Natural Disaster Survey Report 78-1

Northeast Blizzard of '78
February 5-7, 1978

A Report to the Administrator

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Rockville, Md.
September 1978

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U. S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

FOREWORD

As New England was digging out from under one of its worst storms in history, a survey team of the National Oceanic and Atmospheric Administration was formed and dispatched to the area as soon as transportation became available.

The purpose of the survey team was to assess the effectiveness of the storm warning system and to make recommendations for improvement. This report - NORTHEAST BLIZZARD OF '78 - describes the meteorological conditions causing the storm, the dissemination of warnings, and public preparedness, and presents the findings and recommendations of the survey team.

Richard E. Hallgren
Acting Assistant Administrator
Oceanic and Atmospheric Services

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PREFACE

The NOAA Survey Team reviewed the performance of the National Weather Service and National Environmental Satellite Service related to the severe winter storm that struck the Northeast Coast of the United States on February 5-7, 1978.

The team was composed of Robert E. Beck, Deputy Assistant Administrator for Oceanic and Atmospheric Services; Robert L. Sorey, Director, Atmospheric Services; James Giraytys, Office of Atmospheric Services; Blaine K. Tsugawa, Office of Atmospheric Services; Gerald A. Petersen, Chief, Meteorological Services Division, NWS; Robert L. Nolan, Assistant Chief, Meteorological Services Division, NWS, Eastern Region; John McClain, Meteorologist-in-Charge, Weather Service Forecast Office Raleigh; and Donald C. Winner, Satellite Services Division, NESS.

The survey commenced on February 10, with briefings at the Washington Weather Service Forecast Office and Satellite Field Service Station and the National Meteorological Center. Field office visits began on February 13, at the forecast offices in New York City and Boston. The team was then divided into three groups to visit the National Weather Service offices in Atlantic City, NJ, Philadelphia, PA, Hartford, CT, Providence, RI, and Portland, ME.

The team wishes to thank the many local government officials for their cooperation and assistance in allowing valuable time for interviews. The team also wishes to extend a "well-done" to those individuals who participated in the operation of the warning system. The team is particularly grateful to the Long Island NEWSDAY for the cover photograph of motorists stranded on Route 110.

CHAPTER I

GENERAL DESCRIPTION OF THE STORM

The Northeast Blizzard of '78 was one of the worst of the century. From February 5 to 7, it created havoc along the Eastern seaboard. In New York City, the 17.7-inch snowfall was the sixth largest since records began in 1869. Boston, MA, had over 2 feet, as did Providence, RI. Winds of over 55 miles per hour caused massive snowdrifts, drove seas through seawalls, undermined homes, destroyed beaches (including both Rockaway Beaches on Long Island), breached protective dunes, and left many areas from Cape May, NJ, northward open to further damage from spring coastal storms.

The American Red Cross reported 99 deaths and 4,587 injuries or illnesses attributable to the storm. More than 1,700 single-family dwellings were destroyed or suffered major damage. The Red Cross provided shelter for more than 39,000 persons stranded or forced from their homes by the storm. Table 1 shows the Red Cross casualty and loss statistics. The State of Massachusetts estimated losses from the storm at $500 million. Maine had an estimated $50 million loss, while total storm damage in New Hampshire was estimated at $14 million, including $1.5 million to highways. Property damage resulting from tidal flooding and beach erosion reportedly reached $44 million in New Jersey and over $40 million in New York. Total Federal assistance for the area affected by the storm, as reported by the Federal Disaster Assistance Administration, was $202 million.

On Friday, February 3, the Eastern portion of the United States was dominated by a high-pressure system with generally fair winter weather. The only indication of a storm was a weak frontal system in the far West near the Canadian border. East Coast conditions changed little until late Saturday night when a weak low-pressure center began moving through the Great Lakes with typical, although significant, snow on the southern shores. The weak front from that low moved slowly through the Mid-Atlantic States during the day on Sunday, February 5. Snowfalls of several inches were recorded in the Appalachians, but it was not a particularly severe storm.

Late Sunday night, as depicted on Figure 1, the low which was to create the blizzard was about 150 miles due south of Cape Hatteras. This was first noted by data received via satellite from a NOAA weather buoy near that area. The storm moved rapidly northeastward and was 180 miles due east of the Delaware/Maryland/Virginia Peninsula at noon on Monday, February 6. Major intensification occurred; winds increased to near-hurricane velocity; and the storm center slowed and moved to within 75 miles of the New Jersey coast by 6 p.m. on Monday.

For the next 24 hours the storm intensified and moved parallel to the Coasts of New Jersey, Long Island, NY, and Rhode Island. At 6 p.m., on Tuesday, February 7, it was about 75 miles due south of Nantucket. The speed increased rapidly, and the storm moved due east away from the coast Tuesday night and Wednesday morning.

	MA	RI	NH	ME	NY	CT	PA	NJ	TOTAL
Deaths	73	26							99
Injured or illnesses	4,324	232	28	3					4,587
Hospitalized	483	50	1						534
Single family dwellings: Destroyed	301		13	22				3	339
Major damage	1,057	15	170	200					1,442
Minor damage	4,995	15	170	300		20		150	5,650
Mobile homes destroyed			1	1					2
Apartment or condominium units, minor damage	16		7	50	60			85	218
Small businesses, damaged or destroyed	97		64	91				30	282
Total families reporting loss	6,466	15	425	664	60	20		208	7,858
Shelters operated	91	66	3		34	39	30	2	265
Persons sheltered	23,520	9,150	483		2,107	2,598	1,376	155	39,389
Victims and workers given mass care	50,930	52,317	560	20	5,350	1,819	1,500	500	112,996

Table 1. -- Casualties and losses as reported by the American Red Cross

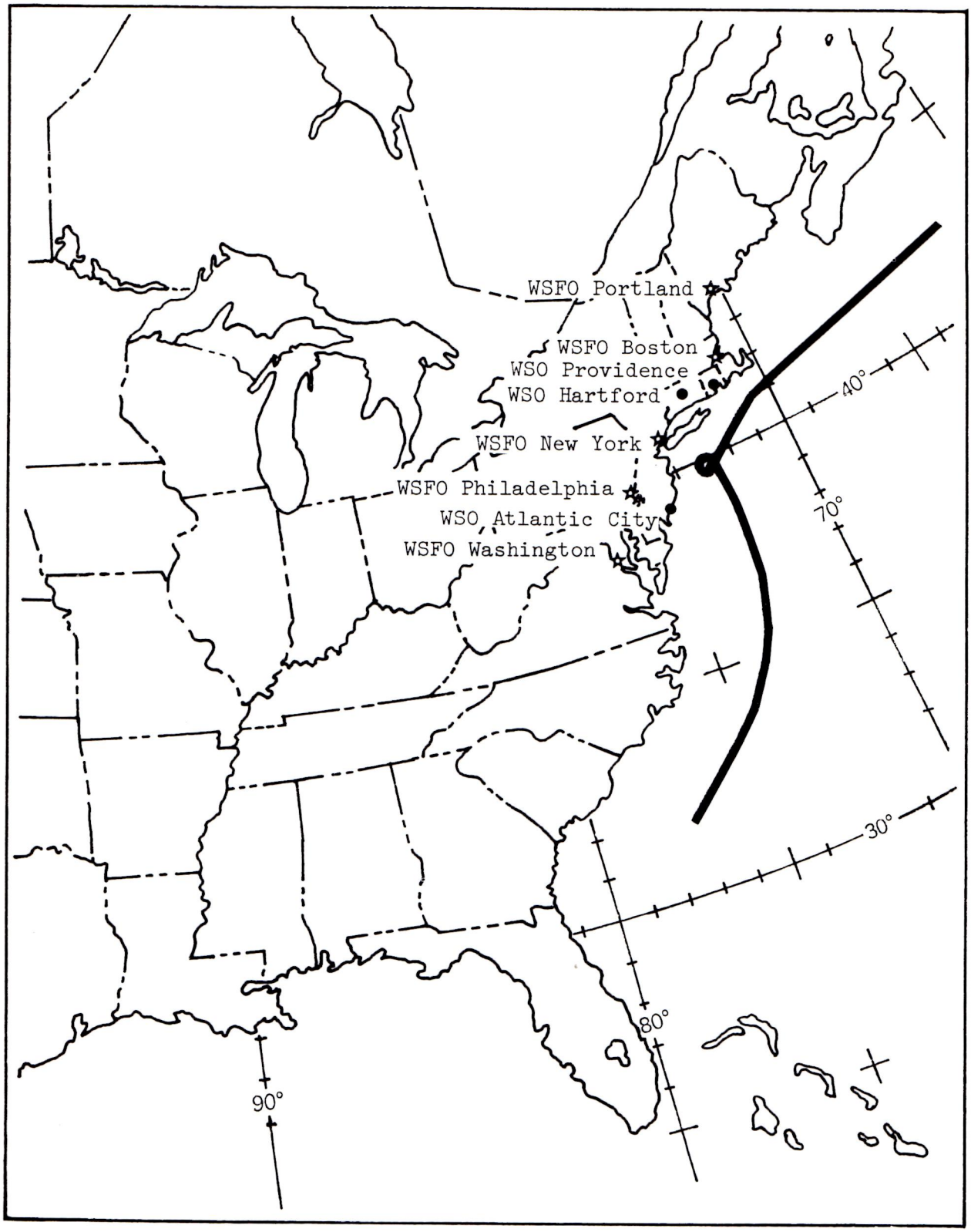


Figure 1. NWS forecast and service offices visited by the survey team. Also indicated is the storm track of the sea-level center.

CHAPTER II

SUMMARY AND CONCLUSIONS

The February 5-7, 1978, East Coast Winter storm hit an area with the Nation's highest concentration of people and capital investment. From the outset it had the potential for great destruction.

Overall, the Survey Team found that the entire National Weather Service (NWS) system operated in an outstanding manner in providing forecasts and warnings for this extremely severe winter storm. Staffs at each of the weather offices visited were quick to grasp the threat of this storm and to convey the nature and extent of that threat to the public and local, state, county, and city officials responsible for community preparedness. Certain individuals and groups of NOAA employees well deserve special recognition for their dedication and skillful performance.

Three important factors led to the very accurate forecasts and warnings for this storm. First, the meteorological guidance provided by the National Meteorological Center (NMC) was accurate and consistent. This was especially true of the LFM 2 (Limited-Area Fine Mesh) guidance. When observational data on Sunday and early Monday indicated that the storm was developing as predicted, NWS field offices gained even greater confidence in that guidance. The forecasts based on this guidance provided the public some 36 hours for orderly preparation. Second, the storm was "well-behaved." There was never a question of, for example, "Will it be rain or snow?" Field offices could concentrate on how much snow, the strength of the winds, and similar details. Third, the weather observations available from the area in which this storm formed were adequate to assess its intensity and location at all times.

The team found that the offices visited were marginally staffed for even "fair weather" situations. Weather Service Forecast Office (WSFO) New York, for example, regularly relies on unpaid volunteers from local universities to operate the NOAA Weather Radio (NWR). While the WSFOs in Boston and New York City had disaster preparedness meteorologists assigned, there was no staffing available at other offices visited to provide for training or concentrated efforts to conduct community preparedness programs. Therefore, such activities had to be conducted at the expense of other programs, with priorities being judgment decisions on the part of the Meteorologists-in-Charge (MICs).

In discussions with the team, NWS and local officials emphasized the importance of preparedness, the need to sensitize the people to the impact of the weather, and the difficulty of maintaining that sensitivity. One county coordinator near Atlantic City related his difficulty in convincing others in his area of the need for evacuation plans. When offered the opportunity last year, only two schools in the entire WSFO Boston area accepted the NWS offer to give presentations on weather preparedness.

Fortunately, a previous storm (January 19-20, 1978) had sensitized the public and agencies to the threat posed by major winter storms. This sensitivity, combined with the advance notice, convinced people to prepare themselves for the February 5-7 storm.

Only two WSFOs and none of the Weather Service Offices (WSOs) in the Northeastern coastal area have a community preparedness focal point. Each MIC stressed the problem of trying to reach millions of people directly. All concluded it could not be done. Dr. Frank Fields, the NBC TV "weatherman" in New York City, concluded that the NWS can have an impact only by working through local agencies and the media, rather than trying to reach people directly.

The team was able to document examples of the utility of new technology and recently installed modern equipment. Satellite information, sectorized and relayed to the forecast offices by the Washington Satellite Field Service Station, was especially valuable in validating the guidance products and timing the events included in the forecasts on Monday, February 6. Data from NOAA's offshore meteorological buoys were particularly important to the New York City and Boston forecast offices. The importance of cooperative observations was evident as was the large amount of time consumed in obtaining those data with currently available communications.

In conclusion, the team found that the warning system worked well during this severe winter storm, but it believes that there is room for improvement in several areas. The following specific findings and recommendations are generally applicable to all or most of the offices visited during the survey:

Finding 1. The NOAA employees in the field offices and at NMC performed their jobs in a highly commendable manner and were a credit to the organization and the Federal Government.

Recommendation: Management should take appropriate actions to commend those individuals and groups involved. (Action: NWS and NESS).

Finding 2. The following deficiencies in data networks and communications were noted:

(a) Data from the meteorological buoys now in place off the East Coast did not always reach all of the offices or external users who had need of them.

