF 32N FOR HURRICANE GRACE 31.5N 67.8W AT 2200 UTC.

DEVELOPING STORM 45N 73W 1013 MB AT 1800 UTC MOVING E 25 KTS WILL TURN ESE 20 KTS AFTER 18 HRS. BY 1200 UTC OCT 28 WINDS INCREASING TO 25 TO 35 KTS AND SEAS BUILDING TO 10 TO 16 FT WITHIN 400 NM OVER THE NW SEMICIRCLE. FORECAST STORM 42N 55W 999 MB. EXCEPT AS MENTIONED IN WARNINGS SECTION FOR AREA S OF 32N FORECAST WINDS 40 TO 55 KTS AND SEAS 14 TO 24 FT W OF A LINE FROM 46N 50W TO 40N 60W. ELSEWHERE FORECAST WINDS 25 TO 35 KTS AND SEAS 12 TO 18 FT WITHIN 650 NM OVER THE SW SEMICIRCLE.

GALE 50N 38W 996 MB AT 1800 UTC MOVING E 25 KTS THEN TURNING NE OVER THE NEXT 18 HRS. WINDS 25 TO 35 KTS AND SEAS 12 TO 18 FT WITHIN 550 NM OVER THE SW SEMICIRCLE. FORECAST GALE E OF AREA. FORECAST WINDS DESCRIBED WITH DEVELOPING STORM MENTIONED ABOVE.

SYNOPSIS AND FORECAST.

HIGH 38N 47W 1026 MB AT 1800 UTC MOVING ESE 15 KTS WITH A RIDGE EXTENDING WNW THRU 41N 60W AND ANOTHER ESE THRU 33N 35W. FORECAST HIGH 36N 36W 1024 MN.

DAS

HIGH SEAS FORECAST NATIONAL WEATHER SERVICE WASHINGTON,
DC
1000 UTC MON OCT 28, 1991
NORTH ATLANTIC NORTH OF 32N TO 65N WEST OF 35W
.FORECAST VALID 1800 UTC TUE OCT 29 1991

HURRICANE GRACE 32.5N 68.9W AT 1000 UTC MOVING NW 8 KTS BUT WILL TURN NE AND ACCELERATE. MAXIMUM SUSTAINED WINDS 65.KTS GUSTS TO 80 KTS. RADIUS OF 50 KTS WINDS 125 NM E SEMICIRCLE AND 75 NM W SEMICIRCLE. RADIUS OF 34 KT WINDS AND SEAS 12 FT OF HIGHER 350 NM N SEMICIRCLE AND 200 NM S SEMICIRCLE. FORECAST HURRICANE 35.0N 65.5W. FORECAST MAXIMUM SUSTAINED WINDS 65 KTS GUSTS TO 80 KTS. RADIUS OF 34 KT WINDS AND SEAS OF 12 FT OR HIGHER 350 NM N SEMICIRCLE AND 200 NM S SEMICIRCLE. SEE DEVELOPING STORM BELOW FOR FORECAST OF HIGHER WINDS AND SEAS TO THE W AND N OF HURRICANE.

DEVELOPING DANGEROUS STORM 46N 63W 1013 MB AT 0600 UTC MOVING E 35 KTS WILL TURN SE AND SLOW BY 12 HRS. BY 1800 UTC OCT 28 WINDS INCREASING TO 25 TO 40 KTS AND SEAS BUILDING TO 10 TO 17 FT WITHIN 450 NM OVER THE NW SEMICIRCLE. FORECAST DANGEROUS STORM 41N 54W 990 MR. FORECAST WINDS 50 TO 65 KTS AND SEAS 22 TO 32 FT WITHIN 400 NM NE SEMICIRCLE. ELSEWHERE WITHIN 900 NM W QUADRANT AND 200 NM SE SEMICIRCLE WINDS 35 TO 50 KTS SEAS 12 TO 22 FT.