Recommendation: Immediate action should be taken to improve the distribution of these data. (Action: NWS).

(b) Offshore data sources were not dense enough to adequately locate and track all the developing storms this winter.

Recommendation: Additional meteorological data buoys should be installed offshore from Cape Hatteras to Maine as specified in the Federal Plan for Environmental Data Buoys. (Action: OAS).

(c) There are too few tidal observations available in real-time to assess properly the threat of coastal flooding.

Recommendation: Action should be taken to automate and augment the tide gage network. (Action: NWS, NOS, OAS).

(d) There are not enough surface wind reports to support detailed coastal marine forecasts. Some equipment, such as the RAMOS (Remote Automatic Meteorological Observing Station) destroyed by the storm at Half Way Rock, Portland, ME, is not adequately sited to survive the environment and to provide vital data under severe conditions.

Recommendation: Action should be taken to augment the wind reporting network and to improve the reliability and siting of automatic equipment. (Action NWS and OAS).

Finding 3. There is doubt as to our capability to forecast beach erosion or the value of such forecasts, since few protective actions can be taken when the storm is imminent. Tidal forecasts seem to be sufficient for local officials to decide when evacuation should be ordered.

Recommendation: The effectiveness of and need for beach erosion forecasts should be examined. (Action: NWS).

Finding 4. There were excessive delays in the dissemination of forecasts and warnings because the large amount of traffic through the computer at NMC delayed Keyboard Cathode Ray Tube (KCRT) traffic. In addition, the current KCRT system does not provide the office preparing the forecasts and warnings a hard copy of the material until it goes through the dissemination process. Therefore, WSFOs could not read the warnings to WSOs. The team considers this a very serious problem.

Recommendation: Means should be devised to eliminate delays in warning dissemination and to provide immediate hard copy of products to the preparing office. If necessary, a priority system must be established which would permit high precedence traffic (warnings) to pre-empt lower precedence material. (Action: NWS).

Finding 5. Because of aging equipment, a high number of maintenance hours are required to keep the older NOAA Weather Radio (NWR) equipment operating. These stations were used extensively, and with dramatic effectiveness, in the New England area during the storm. In one instance, NWR was utilized to relay emergency messages from the Governor to the public.

Recommendation: An effort should be made to accelerate the updating and installation of new equipment in these locations. Consideration should be given to replacing this old equipment before installing equipment in new locations. This will save critical NWS staff time. (Action: NWS).

Finding 6. Because of staff shortages, the magnitude of the task, and frequent indifference on the part of the public, NWS community preparedness programs had been limited in scope. There was no indication that a more comprehensive preparedness program would have improved the reaction of the public. The exceptions were Atlantic City, NJ, and Portland, ME. Here, the smaller concentration of people who are exposed to the effects of frequent coastal storms were well served by the effort put into the preparedness programs by people from NWS and local agencies.

Recommendation: The approach to community preparedness should be reviewed in light of the limited NWS staff available, the ability of the staff to be effective in large metropolitan areas, and the availability of civil disaster agencies and the news media. (Action: NWS).

Finding 7. The offices visited were marginally staffed even for "fair weather" situations. There is no special staffing to provide for supernumerary shifts to conduct training, community preparedness programs, or to work with user groups on other than a sporadic basis. Overtime and the time of unpaid volunteers are used routinely to compensate for the lack of staff. Our MICs are hard pressed to be managers, work shifts, and still interact with user groups. The impending loss of the Principal Assistant at many of the offices will aggravate this situation. In the team's view, staff shortages have reached a critical point. Only the dedication, personal sacrifice, and outstanding professionalism of the field personnel involved made the warning system work in this disaster.

Recommendation: (a) This finding and Finding 6 above should be taken into account as actual operational examples of critical staffing in any major program or personnel justification review. (Action: OAS, NWS). (b) The impact of losing the Principal Assistant on the managerial responsibilities should be assessed as a matter of urgency, particularly during periods requiring weather support for extended emergency periods. (Action: OAS).

CHAPTER III

PERFORMANCE OF NWS FORECAST AND SERVICE OFFICES

WSFO WASHINGTON

Forecast/Warning Responsibilities and Facilities

WSFO Washington serves Maryland, Virginia, and Delaware with local, zone, and State public forecasts and warnings. The office has hydrologic service and data collection functions; provides agricultural, fire weather, aviation, and both coastal and high-seas marine services; has hurricane warning responsibilities; and provides warnings to 20 counties and the District of Columbia. WSOs in the forecast area are at National Airport, Dulles Airport, Baltimore-Washington International Airport, Richmond, Lynchburg, Norfolk, Roanoke, and Wilmington. These WSOs have warning responsibilities for an additional 138 counties. Units at Wallops Island and Sterling, VA, provide upper air observations. Network radars are located at Patuxent River, MD, and Volens, VA.

Dissemination from the WSFO is made over NOAA Weather Wire, NOAA Weather Radio (KHB-36 and KEC-92), Radar Reports and Warning Coordination System (RAWARC), recorded telephone, and the National Warning System (NAWAS), and a Washington Regional Warning System (WAWAS). NAWAS and WAWAS are telephone hotlines to civil defense and local officials. A NAWAS drop is also located in WSO Norfolk. WSO's broadcast from NOAA Weather Radio sites near Norfolk (KHB-37) and Baltimore (KEC-83).

Chronology

WSFO Washington was the southern anchor in the forecast system for this storm. The critical period for the Washington, D. C., area occurred Sunday night, February 5, and early Monday morning. Due to the depth of the subfreezing layer over the area, there was never any doubt the precipitation would be snow. The questions were of intensity and duration, and, of course, amount. The public was advised of the storm late on Saturday afternoon with a special weather statement. Following are extracts of significant issuances:

> 5:30 PM EST SATURDAY FEBRUARY 4, 1978
>
> SNOW IS EXPECTED TO MOVE TO THE COAST DURING THE AFTERNOON SUNDAY AND CONTINUE INTO SUNDAY NIGHT. THE AREA MOST THREATENED BY SNOW WILL BE CENTRAL AND EASTERN MARYLAND...DELAWARE...AND EASTERN VIRGINIA.

5:30 AM EST SUNDAY FEBRUARY 5, 1978

THE NATIONAL WEATHER SERVICE HAS PLACED A WINTER STORM WATCH IN EFFECT FOR DELAWARE AND CENTRAL AND EASTERN MARYLAND FOR TONIGHT AND MONDAY.

A LOW PRESSURE CENTER SHOULD DEVELOP TODAY OFF THE CAROLINAS AND IT WILL MOVE SLOWLY NORTHWARD NEAR THE COAST LATER TONIGHT AND MONDAY. AT THIS TIME...SINCE THE LOW HAS NOT YET FORMED...THE EXACT TRACK AND TIMING IS UNCERTAIN BUT IT HAS THE POTENTIAL TO BECOME A MAJOR WINTER STORM AS IT MOVES NORTHWARD.

The guidance based on the 7:00 a.m. data on February 5 gave the first opportunity to forecast the intensity of the threatening storm. Travelers advisories and a special weather bulletin were issued at 10:45 a.m.:

10:45 AM EST SUNDAY FEBRUARY 5, 1978

DC AND VICINITY UPDATED FORECAST

...TRAVELERS ADVISORY THIS AFTERNOON...
...HEAVY SNOW WATCH TONIGHT AND MONDAY...

OCCASIONAL LIGHT SNOW THIS AFTERNOON MAY BECOME HEAVY TONIGHT AND EARLY MONDAY...ACCUMULATING 2 TO 4 INCHES BEFORE TAPERING OFF TO FLURRIES LATER MONDAY.

A special weather statement was read into the regional Washington Warning System (WAWAS) and the National Warning System (NAWAS) for Virginia and Maryland:

10:45 AM EST SUNDAY FEBRUARY 5, 1978

A HEAVY SNOW WATCH...INDICATING A POSSIBILITY OF 4 INCHES OR MORE OF SNOW...IS IN EFFECT FOR TONIGHT AND MONDAY IN DELAWARE MARYLAND AND NORTHWESTERN VIRGINIA. ELSEWHERE IN VIRGINIA ACCUMULATIONS SHOULD BE ON THE ORDER OF 1 TO 3 INCHES...AND TRAVELERS ADVISORIES ARE IN EFFECT.

THOSE WHO ARE PLANNING TO TRAVEL TONIGHT OR MONDAY...ESPECIALLY THOSE GOING BY AUTOMOBILE...SHOULD CONSIDER POSTPONING THEIR TRIP UNTIL CONDITIONS IMPROVE. RUSH HOUR TRAFFIC MONDAY MORNING SHOULD BE DIFFICULT IN MANY PLACES.

By late afternoon Sunday, the potential danger of the storm was clear:

4:30 PM EST SUNDAY FEBRUARY 5, 1978

4 INCHES OR MORE OF SNOW WILL ACCUMULATE OVER DELAWARE MARYLAND THE DISTRICT OF COLUMBIA AND NORTHERN VIRGINIA...WITH UP TO 8 INCHES

POSSIBLE IN SOME SECTIONS...AND HEAVY SNOW WARNINGS ARE IN EFFECT IN THESE AREAS FOR TONIGHT AND MONDAY.

AUTOMOBILE TRAVEL IN THE WARNING AREA WILL BE DIFFICULT AND DANGEROUS.

Early Monday morning, February 6, the snow in the immediate Washington area had accumulated less than 2 inches, generally less than 1 inch, and the heavy snow was forecast to occur north and east of the city. The storm had yet to develop fully. The forecast at 1:30 a.m. on Monday, however, continued to call for a total accumulation of 2 to 4 inches in the Washington area. The measured storm total early Monday was 2 inches at National Airport, 2 to 5 inches in the southern and western suburbs, and up to 8 inches in the northern and eastern areas. Annapolis, some 25 miles northeast, had reports of up to 11 inches.

Gale warnings were issued at 5 a.m., February 6, for Delaware, Virginia, and Maryland waters. The 8:30 a.m. forecast and travelers' advisory continued the pattern of heaviest snow over the north and east portions of the forecast area. The total accumulations forecast at the time (up to 4 inches with heavier amounts in the eastern suburbs) were essentially the same as had been forecast 20 hours earlier, well before the storm had developed.

Throughout the day, the forecast carried the same basic message -- snow during the day, tapering off by Tuesday. At 9:45 p.m. on Monday, February 6, the snow was ending and the last statement on this storm was issued. Travelers' advisories were kept in effect, because of the high winds and drifting snow:

9:45 PM EST MONDAY FEBRUARY 6, 1978

ALTHOUGH THE SNOWFALL DID NOT SET ANY RECORDS...THE COMBINATION OF SEVERAL INCHES OF SNOW...THE STRONG WINDS GUSTING TO MORE THAN 40 MPH...THE DURATION OF SNOWFALL WHICH EXCEEDED 24 HOURS...AND BELOW FREEZING TEMPERATURES MADE THIS A MEMORABLE STORM FROM THE STANDPOINT OF HUMAN DISCOMFORT. IN ADDITION...IT CREATED MISERABLE DRIVING CONDITIONS...

Staffing and Operational Considerations

WSFO Washington is in a unique position, because it is collocated with the National Meteorological Center (NMC) and a Satellite Field Service Station (SFSS). More and earlier information is available directly to forecasters. The normal operational procedure is to contact people in NMC to obtain the computer-generated guidance, usually before it can be disseminated generally. This gives the Washington forecasters advance information to gain an additional edge on a storm. Throughout this storm, forecasters at WSFO Washington took the opportunity to obtain the guidance and to discuss it with other affected forecast offices.

By Sunday, all forecast offices on the East Coast from Washington north to New England were in telephone contact to coordinate their efforts and to exchange information. Because of the expected location and projected movement of the storm, WSFO Washington was the first office to issue a watch.

There was some consideration early Monday morning that the snow depths would be less than 2 inches, because the snow had virtually stopped in the Washington area for some 5 to 8 hours after midnight Sunday. However, the consistency of the guidance and the rapidly falling coastal pressure reports convinced the forecasters to continue the snow forecast through Monday. That forecast verified.

Local Agency Actions

No unusual situations arose in providing information to the Civil Defense or other emergency units, or to the media. Media coverage was accurate and timely, although some minor confusion did exist between NWS forecasts and those issued by private forecasters. The differences were judged not to be serious and were primarily differences in the estimates of total snow accumulation.

WSFO NEW YORK CITY

Forecast/Warning Responsibilities and Facilities

WSFO New York City has a forecast area covering New York City, Long Island, northern New Jersey, and extreme southern New York State. Observations are taken at WSOs at John F. Kennedy, La Guardia, and Newark airports. The WSFO is in the Rockefeller Center; and a WSR-57 network radar is on top of the building. Local, zone, and State forecasts are issued, and aviation, fire weather, agricultural, and coastal marine service programs are conducted. Dissemination from the WSFO is made over NOAA Weather Wire, NOAA Weather Radio (KWO-35), RAWARC, recorded telephone, and NAWAS.

Chronology

The following, extracted from a 5 a.m. release on Monday, February 6, attests to the severity of the storm, as expected by the forecasters at WSFO New York City:

> NEAR BLIZZARD CONDITIONS, POSSIBLE ACCUMULATIONS OF MORE THAN A FOOT. ROADS ARE LIKELY TO BECOME IMPASSABLE BY LATE AFTERNOON...

The initial watch for the storm had been issued 36 hours earlier. The exceptional lead time for this storm was due to excellent NMC guidance and the ability of forecasters to grasp the meteorological threat. In New York City, the first alert was passed to the Department of Sanitation

at 4:25 p.m. on Friday, February 3, when the Principal Assistant advised of the possibility of a "major storm" to begin Sunday. New York City was almost $12 million overspent at that time for snow removal during the 1977-78 season. The cost of preparation for a snowstorm is $1 million. The city was prepared, but there was no way to cope fully with the rapid accumulation of snow and the driving wind.

Snow was included in the forecast as early as Friday evening, February 3, and the first indications of a major winter storm were issued to the public at 5 p.m. Saturday, February 4:

> FOR NEW YORK CITY...NORTHERN NEW JERSEY...LONG ISLAND AND ROCKLAND AND WESTCHESTER COUNTIES
>
> WINTER STORM WATCH FOR LATE SUNDAY AND MONDAY...
>
> A LOW PRESSURE CENTER IS EXPECTED TO FORM NEAR THE CAROLINAS COAST DURING SUNDAY AND MOVE NORTH NORTHEASTWARD SUNDAY NIGHT AND MONDAY. IF THIS SYSTEM DEEPENS STRONGLY ENOUGH IT COULD CAUSE A HEAVY SNOWFALL OVER OUR REGION SUNDAY NIGHT AND MONDAY. THEREFORE A WINTER STORM WATCH HAS BEEN PUT INTO EFFECT FOR LATE SUNDAY AND MONDAY TO ALERT ALL INTERESTS TO THIS POTENTIAL.
>
> A WATCH MEANS THAT THERE IS THE POSSIBILITY OF A HEAVY STORM...BUT IT IS NOT A CERTAINTY. RIGHT NOW THE STORM HAS NOT EVEN DEVELOPED AND IS NOT EXPECTED IN OUR AREA TILL SUNDAY AFTERNOON OR EVENING AND WILL PROBABLY NOT REACH ITS PEAK TILL SUNDAY NIGHT OR MONDAY MORNING.

The 10:30 p.m. coastal forecast on Saturday gave the first indication of high tides, 2 to 3 feet above normal, and strong winds, 20 to 30 knots. Twelve hours later, Sunday morning, the coastal forecast called for tides of 3 to 5 feet above normal and advised of coastal flooding along low-lying areas.

The first forecast of snow depth called for a foot or more:

> 4 PM EST SUNDAY FEBRUARY 5, 1978
>
> HEAVY SNOW WARNING...A FOOT OR MORE POSSIBLE...FOR LATE TONIGHT AND MONDAY...
>
> GALE WARNINGS AND COASTAL FLOOD WARNING ALSO...
>
> THIS STORM HAS NOT DEVELOPED AS YET...THEREFORE WE ARE NOT ABLE TO BE SURE ABOUT THE TOTAL AMOUNTS THAT MIGHT BE EXPECTED...SINCE THE FUTURE PATH AND INTENSITY OF THE STORM ARE STILL VERY UNCERTAIN. HOWEVER, THE PROSPECTIVE STORM DOES HAVE THE POTENTIAL OF BEING ONE OF THE BIGGEST SNOWSTORMS IN NEW YORK CITY WEATHER HISTORY...IF IT DEVELOPS EVEN CLOSE TO ITS POTENTIAL IT SHOULD MATCH THE SNOWSTORM OF LAST JANUARY 20TH.

By Monday morning, the potential severity of the storm was evident, and the morning forecast reflected the concern of WSFO New York City:

> 10:30 AM EST MONDAY FEBRUARY 6, 1978
>
> WATCH HILL RHODE ISLAND TO MONTAUK POINT TO MANASQUAN AND 20 MILES OFFSHORE...
>
> GALE WARNINGS AND COASTAL FLOOD WARNINGS IN EFFECT.....AN INTENSIFYING STORM OFF THE MID ATLANTIC COAST WILL MOVE SLOWLY NORTHWARD REACHING THE CAPE COD AREA TUESDAY MORNING...NORTHEAST WINDS INCREASING TO 30 TO 40 KNOTS WITH STRONGER GUSTS THIS AFTERNOON AND TONIGHT. WAVE HEIGHTS INCREASING TO 7 TO 10 FEET THIS AFTERNOON AND TONIGHT DECREASING TUESDAY. TIDES RISING TO 3 FEET ABOVE NORMAL LATE THIS AFTERNOON AND TONIGHT WILL CAUSE FLOODING ALONG COASTAL AREAS WITH SIGNIFICANT BEACH EROSION.

By 1 p.m. on Monday, the snow accumulations ranged from 4 to 5 inches in Yonkers and Manhattan to 8 to 10 inches in Point Pleasant, NJ. A total accumulation of 14 to 18 inches was forecast at 1 p.m. That forecast was carried through the evening hours with winds forecast to gust to over 30 mph on land and to 55 knots over the coastal waters. The snow as forecast to end by daybreak on Tuesday.

At 8 p.m. on Monday, snow accumulations ranged from 9 inches at White Plains to 14.5 inches at Pelham Bay. In many areas the rate of accumulation had exceeded 1 inch per hour.

By Tuesday morning, February 7, the snow had stopped, leaving accumulations of 14 to 20 inches over the Metropolitan area and up to 2 feet in northern New Jersey. In mid-Manhattan the total was 17.7 inches, the sixth greatest since records began in 1869.

Staffing and Operational Considerations

The dissemination system used to distribute forecasts and warnings over NOAA Weather Wire and RAWARC from WSFO New York City consists of a KCRT computer terminal which is time-shared with other offices in a tie-in to a computer at NMC. This computer receives the messages directly and makes the dissemination. Power failures at NMC on Monday caused outage of the system, and text material was entered manually on alternate circuits. At other times during the storm, the volume of traffic into the NMC computer caused a backup in messages, resulting in forecasts and warnings running 30 minutes late. This created serious problems because the forecasts and warnings were unavailable in hard copy to anyone, including the issuing office, during the periods of delay.

On Sunday morning, February 5, the line which provides the satellite imagery to WSFO New York City was out from around 3 a.m. to shortly after

7 a.m. The impact of this outage was not critical, because the Washington SFSS provided verbal updates to the WSFO.

The LFM guidance based on the 7 p.m. data on Saturday evening was missing due to a power outage at NMC. The loss of this guidance was considered minimal because the observations available indicated that the situation was developing in line with the previous guidance.

Duty personnel were able to work around these difficulties despite staff shortages. One telecommunicator worked 24 straight hours when his relief was not able to report, because of the storm. No staff are authorized for operation of NOAA Weather Radio. Normally, forecasters or the telecommunicator update the broadcasts. During the storm, the broadcasts were updated by unpaid volunteers, undergraduates at local universities who regularly contribute their time in the WSFO.

The MIC and duty forecasters stressed the importance of the LFM guidance, particularly its consistency from Saturday through Monday. The most critical forecast period was between 5 a.m. and 5 p.m. on Monday, February 6. Early in the morning, the snowfall pattern was narrow and the severity of the storm was in question. The LFM guidance and observational data agreed, and a severe winter storm was forecast. NOAA meteorological buoy data were obtained hourly on RAWARC and were essential to forecasting the severity of the storm. These data were "more than helpful" in indicating the rapid intensification on early Monday. In fact, this data along with satellite information convinced forecasters that the severe winter storm was developing as predicted.

An important deficiency was the scarcity of tide information. One gage is remoted to the WSFO from Battery Park, where tides of 8.5 feet, or 4.5 feet above normal, were reported. Real time tide reports are needed on the south shore of Long Island, such as at Fire Island and Jones Beach, to assess the buildup of storm-driven water. As an example of the damage, the storm wiped out the work done in 1977 to build up the Rockaways Beaches on the Atlantic side. The cost of this work had been $16 million.

Local Agency Actions

All the TV stations receive forecasts over the local NOAA Weather Wire. Being in the Rockefeller Center, the WSFO is easily accessible to NBC TV. During the storm, NBC broadcast live from the WSFO beginning Sunday afternoon and continued broadcasts through Monday evening. Dr. Frank Fields, the NBC TV "weatherman", praised the work of the WSFO duty personnel. To get the message as accurate as possible, Fields confined his role to that of a reporter, and the duty forecaster presented the information directly. CBS sent a "mini-cam" crew to do regular live broadcasts from the WSFO. One reaction was the coverage "was almost a continuous TV event" for some 18 to 20 hours. This meant that the information getting to the public was clear, unambiguous, consistent, and timely. The MIC said that this kind of excellent TV coverage eases his work load significantly,

because it reduces the possibility of error or confusion and eliminates many individual calls, briefings, and explanations he and the staff would otherwise have to make.

The principal WSFO contact with local New York City agencies is through the City Sanitation Department. That initial contact was made at 4:25 p.m. Friday and extra help was mobilized from the Parks and Highway Department. Sanitation Commissioner Anthony Vaccarello was reported in the News to have said, "We had a little advantage: we had the warning. We were prepared. We didn't have to mobilize upward after the storm."

WSFO PHILADELPHIA

Forecast/Warning Responsibilities and Facilities

The Philadelphia WSFO is in the Federal Building, downtown, where local and zone forecasts are issued for eastern Pennsylvania and southern New Jersey. Hydrologic data collection and service programs are conducted, as are agriculture, fire weather, aviation, and coastal marine programs. WSOs are at Harrisburg, Philadelphia Airport, Atlantic City, and Trenton.

Dissemination is made over NOAA Weather Wire, NOAA Weather Radio (KIH-28), RAWARC, and recorded telephone.

Chronology

> "There was so much advance notice and publicity that we couldn't help but be ready," said Edward Grim, Chief, Philadelphia Communications Department.

The snow began at 9:17 p.m., Sunday, February 5, and ended at 8:46 a.m., Tuesday. Between 7 a.m. and 7 p.m. on Monday over 7 inches fell at the airport. The storm total was 14.1 inches; the sixth largest in this century at Philadelphia. As with WSFO New York City, the initial outlook for snow was issued early Friday evening. The forecast at 5 p.m., Saturday called for snow Sunday into Monday night. A Winter Storm Watch was issued at 5 a.m., Sunday, followed 12 hours later by a Winter Storm Warning.

> 5:00 PM EST SUNDAY FEBRUARY 5
>
> ...WINTER STORM WARNING LATE TONIGHT AND MONDAY....
>
> SNOW DEVELOPING THIS EVENING...BECOMING HEAVY AT TIMES LATE TONIGHT AND MONDAY...CONTINUING INTO MONDAY NIGHT. SNOW ACCUMULATIONS SIX INCHES OR MORE...BECOMING WINDY MONDAY AND MONDAY NIGHT WITH CONSIDERABLE BLOWING AND DRIFTING SNOW.

arteries open on Monday and Tuesday in and around Philadelphia. Philadelphia International Airport was closed for 23 hours. As in New York City, the primary contact with local authorities is through the Sanitation Department. Civil Defense groups have NOAA Weather Wire and usually do not make direct contact with the WSFO. Information from the NOAA Weather Wire is re-transmitted over the Commonwealth Law Enforcement Agency Network (CLEAN), a communications link with all regional law enforcement agencies. Important cooperative reports were received, notably from the Pennsylvania Department of Highways, State Police, and Philadelphia Electric Company.

WSO ATLANTIC CITY

Forecast/Warning Responsibilities and Facilities

WSO Atlantic City is at the FAA's National Aviation Facility Experimental Center (NAFEC) adjacent to Atlantic City. It has forecast dissemination and warning responsibilities for the counties of Cape May, Atlantic, Ocean, Cumberland, and Burlington as well as for Atlantic City. In the summer, these areas have between 2 and 3 million residents and several hundred thousand more transients on weekends. The winter population is about one-tenth this number. The associated WSFO is at Philadelphia. Local public and aviation service programs are conducted, and warnings are issued for coastal flooding and beach erosion. Synoptic and aviation surface observations and network radar observations are taken by the WSO. This office operates NOAA Weather Radio Station KHB-38.

Chronology

On January 25, a local paper, The Press, praised the support given by the National Weather Service, noted that the winter was not over, and pointed out that the area might not be as lucky as it had been on January 19-20 in missing a large snowfall. "Listen to the forecasts and be prepared." They were right, winter was not over and the forecasts would be needed.

A winter storm watch was issued by the WSO on Sunday, February 5, at 5:15 a.m. The storm wrap-up went out at 5:15 a.m. on Tuesday. In the interim, 13 inches of snow fell at the WSO and up to 20 inches elsewhere in the area. The peak recorded wind was 49 miles per hour on the 6th. Coastal flooding and beach erosion resulted in losses of tens of millions of dollars. Several additional millions were spent in snow removal. By February 14, there appeared to have been only two storm-related deaths--one of a heart attack and one in a house fire.

5:40 AM EST MONDAY FEBRUARY 6

A WINTER STORM WARNING AND GALE WARNING IS IN EFFECT FOR ATLANTIC... CAPE MAY...OCEAN...CUMBERLAND AND THE EASTERN HALF OF BURLINGTON COUNTIES OF SOUTHERN NEW JERSEY.