STORM 62N 32W 980 MT AT 0600 UTC WILL MOVING W 10 KTS WILL

TURN SW AFTER 12 HRS. WINDS 35 TO 50 KTS AND SEAS 14 TO 22 FT WITHIN 550 NM W QUADRANT. ELSEWHERE WINDS 25 TO 40 KTS SEAS 10 TO 18 FT WITHIN 900 NM OF CENTER. FORECAST STORM 59N 36W 998 MN. FORECAST WINDS 40 TO 55KTS AND SEAS TO 30 FT WITHIN 450 NM W QUADRANT. ELSEWHERE WINDS 30 TO 45 KTS SEAS 12 TO 20 FT WITHIN 600 NMOF CENTER.

GALE 48N 29W 999 MB AT 0600 UTC MOVING E 25 KTS. WINDS 25 TO 30 KTS AND SEAS 11 TO 17 FT WITHIN 500 NM OVER THE SW SEMICIRCLE. FORECAST GALE AND CONDITIONS E OF AREA.

SYNOPSIS AND FORECAST.

EXPECT AS NOTED IN WARNING SECTION WINDS INCREASING TO 20 TO 30 KTS SEAS 8 TO 15 FT N OF 35N W OF 48W.

HIGH SEAS FORECAST NATIONAL WEATHER SERVICE WASHINGTON,
DC
1000 UTC TUE OCT 29 1991
NORTH ATLANTIC NOTHER OF 32N TO 65N WEST OF 35W
.FORECAST VALID 1800 UTC WED OCT 30 1991

WARNINGS. CORRECTED CURRENT POSITION OF HURRICANE GRACE

SEE SECTION BELOW FOR FORECASTS S OF 32N FOR CURRENT CONDITIONS WITH HURRICANE GRANCE 31.6N 64.2W AT 1000 UTC. FORECAST EXTRATROPICAL CENTER 38.5N 57.5W AND MERGING WITH DANGEROUS STORM DISCUSSED NEXT PARAGRAPH. DESCRIPTION OF THE FORECAST WINDS AND SEAS ARE DESCRIBED IN RELATION TO THIS DANGEROUS STORM.

DANGEROUS STORM 42N 55W 994 MB AT 0600 UTC MOVING E 15 KTS WIL BECOME NEARLY STATIONARY THEN DRIFT SW AND MERGE WITH REMAINS OF HURRICANE GRACE. CURRENT WINDS 55 TO 70 KTS SEAS 17 TO 27 FT WITHIN 250 NM N SEMICIRCLE. ELSEWHERE WITHIN 700 NM NW SEMICIRCLE WINDS 40 TO 55 KTS SEAS 14 TO 24 FT. ELSEWHERE WITHIN 1000 NM W QUADRANT AND STORM 39N 56W 981 MB. FORECAST WINDS 50 TO 70 KTS SEAS 25 TO 35 FT WITHIN 400 NM SE SEMICIRCLE WINDS 35 TO 50 KTS AND SEAS 15 TO 25 FT.

STORM 60N 39 W 989 MB AT 0600 UTC WILL MOVE SE KTS. WITHIN 500 NM W SEMICIRCLE WINDS 40 TO 55 KTS SEAS 20 TO 30 FT. ELSEWHERE WITHIN 600 NM OF CENTER WINDS 25 TO 40 KTS SEAS 13 TO 23 FT. FORECAST STORM 57N 32W 992 MB. FORECAST WINDS 35 TO 50 KTS SEAS 18 TO 28 FT WITHIN 400 NM OF CENTER.

SYNOPSIS AND FORECAST.

EXCEPT WHERE MENTIONED IN WARNINGS ABOVE WINDS 20 TO 30 KITS SEAS 10 TO 18 FT N OF 43 N.

EXCEPT WHERE MENTIONED IN WARNING ABOVE WINDS 20 TO 30 KTS SEAS TO 18 FT W OF 50W.