SNOW CHANGING TO FLURRIES TONIGHT WITH STORM ACCUMULATIONS OF 14 INCHES OR MORE. WINDY WITH SOME DRIFTING AND BLOWING SNOW THROUGH TONIGHT. TIDES 1 TO 2 FEET ABOVE NORMAL WITH SOME FLOODING AND BEACH EROSION INTO TONIGHT.

12 NOON EST MONDAY FEBRUARY 6

A WINTER STORM WARNING REMAINS IN EFFECT FOR THE MID ATLANTIC AREA WITH BLIZZARD CONDITIONS EXPECTED IN COASTAL SECTIONS. NEW SNOW ACCUMULATIONS RANGED FROM JUST OVER AN INCH TO TWO IN THE SUSQUEHANNA VALLEY TO ABOUT TEN INCHES IN PARTS OF NEW JERSEY. THE SNOW IS EXPECTED TO CONTINUE THROUGHOUT THE AFTERNOON BEFORE TAPERING OFF TO FLURRIES EARLY TONIGHT.

TOTAL SNOW ACCUMULATIONS FROM THE STORM IS EXPECTED TO RANGE FROM 3 TO 6 INCHES IN THE SUSQUEHANNA VALLEY TO WELL OVER A FOOT ALONG THE NEW JERSEY COAST.

MOTORISTS AND PEDESTRIANS ARE URGED TO USE CONTINUED CAUTION. TRAVEL SHOULD BE REDUCED WHENEVER POSSIBLE.

The last official statement on the storm was issued at 6 a.m., Tuesday.

6:00 AM EST TUESDAY FEBRUARY 7

TOTAL SNOW ACCUMULATIONS FROM THE STORM RANGED FROM 13 INCHES ALONG THE SOUTHERN NEW JERSEY SHORE...TO 14 INCHES IN PHILADELPHIA...TO 9 INCHES IN WILLIAMSPORT. A FEW LOCATIONS ON SOUTHERN NEW JERSEY AND SOUTHEASTERN PENNSYLVANIA HAD UP TO 20 INCHES BUT MOST AMOUNTS WERE UNIFORM IN THIS AREA.

STRONG NORTHWEST WINDS ARE CAUSING CONSIDERABLE BLOWING AND DRIFTING OF THE SNOW. DRIFTS OF UP TO 9 FEET HAVE BEEN REPORTED IN NEW JERSEY. MOTORISTS AND PEDESTRIANS ARE URGED TO CONTINUE USING CAUTION. THIS IS THE LAST SCHEDULED STATEMENT TO BE ISSUED ON THIS STORM.

Staffing and Operational Considerations

The MIC at WSFO Philadelphia said that Tuesday, February 7, was one of the more quiet days in the forecast office. The story was the storm itself and not the forecast of the storm. The accurate forecast meant that, among other duties, the forecast personnel were able to make hourly updates on NOAA Weather Radio. Due to transportation problems, some people were not able to report as scheduled and a number of 16-hour shifts were worked. The MIC stayed in a motel adjacent to the forecast office.

Local Agency Actions

The snow was light and dry and flew back over the roads as the wind reached 40 mph. Over 1,600 pieces of equipment were barely able to keep the major

10:30 AM EST MONDAY FEBRUARY 6

HEAVY SNOW WARNINGS IN EFFECT FOR TOTAL SNOW ACCUMULATIONS OF 10 INCHES. NEEDLESS TO SAY WE ARE IN THE THROES OF THE WORST STORM-SNOWWISE - IN ABOUT 10 YEARS. IT IS A DANGEROUS SITUATION AND ONE THAT MUST BE TAKEN SERIOUSLY. IN ALL HONESTY - IF YOU NEEDLESSLY TRAVEL AT ALL TODAY AND ARE NOT PREPARED FOR THE WORST - YOU ARE PUTTING YOUR LIFE ON THE LINE.

WSO Atlantic City put it on the line; no grey wording, no way to misinterpret. Regular advisories and statements were issued in a timely fashion throughout the storm, and these two excerpts typify the seriousness of the storm that was communicated to the public.

Staffing and Operational Considerations

The WSO operates with a MIC, a Principal Assistant (PA) who had been a meteorologist, nine meteorological technicians, and three electronics technicians. Neither the MIC nor the PA could make it to the station during the period of the storm. One meteorological technician reached the NAFEC gate, but could go no further and returned home. Some of the people worked 20-hour shifts. Members of the staff were well briefed on the procedures to be followed and were in contact by phone with both the MIC and PA.

The WSO adapted the forecasts from the Philadelphia WSFO to the local conditions. The problems of beach erosion and coastal flooding received particular attention. By prior agreement from the WSFO, the coastal flooding and tide forecasts are the primary responsibility of the WSO. Only one tide gage is remoted to the office. It is at the Steel Pier and provided valuable data throughout the storm. Virtually no information is available on water levels in the back bays where water tends to pile up and create serious flooding problems.

The accurate and timely guidance from NMC and WSFO Philadelphia and the initiative of the WSO staff allowed them to "get ahead" of the storm and stay there. These factors were critical to the ability of the short staff to handle the work load.

Local Agency Action

The MIC and PA have established an excellent rapport with the local officials and county coordinators. An example is the January 25 article in The Press commending the efforts of the WSO. However, the MIC expressed concern over his ability to continue or expand the level of his work with the various agencies. He is not authorized clerical assistance, there have been staff vacancies and there is the potential loss of authorization for a PA. All these factors combine to place a greater load on the MIC and reduce the amount of time available for community preparedness, liaison with local officials, and effective leadership of the staff.

New Jersey Governor Brendan T. Byrne estimated that the damage to the shore areas would exceed $44 million. Waters that broke over the boardwalks and shorefronts caused much of the damage. Beach erosion damage in Monmouth County was estimated to be over $8 million. The cost of snow removal exceeded $100,000 for each county in the WSO area of responsibility. Most areas, Atlantic City for example, do not have enough equipment to handle the extreme amount of snow that fell and had to hire private contractors to bring in heavy earth-moving equipment.

The Emergency Broadcast System (EBS) became a reality in New Jersey in September 1977. It was activated at 5 p.m. Sunday, February 5. Lee Stanford, Cape May County Civil Defense Coordinator, said, "I do not know how to get better weather service." An early advisory at 4:30 p.m. on Saturday allowed him to alert the County Supervisor of Roads to bring in extra crews.

Stanford is sensitive to the need for good weather information, and he is working to install, at county expense, a two-way radio link with the WSO. He is also working to have the WSO included on the NAWAS. There is a trained meteorologist on the County Coordinator's staff who has access to a weather teletypewriter and a facsimile circuit as well as a complement of wind, temperature, humidity, and precipitation measuring equipment. Stanford emphasized that his staff does not issue forecasts and the the meteorologist prepares analyses of weather situations tailored to the specific needs of the county.

Beach erosion is a critical problem, particularly near Sea Isle. The beaches have been eroded to 2 to 3 feet below normal, and the protective dunes are nearly gone.

Stanford voiced some futility in developing evacuation plans. The summer population swells tenfold to 700,000 in residence in Cape May County alone. While he has evacuation plans, the counties inland do not because "it isn't thought to be their problem." Some 15,000 people per hour can be evacuated from Cape May County, but there are no provisions to absorb them inland. The survey team notes that this situation assumes crisis proportions when viewed in the light of a major hurricane moving up the Eastern Seaboard.

WSFO BOSTON

Forecast/Warning Responsibilities and Facilities

WSFO Boston has public forecast and warning responsibilities for Massachusetts, Rhode Island, and Connecticut. This area includes four WSOs - Worcester, Providence, Hartford, and Bridgeport - and one Weather Service Meteorological Observatory (WSMO) - Chatham. Their service program consists of aviation, public (local, zone and State), fire weather, hurricane, and marine (coastal and offshore) forecasts and warnings. WSFO Boston's county warning area has 11 counties.

Dissemination begins with message composition on Keyboard Cathode Ray Tube and transmission via FAA circuits (Services C, A, and O), RAWARC, and the East Coast Overlay circuit (a dedicated weather teletypewriter circuit). Local and State dissemination of warnings are made over NAWAS, and a weather circuit to radio-TV stations, newspaper, State Civil Defense, and local law enforcement agencies. Boston operates NOAA Weather Radio facilities at Boston (KHB-35) and Hyannis (KEC-73). Massachusetts does not have NOAA Weather Wire Service.

Chronology

"One hell of a job", and
"No surprises" summed up the reactions of two local officials. First indications to the public of impending severe winter weather were issued Saturday, February 4, at 11 p.m., in the Marine forecast:

MARINE WARNINGS WILL LIKELY BE ISSUED TOMORROW (SUNDAY)

At 5 a.m., Sunday, February 5, a Winter Storm Watch was issued:

SNOW IS EXPECTED TO SPREAD INTO THE STATE TONIGHT AND CONTINUE ON MONDAY. IT MAY BECOME HEAVY AT TIMES DURING THE DAY.

INCREASING NORTHEASTERLY WINDS TONIGHT AND MODERATE NORTH TO NORTHEAST WINDS ON MONDAY MAY CAUSE CONSIDERABLE BLOWING AND DRIFTING SNOW.

...A SUBSTANTIAL SNOW MAY COME FROM IT.

The storm developed as forecast in the NMC guidance and warnings of heavy snow - 6 inches or more - and gales for the southern New England coasts were issued Sunday afternoon. The 11:30 p.m. statement, on Sunday, forecast the potential of strong winds and above-normal tides Monday afternoon and night:

...SOME FLOODING OF LOW LYING COASTAL AREAS AT TIMES OF HIGH TIDES. IN ADDITION, A ROUGH SURF WILL COMBINE WITH THE HIGH TIDE TO CAUSE CONSIDERABLE EROSION ALONG EAST FACING BEACHES.

Snow began to fall in the Boston area around 7:30 a.m., Monday, February 6, 26 hours after the Winter Storm Watch had been issued. The 10 a.m. Special Weather Statement on Sunday was headlined by:

HEAVY SNOW WARNINGS FOR MASSACHUSETTS THIS AFTERNOON AND TONIGHT... ACCUMULATIONS OF EIGHT TO SIXTEEN INCHES EXPECTED IN MOST SECTIONS.

COASTAL FLOOD WARNINGS TONIGHT AND TUESDAY MORNING.

MARINE STORM WARNINGS ALONG THE COASTS.

Although Boston's 1 p.m. observation on Monday reported that only 3 inches had fallen at the airport, heavy snowfall was reported along the south coast of New England. Statements by WSFO Boston during the afternoon and evening hours warned of "Blizzard conditions at times." By 11:30 p.m., snow depths of 8 to 12 inches were common throughout the State and the zone forecasts for Connecticut, northern Rhode Island, and southeastern Massachusetts were revised to indicate accumulations of "up to 2 feet."

Marine Storm Warnings continued throughout Monday afternoon and evening. WSFO Boston's 8 p.m. Special Weather Statement included:

> ...VERY STRONG GUSTY EAST AND NORTHEASTERLY WINDS...UP TO HURRICANE FORCE ALONG THE COAST. CHATHAM ON CAPE COD GUSTED TO 92 MPH SHORTLY AFTER 7 O CLOCK AND EARLIER HAD REPORTED A GUST OF 83 MPH WHILE BOSTONS LOGAN AIRPORT RECORDED GUSTS TO 75 MPH SHORTLY AFTER 6 PM.

The strong winds combined with already high spring tides were resulting in water levels 2 to 4 feet above normal. The statement continued:

> STRONG EASTERLY WINDS WILL PUSH TIDES 2 TO 4 FEET ABOVE NORMAL...

Coastal Flood Warnings called for flood levels of 12 to 13 feet above mean low water for Monday night and 13 to 14 feet above for Tuesday morning. Many coastal roads were washed out by pounding surf, and others were completely under water during high tides. The Commonwealth Pier tide gage recorded the water level in Boston Harbor at 14.6 feet at 10:20 p.m. on Monday evening. The normal height is 9.5 feet for that part of the tidal cycle.

The 5:30 a.m. statement on Tuesday morning summarized the situation.

> THE COASTAL AREAS WERE HARD HIT BY TIDAL FLOODING DURING THE PERIOD OF HIGH TIDE LAST EVENING...THE PROBLEM SHOULD RECUR FOR SEVERAL HOURS AROUND HIGH TIDE THIS MORNING. SINCE THE ASTRONOMICAL TIDE IS ABOUT A FOOT AND A HALF ABOVE LAST NIGHTS, CONSIDERABLE AND EXTENSIVE FLOODING IS PROBABLE LATER THIS MORNING.
>
> EXTENSIVE SURF BATTERY AND BEACH EROSION WILL CONTINUE THROUGHOUT THE DAY.
>
> SHOREFRONT ROADS WILL FREQUENTLY BE INUNDATED...EITHER BY TIDAL FLOODING OR BY BREAKING SURF.

At 8 a.m., Tuesday, February 7, the Greater Boston Metropolitan area forecast was revised to call for up to 24 inches of snow from this storm. WSFO Boston's statements contained strong appeals to the public to "simply...stay at home." The appeals were backed with reports of the State highway system being at a virtual standstill.

By late Tuesday morning, the worst of the storm had passed. At 11 a.m., the marine forecast reduced the storm warnings to gale warnings. The public forecast dropped heavy snow warnings, but continued "snow with considerable blowing and drifting." Although the winds had decreased, warnings for lighter coastal flooding and surf were continued through the remainder of the day.

On Wednesday morning, February 8, the 5 a.m. public forecast dropped all warnings. Marine gale warnings were changed to small-craft advisories, but coastal zone forecasts indicated:

> TIDES 1 TO 2 FEET ABOVE NORMAL WITH LOCAL FLOODING OF LOW LYING COASTAL AREAS. ROUGH SURF CONTINUING.

Snow finally ended in Boston around 6 a.m., Wednesday, February 8. The storm snowfall was 27 inches, an all-time record for a single storm, and this fell on top of 2 inches already on the ground. Also, a new 24-hour snowfall record was established when 23.6 inches of snow fell in the 24-hour period, ending at 7 p.m., February 7.

Staffing and Operational Considerations

Normal operational staffing of the Boston forecast office is three forecasters on duty during the hours from 8 a.m. to 12 p.m.; two forecasters handle the 12 p.m. to 8 a.m. shift. A briefer/observer and a forecaster's aide are on each shift. The staff was augmented by three people Monday evening and an additional two over the next 2 1/2 days. The MIC and PA remained at the office throughout the storm. A total of 269 hours of overtime were accumulated. The doubling of the normal staff contributed greatly in handling the work load of issuing special statements, gathering data, writing summaries, and plotting hourly charts to keep abreast of the storm's movement and intensity.

Satellite photos received from Washington SFSS were used extensively during the storm. Both infrared and visual imagery gave WSFO Boston excellent data on the areal extent of precipitation and aided at times in pinpointing the storm center. Frequent telephone calls to the Washington SFSS provided up-to-the-minute picture interpretations, as well as coordination for special sector requests and cloud enhancement changes. The SFSS support was outstanding.

NOAA's Environmental Data Buoys performed exceedingly well and were a vital source of data for detecting and monitoring the storm's development, intensity, and movement. Normal operations call for buoys to report at 3-hour intervals; however, throughout the period of the storm, WSFO Boston requested and received hourly reports. The MIC praised the buoy program and requested that more buoys be added to complement those now in operation.

The only real-time tide gage for the Boston area available to the WSFO is in the inner harbor at Commonwealth Pier. Its data were of tremendous help to the Boston forecasters, but several additional real-time gages along the coast are needed to do a satisfactory job of giving precise public warnings of hazardous tidal conditions.

Over the years, surface observational data in Massachusetts have been eroded badly. For example, no surface observations are available for the 150 miles between Boston and Albany, NY, between the hours of 11 p.m. and 7 a.m. As a solution to the problem, WSFO Boston has been working to expand its cooperative observer program to regain sufficient areal coverage during bad weather situations. Twenty-five Police Barracks and 40 airports are being contacted and equipped to measure snowfall and rain. In addition, 100 fire wardens will form a heavy rainfall network in western Massachusetts. Another avenue for data collection and information will be the monitoring of ham radio traffic. During the storm, a transceiver in the station was used as a monitor and proved a valuable source of information. Extended two-way communications were not possible on this channel because of FCC regulations requiring the operator to possess a license. The only licensed operator at WSFO Boston was the Electronic Technician, who did make a limited number of calls. Inquiries are being made to permit all members of the office staff to use ham radio. The survey team believes this matter should be reviewed by the NWS for all its offices.

Dissemination of warnings to WSOs and other users was an area of major concern. Here, as at WSFO New York City, the problems centered on the KCRT system. Difficulty was experienced in getting messages via the longline system (RAWARC and East Coast Overlay) into the NMC communications computers. Messages composed on the KCRT are not available in hardcopy form or on teletypewriter reperforated tape until they have been sent to Suitland and received back over the teletypewriter circuits. Without the reperforated tape, relay to WSOs Providence and Hartford was not possible. To meet their responsibilities and schedules, Providence and Hartford turned to hand copying the warnings over the telephone. This practice consumes large amounts of staff time when it can be least afforded and is subject to frequent, and occasionally serious, error.

As a solution to this problem, NWS plans to link WSFO Boston with WSOs Hartford and Providence via a teletypewriter loop, similar to that used between WSFO Portland and WSO Concord. The loop will enable WSFO Boston to have a direct communications link with the WSOs, who depend on its guidance.

NMC guidance on storm surge was good and indicated major erosion would occur along the Massachusetts coast. Although the heights and time of the first surge were accurate, the NMC guidance did not provide for the threat of more damage to occur on subsequent tidal surges. Once waves and swells are set into motion by ocean storm winds, they continue to pose a threat long after the winds have decreased or ceased to be a problem.

The guidance did not show or make allowances for a continuing problem on the next high tide. The WSFO staff felt that the first event would destroy most protective barriers and thus allow following tides to pose a greater threat. Their assessments were reflected in their warnings and proved correct. The second high tide did the major damage.

Local Agency Actions

The general attitude of the State and local agencies was that WSFO Boston had done an outstanding job in alerting and warning people of the storm. These remarks were echoed by members of the Federal Disaster Assistance Administration and the Massachusetts Civil Defense staff.

All 8,500 members of the Massachusetts National Guard were called to active duty to rescue stranded motorists and aid in other relief efforts. People were ordered to keep off the highways, and motorists without emergency credentials were turned back or given citations at over 100 checkpoints and roadblocks. The city of Boston was closed to traffic and was not reopened until February 14, 6 days after the snow ended.

WSO HARTFORD

Forecast/Warning Responsibilities and Facilities

WSO Hartford is at Bradley International Airport. For its public weather program, Hartford adapts State forecasts issued by WSFO Boston to the Hartford/Springfield, MA, areas. It has no marine responsibilities, but distributes marine forecasts prepared by the New York office for the Connecticut coastal and offshore waters. The Hartford office has six counties in its county warning program and provides pilot weather briefings for local aviation interests. Additionally, it carries out NWS liaison functions with the State of Connecticut.

Communication circuits include FAA circuits (Services C, A, and O), RAWARC, and the Connecticut Public Service teletypewriter circuit. There are 23 subscribers to this local circuit, which carries all releases made by WSFO Boston that are pertinent to Connecticut, in addition to those issuances from WSO Hartford.

Three NOAA Weather Radio facilities operated by the Hartford office blanket the State. They are at Hartford (WXJ-41), Meriden (WXJ-42), and New London (KHB-47). There is no NOAA Weather Wire Service, but a statewide weatherphone system is available. The Southern New England Statewide Weatherphone System is controlled by the telephone company and utilizes taped broadcasts prepared by the Hartford staff. Broadcasts are entered into the telephone company's computer and made available to the general public via a special weather number.

Chronology

From The Hartford Courant, Monday, February 6:

"Heavy Snow Expected in the State Today"

Springfield Daily News:

"Ready for 16 inches?"

The Winter Storm Watch for the State of Connecticut was issued at 5 a.m. on Sunday and, later in the day, a Heavy Snow Watch was put into effect. Gale Warnings for the Connecticut coastal waters were issued at 5 p.m. by WSFO New York City.

At 5 a.m., Monday, February 6, Travelers' Advisories for the State and the Springfield, MA, area were issued. Four hours later snow began to fall in the Hartford area.

The 10 a.m. Special Weather Statement put into effect a Heavy Snow Warning:

> HEAVY SNOW WARNINGS HAVE BEEN ISSUED FOR SOUTHERN NEW ENGLAND... WITH ACCUMULATIONS OF EIGHT TO SIXTEEN INCHES EXPECTED IN MOST SECTIONS. SNOW WILL BE ACCOMPANIED BY STRONG EASTERLY WINDS RESULTING IN CONSIDERABLE BLOWING AND DRIFTING.

The statement also included Coastal Flood and Marine Storm Warnings for the coasts of Connecticut:

> TIDES WILL INCREASE TO 2 TO 4 FEET ABOVE NORMAL AND COMBINE WITH ALREADY HIGH ASTRONOMICAL TIDES. FLOODING OF LOW LYING COASTAL AREAS OF CONNECTICUT ALSO A DEFINITE POSSIBILITY AT TIMES OF HIGH TIDE.

By 4:30 p.m., Monday afternoon, conditions had deteriorated to a point that issuance of a Special Weather Statement was necessary to describe the blizzardlike conditions. Winds to 50 miles per hour and 3 to 6 inches of snow were creating hazardous drifting and blowing snow situations in most areas.

Shortly after midnight on Tuesday, February 7, with snow accumulations of 12 to 16 inches over most sections of Connecticut, Governor Grasso ordered all roads and highways through the State closed to nonessential traffic and asked all persons and companies not engaged in emergency activities to suspend operations voluntarily.

Snow and gusty winds characterized Connecticut's weather for Tuesday. As the storm moved slowly eastward, a decreasing trend in snowfall was evident. The heavy snow warnings were discontinued by early morning, and the forecast was for flurries by midafternoon and an end to snow later

in the evening. Winds had decreased somewhat, but continued to blow and pile snow into drifts. The near-blizzard conditions were ending over much of New England, and only gale and coastal flood warnings remained in effect.

Staffing and Operational Considerations

Staffing during the storm was adequately planned and consisted of four members performing public service/coordinator, dissemination, and observer functions. These individuals, including the Meteorologist-in-Charge and Principal Assistant, were on duty for 26 consecutive hours. In all, 51 hours of overtime were accumulated at WSO Hartford. Normally, a radar function is required, but, due to maintenance problems, the set was inoperative. Loss of radar observations was not critical in this storm where there were no thunderstorms and all precipitation was in the form of snow.

Due to the excessive traffic on RAWARC and the East Coast Overlay teletypewriter circuits, delays of up to 1 hour were experienced in receiving warnings and forecasts from the forecast offices in New York and Boston. When this occurred, WSO Hartford was unable to obtain its forecast guidance information over the teletypewriter and resorted to hand copying the forecast issuances over the telephone. These delays are typical for the East Coast during bad weather situations and are attributable to the backlog at the NMC Communications Computers. (See WSFO Boston Discussion for a more complete description of the problem.)

During the storm, three messages from Governor Grasso were carried on NOAA Weather Radio. The survey team believes this type of emergency dissemination use was a first for NOAA Weather Radio.

1. Message transmitted on Monday, February 6, at 9:45 p.m.:

   GOVERNOR GRASSO HAS REQUESTED OWNERS OF 4 WHEEL DRIVE VEHICLES TO CONTACT THEIR LOCAL CIVIL DEFENSE OFFICE OR THEIR NEAREST STATE POLICE TROOP IN THIS WEATHER EMERGENCY SITUATION.

2. Message transmitted on Monday, February 6, at 10:15 p.m.:

   THIS IS A MESSAGE FROM GOVERNOR GRASSO, WE QUOTE, "BECAUSE OF THE BLIZZARD CONDITIONS, I AM INVOKING THE POWERS GRANTED TO THE GOVERNOR UNDER SECTION 3-1 OF THE STATUTES. EFFECTIVE AT 10 PM TONIGHT, MONDAY, FEBRUARY 6TH, I AM ORDERING THAT ALL ROADS AND HIGHWAYS IN OUR STATE BE CLOSED TO ALL MOTOR VEHICLES EXCEPT THE FOLLOWING: VEHICLES ENGAGED IN CLEARING ROADS, EMERGENCY VEHICLES ASSISTING STATE AGENCIES IN EMERGENCIES AND PRIVATE VEHICLES ON EMERGENCY MISSIONS. I AM ASKING ALL BUSINESS, INDUSTRIES, SCHOOLS, SERVICE FIRMS, AND ALL PERSONS AND COMPANIES NOT ENGAGED IN EMERGENCY ACTIVITIES TO VOLUNTARILY SUSPEND OPERATIONS.

3. Message transmitted on Tuesday, February 7, at 8:10 a.m.:

GOVERNOR GRASSO HAS MADE AN APPEAL FOR PERSONS WITH 4 WHEEL DRIVE VEHICLES WITH AMPLE SUPPLIES OF GASOLINE, TO CONTACT THEIR LOCAL HOSPITALS AND CONVALESCENCE HOMES FOR TRANSPORTATION OF NURSES AND DOCTORS.

WSO Hartford was fortunate in possessing an exceptionally good cooperative observer network. This system was developed and carefully cultivated over the past several years for use during winter weather situations. It consists of 2-hourly reports from the State Department of Transportation Highway Reporting Network supplemented by State Police Barracks reports and the weather service cooperatiave reporting network. Data are called into the WSO, where is is plotted, analyzed, and relayed to WSFO Boston.

Local Agency Actions

The Hartford Area School System received advisories of the storm on Sunday evening and Monday morning. This gave the system's emergency council ample time to act on cancellation of some classes and early dismissal for all school children. About 70 children were unable to return to their homes and were sheltered in the school buildings. Realistic community preparedness planning and prompt action under these plans, triggered by WSO Hartford's warnings, had made available the necessary supervision, health care, sleeping facilities, and food services to care for these children.

The Hartford Courant reported on February 11, 1978, that Federal Disaster Assistance officials had declared Connecticut nearly recovered from the "Blizzard of 78." Connecticut had not suffered like Massachusetts and Rhode Island. It appeared to the team that this was due in large measure to their readiness to handle the situation and to the exemplary work of the staff of WSO Hartford.

A number of complimentary letters were sent to WSO Hartford for their handling of the severe winter storm. Heading the list was a letter from Governor Ella Grasso expressing her gratitude for a job well done. "The National Weather Service had enabled the citizens of our State to meet this challenging ordeal."