HIGH SEAS FORECAST NATIONAL WEATHER SERVICE
WASHINGTON,DC
1600 UTC WED OCT 30 1991
FORECAST VALID 0000 UTC FRI NOV 01 1991

WARNINGS

DANGEROUS STORM 40N 64W 972 MB AT 1200 UTC MOVING W 10
KTS TURNING SW. WINDS 55 TO 70 KTS AND SEAS 35 TO 50 FT
WITHIN 300 NM W SEMICIRCLE AND W QUADRANT. ALSO... WINDS 40
TO 50 KTS SEAS 25 TO 40 FT WITHIN 450 NM NW SEMICIRCLE AND
600 NM NE QUADRANT. ELSEWHERE WINDS 25 TO 40 KTS AND SEAS
15 TO 30 FT WITHIN 750 NM OF CENTER. FORECAST STORM 37N 70W
988 MB. FORECAST WINDS 35 TO 50 KTS AND SEAS 20 TO 35 FT
WITHIN 300 NM NW SEMICIRCLE. ELSEWHERE FORECAST WINDS 25
TO 40 KTS AND SEAS 16 TO 25 FT WITHIN 600 NM OF CENTER
EXCEPT WITHIN 750 NM OVER NE QUADRANT.

AREA OF WINDS 35 TO 50 KTS AND SEAS 18 TO 30 FT N OF 45N OF
45W. ELSEWHERE WINDS 25 TO 35 KITS AND SEAS 15 TO 22 FT N OF
40N AND E OF 50 W. FORECAST WINDS 25 TO 40 KTS AND AREAS 12
TO 16 FT N OF 58N AND W OF GREENLAND WITH MODERATE
SUPERSTRUCTURE ICING.

SYNOPSIS AND FORECAST.

HIGH 50N 65W 1043 MB AT 1200 UTC MOVING ESE 15 KTS. FORECAST
HIGH 49N 51W 1033 MB.

EXCEPT WHERE DESCRIBED ABOVE WINDS TO 25 KTS AND SEAS TO
14 FT W OF 45W N OF 32N.

HURRICANE GRACE ADVISORY NUMBER
NATIONAL WEATHER SERVICE MIAMI FL
6 AM AST MON OCT 28 1991

TROPICAL STORM WARNINGS REMAIN IN EFFECT FOR BERMUDA.

STEERING CURRENT ARE EXPECTED TO KEEP GRACE WELL OFF
THE U.S. EAST COAST. HOWEVER..THERE IS UNCERTAINTY IN THE
FORECAST TRACK AND ALL INTERESTS ALONG THE CENTRAL AND
NORTHERN U.S. ATLANTIC COAST SHOULD MONITOR THE
PROGRESS OF GRACE.

AT 6 AM AST...1000Z...THE CENTER OF GRACE WAS LOCATED NEAR
LATITUDE 32.5 NORTH...LONGITUDE 68.9 WEST OR ABOUT 235
MILES...380 KM...WEST OF BERMUDA.

GRACE IS MOVING TOWARD THE NORTHWEST NEAR 9 MPH...15
KM/HR..AND A TURN TOWARD THE NORTH AND NORTHEAST IS
EXPECTED DURING THE NEXT 24 HRS.

MAXIMUM SUSTAINED WINDS ARE NEAR 75 MPH...120 KN/HR..AND
LITTLE CHANGE IN STRENGTH IS LIKELY TODAY.

HURRICANE FORCE WINDS ARE EXTEND OUTWARD UP TO 35
MILES..55KN FROM THE CENTER..AND TROPICAL STORM FORCE
WINDS EXTEND OUTWARD UP TO 405 MILES..650 KM TO THE NORTH
OF THE CENTER AND UP TO 225 MILES..360 KM..TO THE SOUTH OF
THE CENTER.

THE LARGE AREA OF STRONG WINDS TO THE NORTH OF THE
CENTER IS PRODUCING LARGE SWELLS ALONG PORTIONS OF THE
U.S. EAST COASTAL FROM NORTHEAST FLORIDA NORTHWARD.
CONSULT STATEMENTS FROM YOUR LOCAL NATIONAL WEATHER
SERVICE FORECAST OFFICE FOR ADDITIONAL INFORMATION.

THE MINIMAL CENTRAL PRESSURE REPORTED BY RECONNAISSANCE
AIRCRAFT WAS 982 MR...29.00 INCHES.