WSO PROVIDENCE

Forecast/Warning Responsibilities and Facilities

The Weather Service Office at Providence, RI, is responsible for issuing forecasts and warnings for the State of Rhode Island. Its programs include local adaptation of public weather forecasts for zones in Rhode Island and marine forecasts and warnings for Narragansett Bay that are issued by WSFO Boston. The office also supports the local aviation community

with pilot weather briefings and operates the NOAA Weather Radio (WXJ-39) station for Rhode Island. Dissemination is accomplished over FAA circuits Services C and A, RAWARC, and a local teletypewriter loop. The users of the local loop include radio-TV stations; the news media; telephone, gas, and electric companies; the city of Providence; and the State Civil Defense. Rhode Island is not part of the NOAA Weather Wire Service.

Chronology

WSO Providence issued its initial Winter Storm Watch at 5 a.m., Sunday, February 5, along with a forecast for Narragansett Bay of possible marine warnings. Later in the day, at 5 p.m., a Heavy Snow Watch -- 6 inches or more -- and Gale Warnings were put into effect.

Early on Monday morning, with the Heavy Snow Watch and Gale Warnings continuing, Travelers' Advisories were issued. Snow began to fall in the Providence area around noon, and at that time a Heavy Snow Warning was put into effect for most of the State:

SNOW...WITH PROBABLE ACCUMULATIONS OF 8 TO 16 INCHES.

This followed the guidance issued by WSFO Boston.

By noon, winds had increased with gusts to 50 miles per hour. As a result, the Gale Warnings were upgraded to Storm Warnings for the Narragansett Bay area. Coastal Flood Warnings for low-lying areas were issued in anticipation of high tides running 2 to 4 feet above normal. Beach erosion due to heavy surf along east-facing beaches was also a matter of concern.

The low center was positioned south of Providence on Tuesday morning and forecast to move eastward indicating relief for Rhode Island. At 5 a.m., the Heavy Snow Warning was discontinued and the Storm Warnings for marine activities downgraded to Gale Warnings. Coastal Flood Warnings remained in effect for the next high tide between 7 and 8 a.m. The 9 a.m. Special Weather Statement discontinued the Coastal Flood Warnings as things began to return to normal.

Snowfall ended shortly before noon with total accumulations of new snow from this storm ranging from 25 to 27 inches up to 33 inches in the Burrville area, located in the northwest corner of the State. While reports of as much as 54 inches of snow were received, the survey team believes that these reports reflect total snow on the ground rather than accumulation from this storm. Accurate measurement of snow depth is difficult during drifting and blowing snow situations.

Gale warnings continued due to gusty northeasterly winds through Wednesday evening and were finally discontinued late that night.

Staffing and Operational Considerations

WSO Providence is a 24-hour station and staffed with six meteorological technicians and an MIC. During the period of the storm, two members and the MIC worked continually to keep abreast of the situation. One person arrived at 2 p.m. on Monday for his 4 p.m. shift and remained on duty until Friday. A total of 89 hours of overtime were accumulated.

Over the past years, the NWS and local and State officials have established a good working relationship. Numerous State offices observe beginning and ending times of precipitation, snow depth, rainfall, etc., and promptly pass this information to the WSO via two-way radio. These cooperative observers, recruited and trained by NWS, are vital cogs in the public warning system in Rhode Island, as they are in every other state and community.

The only area of difficulty experienced by WSO Providence was the delay in receiving forecast and guidance information from WSFO Boston. Like WSO Hartford, the delays were caused by KCRT system backups in the communications computer at NMC. Ultimately, the forecasts and warnings were read and copied over the telephone. (See WSFO Boston Discussion for a more complete description.)

Local Agency Actions

State and local officials were alerted of the approaching storm at 6 p.m., Sunday. Their decision at 9:30 a.m. on Monday to close schools and to release workers early was based on the predicted potential of the storm. Many private businesses made special arrangements with hotels and motels to house their employees in anticipation of hazardous road conditions.

Despite the early warnings and statements, about 1,700 cars had to be abandoned on the Interstate Highways of Rhode Island (Figure 2). Many were stalled as a result of the deep and drifting snow, while others were caught in the traffic between stalled and abandoned cars. Removal of these vehicles was slow, and this hampered state recovery operations. Interstate-95 was not cleared and reopened to traffic until February 13.

WSFO PORTLAND

Forecast/Warning Responsibilities and Facilities

The forecast office at Portland, ME, is responsible for issuance of forecasts and warnings in the States of Maine and New Hampshire. The public weather program includes the issuing of local, zone, and State forecasts. Other services provided are fire-weather, hydrology, agriculture, and pilot weather briefings. Marine responsibility is for the coastal waters extending out to 25 miles. The forecast office has 16 counties within its warning area.

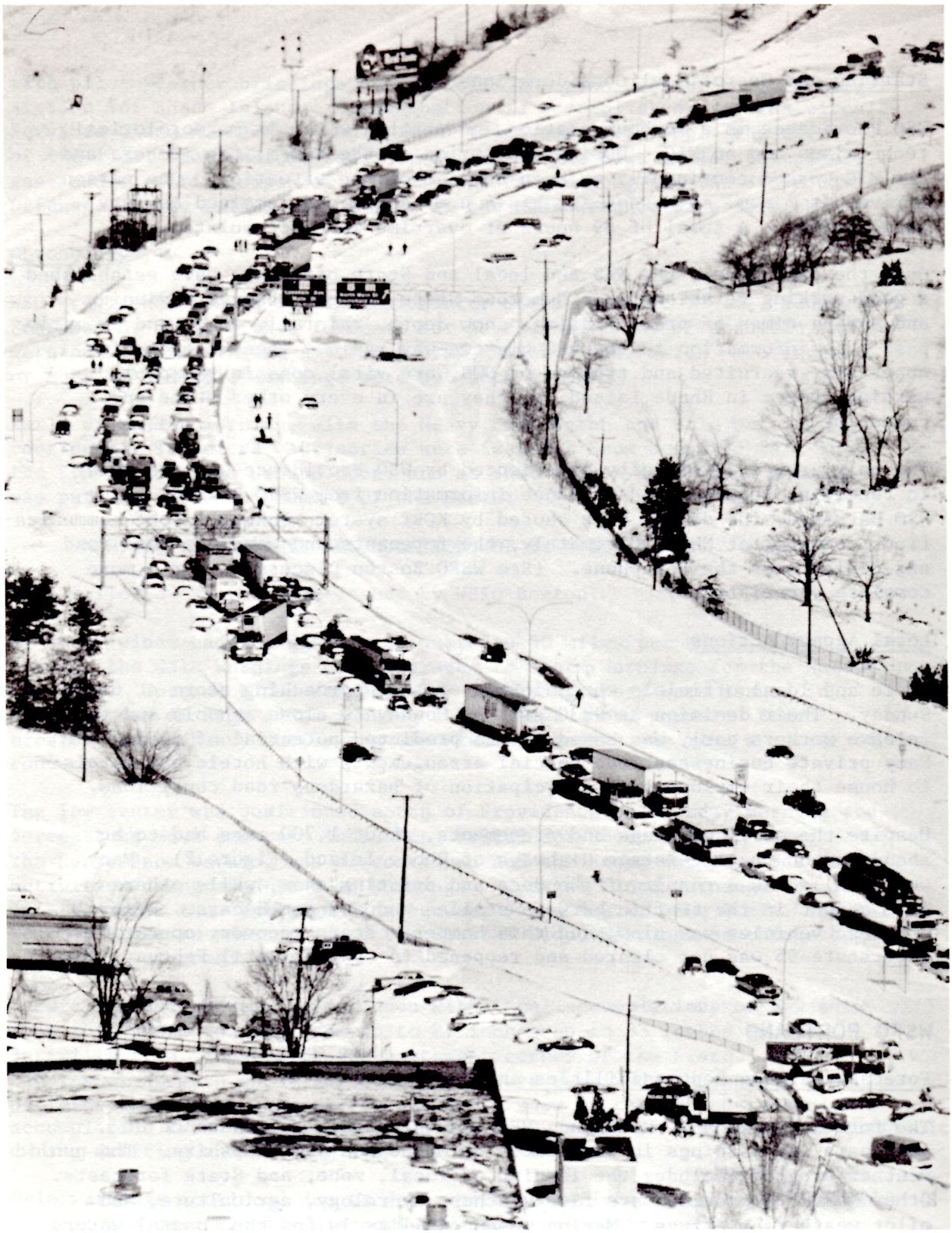


Figure 2. Interstate 95 in Rhode Island on February 7, 1978.
Photograph courtesy of PROVIDENCE JOURNAL BULLETIN.

Within Portland's forecast area are WSMO Portland and the WSOs in Brunswick and Caribou, ME, and Concord, NH.

Dissemination is carried out through FAA circuits (Services A, C, and O); RAWARC; and a local teletypewriter loop to radio-TV stations, local law enforcement agencies, and the State Police warning point for Civil Defense. The State Police also retransmit warnings over their own teletypewriter circuit. Maine, like the rest of the New England States, does not have NOAA Weather Wire Service. NOAA Weather Radio broadcasts are made from sites at Ellsworth (KEC-93) and Portland (KDO-95), ME, and from Concord (WXJ-40), NH. The Portland office controls the Ellsworth facility, while WSO Concord uses the forecasts prepared by WSFO Portland in making their broadcasts over NWR.

Chronology

A Winter Storm Watch for Maine and New Hampshire was issued on Sunday, February 5, at 3 p.m. The forecast called for snow accumulations of 6 inches or more and some minor coastal flooding and beach erosion Monday and Monday night.

The Marine Forecast at 4:30 p.m. on Sunday reflected the possibility of marine warnings being issued on Monday.

Monday morning, February 6, at 5:30 a.m., Gale Warnings were put into effect for Maine and New Hampshire coastal waters--25 miles offshore:

> ALONG THE COAST...NORTHWEST WINDS WILL FRESHEN TO GALE FORCE LATE TODAY AND TONIGHT CAUSING TIDES TO RUN ABOVE NORMAL. THIS COMBINED WITH A HIGH ASTRONOMICAL TIDE COULD CREATE SOME COASTAL FLOODING AND BEACH EROSION LATE TUESDAY MORNING.

A Heavy Snow Warning was issued at 2 p.m. Monday afternoon for southern Maine with accumulations being "from near 6 inches in the mountains to as much as 10 inches along the coast."

The Coastal Waters forecast was amended at 7 p.m., Monday, to reflect the change from gale to storm warning and also put into effect Coastal Flood Warnings.

> EAST TO NORTHEAST WINDS INCREASING (to) 45 TO 60 KNOTS TONIGHT. SEAS BUILDING 10 TO 20 FEET TONIGHT SUBSIDING SLOWLY LATE TUESDAY. TIDES 2 TO 4 FEET ABOVE NORMAL WITH CONSIDERABLE FLOODING OF LOW LYING AREAS AT TIMES OF HIGH TIDES. HEAVY SURF BATTERY WILL CAUSE CONSIDERABLE BEACH EROSION TONIGHT AND TUESDAY.

Through Monday night statements and warnings continued the heavy snow, marine storm, and coastal flood warnings. At 7:30 a.m., Tuesday, February 7, a Coastal Evacuation Warning--for York and Cumberland Counties--was issued:

> ALL PEOPLE IN LOW LYING COASTAL SECTIONS AND ALONG THE IMMEDIATE COAST FROM PORTLAND TO KITTERY SHOULD IMMEDIATELY EVACUATE TO HIGHER GROUND INLAND.
>
> TIDES ARE CURRENTLY RUNNING 3 TO 4 FEET ABOVE NORMAL AND COULD PRODUCE AN ALL TIME HIGH TIDE MARK IN PORTLAND AT 10:30 THIS MORNING. AT THE SAME TIME...POUNDING SURF WILL CREATE SERIOUS THREAT TO ALL STRUCTURES ALONG THE COAST.

Special Tide Statements verified the flood threat:

> AT 9 O'CLOCK THIS MORNING THE TIDE GAGE AT PORTLAND, MAINE STATE PIER WAS READING 12.5 FEET. THIS IS 3 FEET ABOVE NORMAL...PORTLAND POLICE REPORT WATER UP TO MOST PIERS WITH SURF BREAKING OVER PIERS. TIDE IS RUNNING APPROXIMATELY 3 FEET ABOVE NORMAL SO THEREFORE A 13 TO 14 FEET TIDE IS PREDICTED.
>
> THE TIDE AT 10:10 AM THIS MORNING WAS 13.9 FEET BREAKING THE PREVIOUS RECORD HIGH TIDE OF 13.6 FEET...
>
> AT THE TIME OF HIGH TIDE THIS MORNING...10:27 AM...THE TIDE AT PORTLAND HARBOR READ 14.3 FEET.

At 2:30 p.m., Tuesday, as the storm moved eastward from its position southeast of Cape Cod, marine warnings were dropped to the gale category. Coastal flood warnings remained in effect, because of high tides and rough surf. Eventually, gale warnings were downgraded to small-craft advisories Wednesday morning and all warnings and advisories were discontinued later on Wednesday.

Staffing and Operational Considerations

By 3 p.m., on Sunday, most of the forecast offices in the mid-Atlantic Coast States had already issued their watches and forecasts for a winter storm. Their early issuance of the winter storm watches was based on the NMC guidance. Like the other forecast offices, WSFO Portland decided to stay with the LFM 2 forecast. They had been monitoring the observed pressure field to the south and were able to compare it to the guidance. Although the storm had not yet developed, the indications were that it would. It looked good. The calls went out.

Contacts with local officials were made and the potential of the situation discussed. Dissemination of statements via teletypewriter and broadcasts over NWR, NAWAS, and EBS followed. Difficulty was experienced

in reaching the EBS facility over the telephone and resulted in the actual broadcast being aired 15 minutes after issuance of the initial warning. This delay was due to wrong phone numbers being listed in the WSFO call listing and has since been remedied.

Total overtime at WSFO Portland was 10 hours. Unlike the southern New England States, Maine was not paralyzed by the storm and most of the employees scheduled to work were able to get to the office.

Local Agency Actions

The Coast Guard reported: "(We) did not have to go out--everyone heeded and stayed in." The remarks were very complimentary and laudatory.

The warnings allowed many to be evacuated from Old Orchard Beach. The City Manager's comments on the weather service warnings were:

> GREAT...ALLOWED US TO EVAC OVER 100 PEOPLE. NOT ONLY IN THIS INSTANCE BUT AT ALL TIMES.

State Civil Defense officials, who have a drop on the local teletypewriter loop, applauded the timely and advanced warnings. Working with the National Weather Service, Civil Defense had done its job. The people were prepared.

As the storm passed and things returned to normal, 140 National Guard troops were ordered to active duty to aid in storm cleanup and debris removal in York and Cumberland counties, the coastal areas hardest hit by the storm surge.

CONCLUSION

In many cases, employees were ready and willing to devote the extra effort necessary to accomplish their assigned tasks. The instances of 16- and 24-hour shifts worked are evidence of their dedication and commendable performance. Each and every NWS forecast and service office in the affected area played a significant role in alerting the public of the winter storm. In singling out these offices for commendation, the team realizes they are a representative sample of NOAA's entire field staff and that the final product is a result of the effort of others not specifically mentioned in this report.

CHAPTER IV

METEOROLOGICAL CONDITIONS AND GUIDANCE

INTRODUCTION

The record-breaking winter storm of February 6-7 in the Northeastern United States first appeared on the sea-level analyses as a weak extratropical cyclone off the South Carolina coast on the afternoon of February 5. (Figure 3). The storm was not a typical "Cape Hatteras Low" as it had not developed in that area after progressing through the southeastern States. It had formed deep in a cold air mass behind the polar front that lay west to east through the Bahamas. The arctic front was located along the Appalachians. The 500-mb low-pressure was centered over Lake Huron, and the trough associated with the surface front extended from the Great Lakes to the Bahamas.

During the night of February 5-6 and the following day, the 500-mb low plunged southeastward to the Virginia Capes while the sea-level low-pressure center moved rapidly northward and intensified, reaching a minimum pressure of 984 mb.

The intense storm decelerated greatly as the sea-level center came under the 500-mb low (Figure 3). The sea-level center appears to have made a small loop to its left as it came under the low aloft. Thereafter, the sea-level and 500-mb low centers moved east-northeastward together. The mature storm moved very slowly and filled by 5 mb south of New England during the night of February 6-7. Strong winds and heavy snow accompanied this major storm. Hurricane force winds were observed with peak gusts to 83 miles per hour at Boston and to 92 miles per hour on Cape Cod. One to three feet of snow fell from Delaware to Massachusetts and a total of 27 inches of snow was recorded at Providence, RI, and at Boston, MA. The snow blown by the strong winds produced blizzard conditions for much of New England. The strong winds produced a storm surge, which resulted in serious coastal flooding and beach erosion from New Jersey to Maine.

A detailed meteorological description of the storm and guidance forecasts, written by Harry E. Brown and David A. Olson, of the National Meteorological Center, may be found in the May issue of the AMERICAN METEOROLOGICAL SOCIETY BULLETIN.

THE STORM AS SEEN FROM SATELLITE

The National Environmental Satellite Service (NESS) provides support services to the NWS in the form of satellite imagery and interpretive messages. The Washington Satellite Field Services Station (DCA SFSS) is responsible for the transmission of satellite pictures (both visual and infrared) to the forecast offices in the eastern United States. DCA SFSS also issues 6-hourly Satellite Interpretation Messages (SIMs)

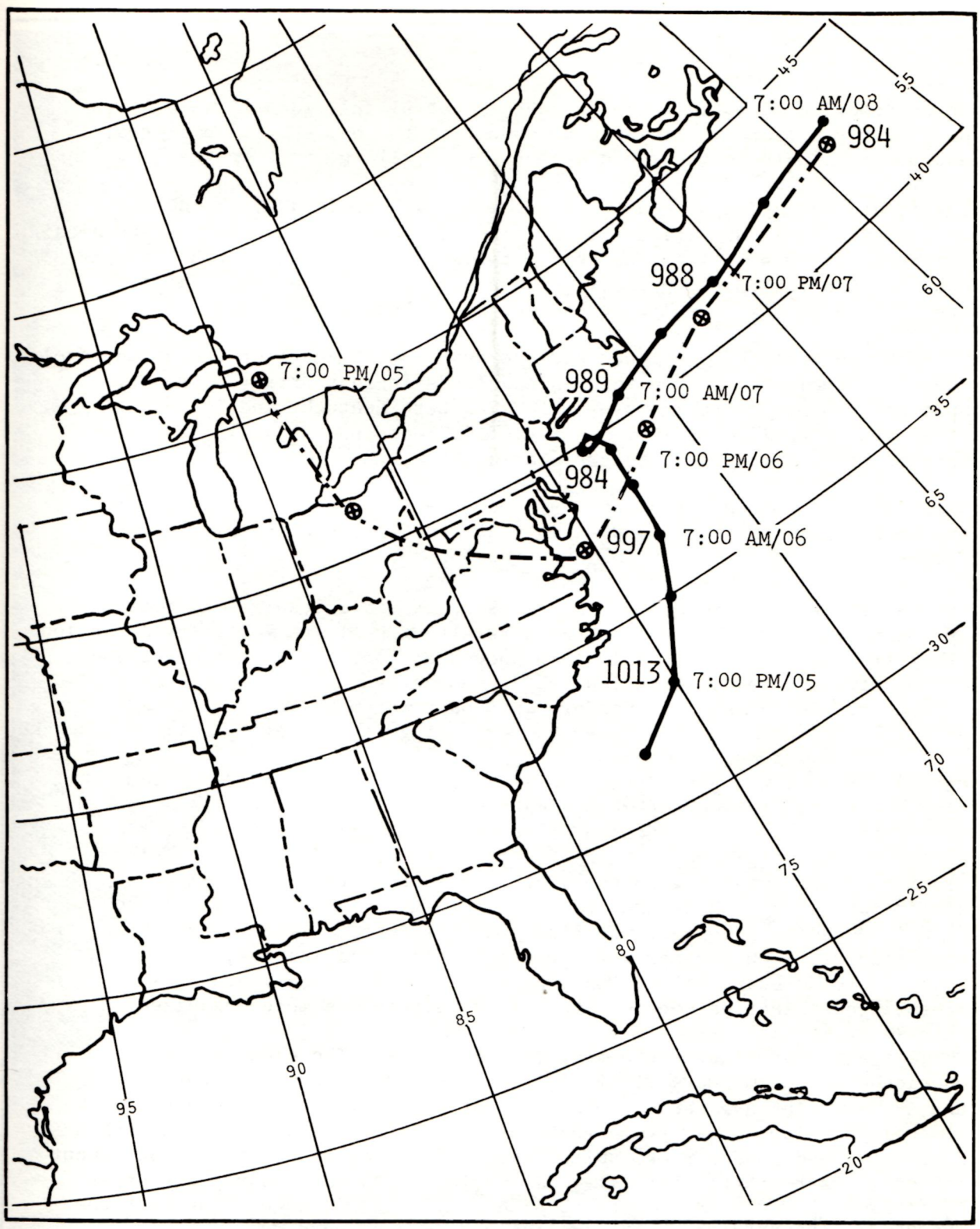


Figure 3. Observed 500-mb low positions (circles) at 12-hr intervals beginning 7 p.m., February 5, 1978, observed sea-level low positions (dots) at 6-hr intervals beginning 1 p.m., February 5, 1978, and observed central pressure (mb).

which describe synoptic activity that is not plainly identifiable on the half-hourly pictures. Movie loops made from the half-hourly pictures, and not available to the field offices, play a large part in the SIM.

The first indication of coastal development was noticed by the DCA SFSS on February 5, 1978. Evident from the movie loop imagery was a subtropical jetstream (75 kts) bulging northward to just south of the North Carolina coast. This indicated upper ridge development along the coast as a cold trough located inland continued to deepen southward.

By noon, on the 5th, continued surface development south of the North Carolina coast was indicated by the thickening clouds in that area (Figure 4). Upstream, an upper trough moved across eastern Kentucky and Tennessee at 30 kts. The 12-hour Infrared (IR) film loop, ending at 11:30 a.m., February 5, confirmed the interpretation.

About 3 p.m., embedded thunderstorms were noted in the cloud mass off the North Carolina coast, indicating continued surface low development (Figure 5).

The Satellite Interpretation Message (SIM) at 9 p.m., suggested continuing cyclogenesis near Hatteras, NC, as a result of Positive Vorticity Advection (PVA) from the west. The film loop showed an increase in the comma-shape of the cirrus shield, which implied deepening, and also that embedded convective cloudiness off the Carolina coast was merging with the PVA area. The convective cloudiness was expanding rapidly at this time.

Monday's 9 a.m. SIM noted that the 12-hour LFM forecast guidance was consistent with the conditions evident on satellite imagery. An apparent vorticity center was located in south-central Virginia with an area of midlevel clouds (producing snow) on its north side (Figure 6). This cloudiness was expanding to the west in a southeasterly flow--implying strong advection of moisture off the water into the storm. The 12-hour film loop ending at 6 a.m. verified that the surface system was curving back towards the upper low which was now inland near Elkins, WV. A SIM update, around noon, stated that the satellite data continued to show storm intensification, because the cloud pattern was more organized.

The storm was still strengthening through 3 p.m. The cloud pattern continued to become more distinct, with the advection of moisture into the system. But now the storm's movement was very slow. The position of the upper low was a little south of the LFM track, although the LFM's forecast speed looked reasonable. The surface low was near 39N 73W--about 150 miles east of Atlantic City, NJ--moving northwest towards the upper low (Figure 7). The data through 8:30 p.m. revealed some signs that the storm was intensifying while continuing to move toward New York City.

At 2 a.m., February 7, the rate of northward progression of the heavy cloud shield associated with the storm indicated a northwest movement

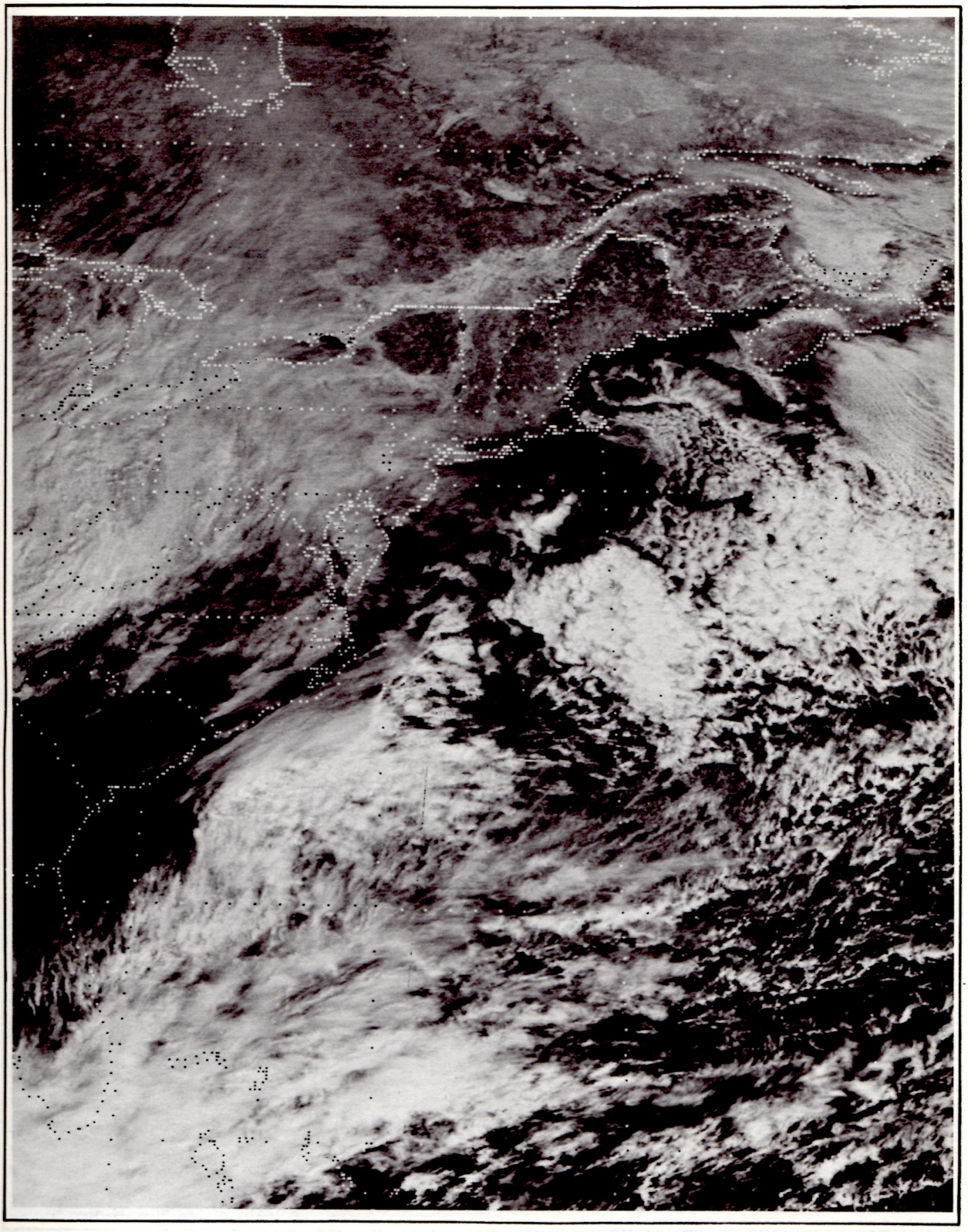


Figure 4. 10:30 a.m., February 5, 1978, visual GOES satellite picture.