REPEATING THE 6 AM AST POSITION...32.5 N...68.9W.
MOVEMENT...NORTHWESTWARD NEAT 9 MPH. MAXIMUM SUSTAINED

WINDS...75 MPH. MINIMUM CENTRAL PRESSURE 982 MB.

AN INTERMEDIATE ADVISORY WIL BE ISSUED BY THE NATIONAL
HURRICANE CENTER AT 9 AM AST FOLLOWED BY THE NEXT
COMPLETE ADVISORY AT NOON AST...11 AM EST.

LAWRENCE

TROPICAL STORM GRACE ADVISORY NUMBER 10
NATIONAL WEATHER SERVICE MIAMI FL
6 PM AST TUE OCT 29 1991

SATELLITE IMAGES SHOW THAT GRACE HAS BEEN OVERTAKEN BY A
COLD FRONT AND IS LOSING ITS TROPICAL CHARACTERISTICS.

AT 6 PM AST..2200Z..THE CENTER OF GRACE WAS LOCATED NEAR
LATITUDE 34.0 NORTH..LONGITUDE 57.0 WEST OF ABOUT 460
MILES...740 KM..EAST NORTHEAST OF BERMUDA.

GRACE IS MOVING TOWARD THE NORTHEAST NEAT 40 MPH...65
KM/HR..AND A TURN TOWARD THE NORTH IS EXPECTED TONIGHT.

MAXIMUM SUSTAINED WINDS ARE NEAR 70 MPH...110 KM/HR..AND
WEAKENING IS LIKELY DURING THE NEXT 24 HOURS.

TROPICAL STORM FORCE WINDS EXTEND OUTWARD UP TO 230
MILES...370 KM.

REPEATING THE 6 PM AS POSITION..34.0N... 57.0W.
MOVEMENT..NORTHEAST NEAR 40 MPR. MAXIMUM SUSTAINED
WINDS...70 MPH.

THE REMNANTS OF GRACE ARE EXPECTED TO BE ABSORBED BY A
DEVELOPING MAJOR STORM OFF THE U.S. EAST FRONT LAST
TONIGHT. FUTURE INFORMATION ON THE EXTRATROPICAL
REMNANTS OF GRACE WILL BE CARRIED IN THE HIGH SEAS
FORECASTS ISSUED BY THE NATIONAL METEOROLOGICAL CENTER
IN WASHINGTON.

THIS IS THE LAST PUBLIC ADVISORY ISSUED BY THE NATIONAL
HURRICANE CENTER ON THIS SYSTEM.

PASCH

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE PORTLAND ME
430 AM EDT WED OCT 30 1991

...MARINE STORM WARNINGS AND LARGE SURF FOR COASTAL
SECTIONS TODAY INTO THURSDAY.

A VERY LARGE AND INTENSE OCEAN TOWN CENTERED 600 MILES
SOUTHEAST OF NOVA SCOTIA IS MOVING TOWARD THE
NORTHWEST. WINDS AND EAVE ALONG THE COAST HAVE BEEN
INCREASING OVERNIGHT. AS OF EARLY THIS MORNING FREQUENT
WINDS GUSTS OF OVER 40 KNOTS WERE BEING REPORTED ALONG
THE MAINE AND NEW HAMPSHIRE COASTS AS WELL AS SWELLS OF
10 FEET. DURING THE DAY AS THE STORM CONTINUES TO MOVE
CLOSER TO LAND, WIND WILL INCREASE TO 50 KNOTS WITH HIGHER
GUSTS AND SEAS WILL CONTINUE TO BUILD TO BETWEEN 12 TO 20
FEET. SOME MINOR BEACH EROSION IS EXPECTED.

DON'T UNDER ESTIMATE THE POWER OF THE OCEAN. LARGE WAVES
CAN BE DEADLY. COASTAL RESIDENTS AND THOSE VISITING THE
SHORE TODAY SHOULD NOT VENTURE TOO CLOSE TO THE WAVES.

FURTHER STATEMENTS WILL BE ISSUED IF NECESSARY.

COASTAL OCEAN STATEMENT
NATIONAL WEATHER SERVICE CAPE HATTERAS NC
400 AM EST FRI NOV 01 1991

...A COASTAL FLOOD WARNING IS IN EFFECT FOR THE
NORTH CAROLINA COAST FROM VA-NC BORDER TO CAPE
LOOKOUT...

...A HEAVY SURF ADVISORY IS IN EFFECT FOR THE NORTH
CAROLINA COAST FROM CAPE LOOKOUT NORTHWARD...

DARE COUNTY CONTINUES TO BE UNDER A STATE OF
EMERGENCY. ACCESS TO COASTAL DARE COUNTY AND
THE OUTER BANKS OF CURRITUCK COUNTY IS LIMITED TO
ONLY THOSE WITH PROOF OF RESIDENCY. HOWEVER
HATTERAS ISLAND REMAINS CLOSED TO ALL TRAFFIC.

TIDE LEVELS DURING THIS MORNINGS HIGH TIDE ARE
AROUND 2 AND A HALF FEET ABOVE NORMAL..THIS
COMPOUNDED WITH 8 FOOT WAVES BRAKING ALONG THE
COASTLINE..COASTAL FLOODING AND SEVERE BEACH
EROSION CONTINUE TO PLAGUE TRAVEL AND PEOPLE
ALONG THE OUTER BANKS.

COASTAL FLOODING AND OCEAN OVERWASH HAVE
RESTRICTED TRAVEL ALONG MOST PLACES ALONG THE
OLD BEACH ROAD FROM KITTY HAWK TO NAGS HEAD. NO
OFFICIAL WORD TO HOW MANY COTTAGES HAVE BEEN
LOST TO THE SEA WITHIN THIS AREA BUT MANY HAVE
SUFFERED PARTIAL TO SEVERE DAMAGE.

HIGHWAY 12 ONTO HATTERAS ISLAND HAS NOW BEEN
CLOSED TO TRAFFIC FOR ALMOST 2 DAYS. DUNE BREAKS
ALONG HATTERAS ISLAND HAS ALLOWED THE OCEAN TO
SURGE OVER HIGHWAY 12 AND INTO SEVERAL VILLAGES
ALONG THE OUTERBANKS. SOME OF THE SPILLAGE HAS
CONTAINANTED SOME OF THE FRESH WATER WELLS IN THE
RODANTHE AREA..PROMOTING OFFICIALS TO PLACE
PORTABLE WATER TANKS AT HE SALVO FIR
DEPARTMENT...SUN REALTY BUILDING IN WAVES..AND
EMILYS RESTAURANT IN ROADATHE.

FERRY SERVICE BETWEEN HATTERAS AND OCRACOKE
ISLAND WILL RESUME AT 5 THIS MORNING. FERRY SERVICE
BETWEEN OCRACOKE ISLAND AND THE MAINLAND WILL BE
RUNNING ON SCHEDULE TODAY..CONTACT FERRY
SERVICES FRO RESERVATIONS.

SPORADIC POWER OUTAGES HAVE BEEN OCCURRING ON
HATTERAS ISLAND SINCE YESTERDAY EVENING. SOME
LOCATION SHAVE BEEN WITHOUT POWER FOR OVER 5
HOURS...MAINLY BECAUSE OF TRANSFORMERS EXPLODING
DUE TO SALT BUILDUP.

ALTHOUGH SEA HEIGHTS THIS AFTERNOON ARE
FORECASTED TO BE LOWER THAN THIS MORNING...TODAY
HIGH TIDE...AROUND 3 PM...MAY CONTINUE TO PRODUCE
COSTAL FLOODING AND OVERWASH. THIS IS IN PART TO
THE OW RESISTANCE OF HAUTE DUNE LINE LEFT BY THE
ONSLAUGHT OF THE ATLANTIC THE PAST SEVERAL DAYS.

STAY TUNED FOR NOAA WEATHER RADIO OR YOUR LOCAL
RADIO AND TELEVISION STATIONS FOR ADDITIONAL
STATEMENTS.
HOEHLER

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