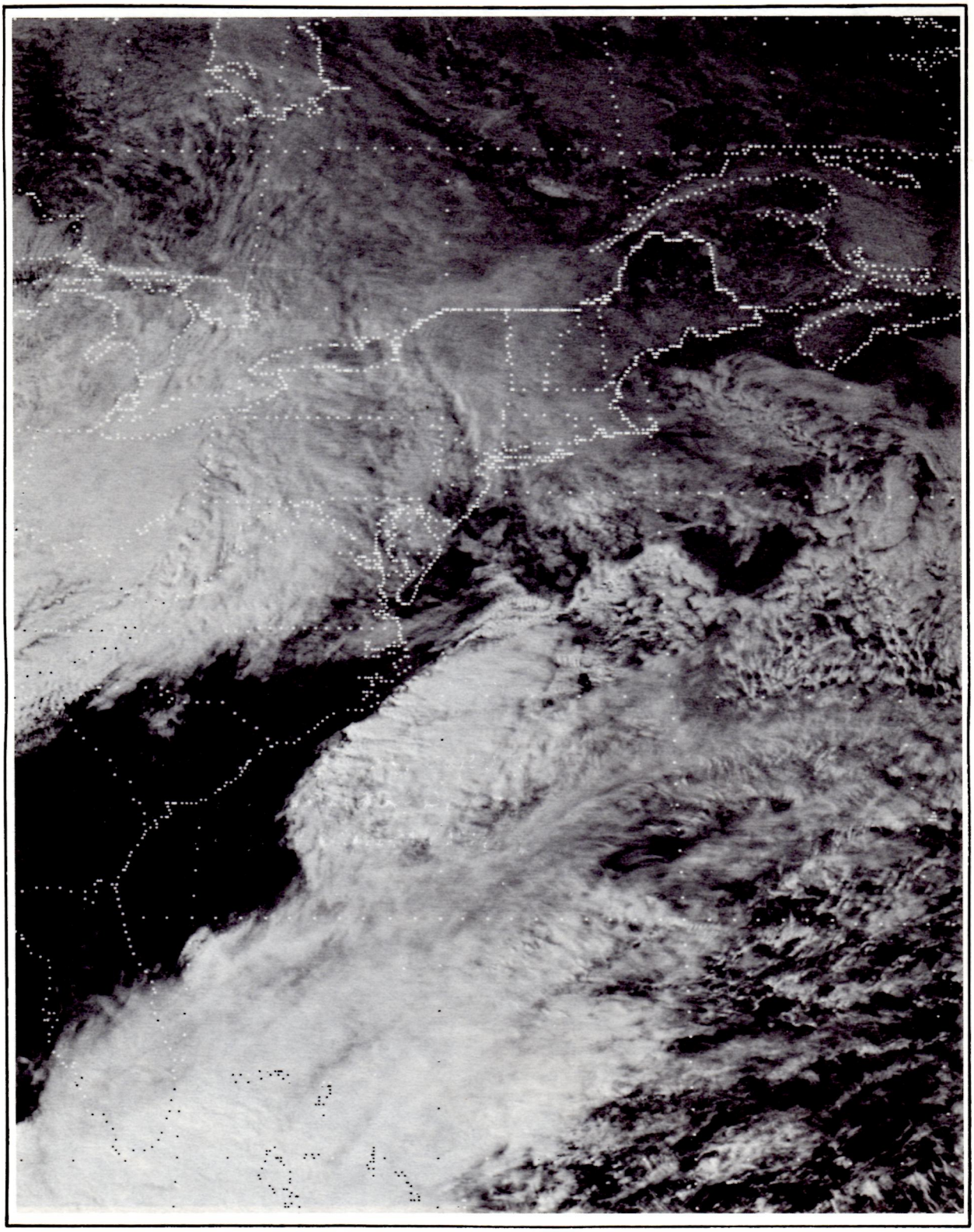


Figure 5. 3:30 p.m., February 5, 1978, visual GOES satellite picture.

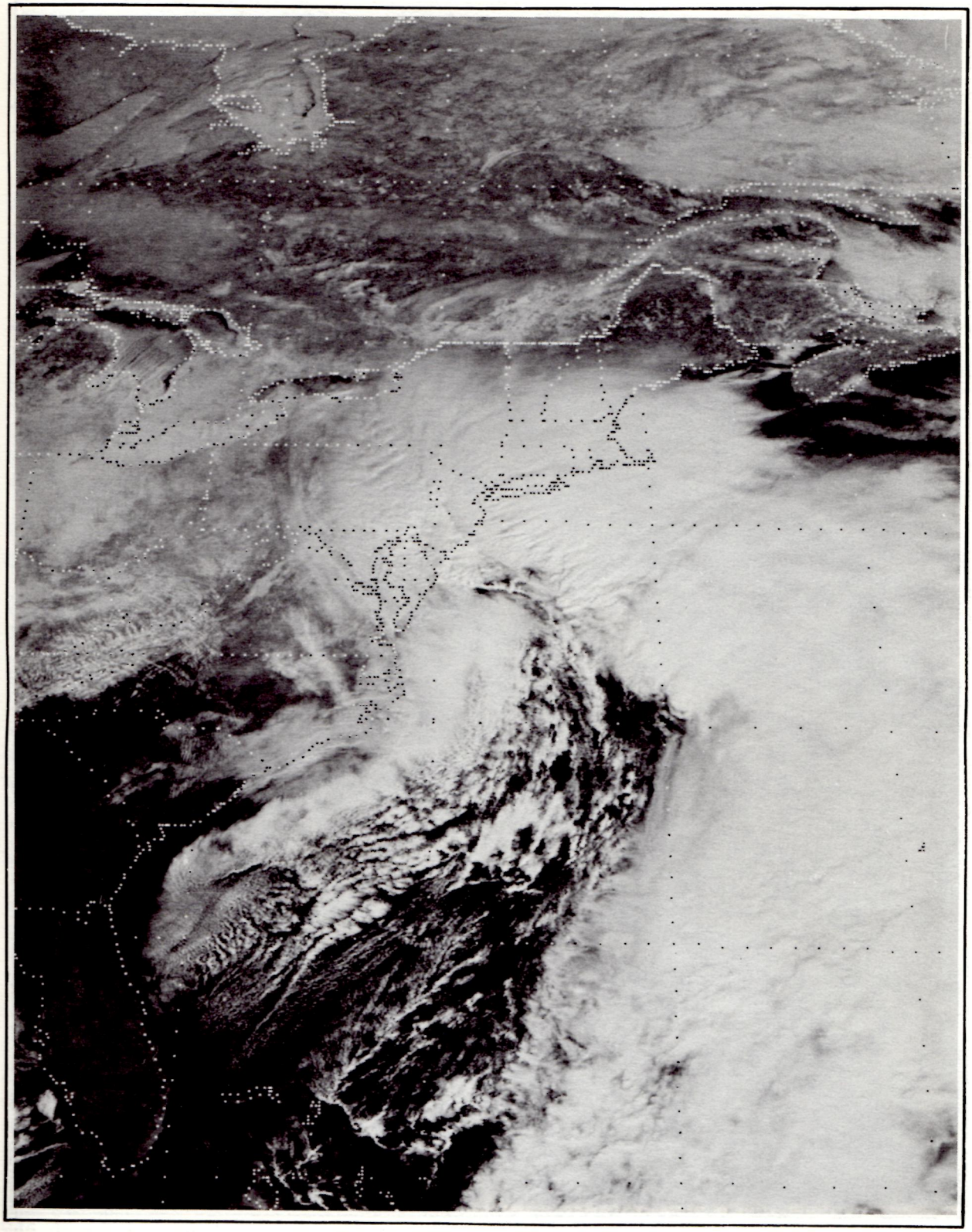


Figure 6. 10:30 a.m., February 6, 1978, visual GOES satellite picture.

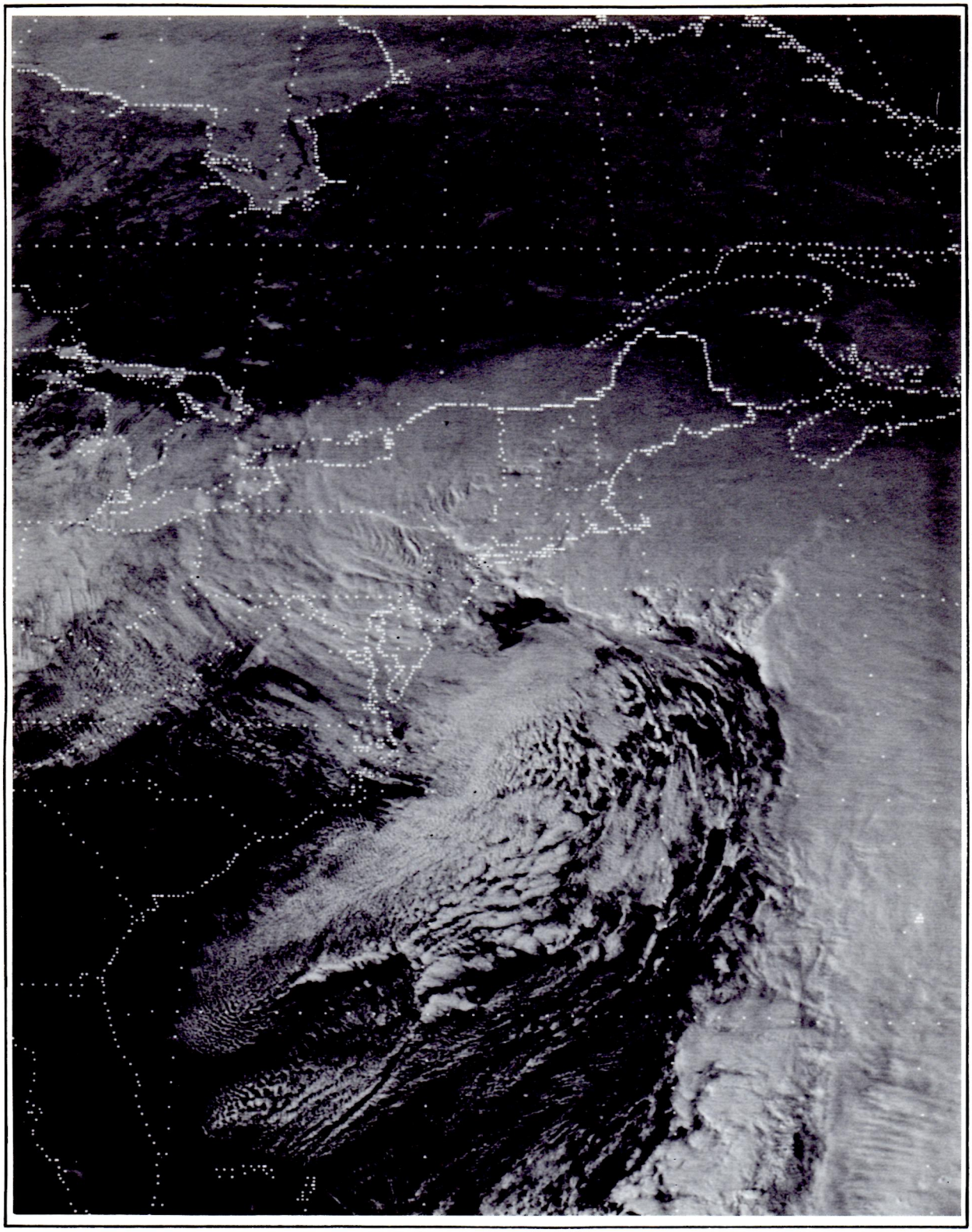


Figure 7. 3:30 p.m., February 6, 1978, visual GOES satellite picture.

of the storm of less than 10 kts. The upper low at this time was just west of the surface system. When this happens, past cases have shown that intensification ceases.

The SIM was updated at 6 a.m. and focused on the continued lack of significant change in the movement of the storm. It was now near Long Island. At 9 a.m., the storm system was centered near 40N 72W. This indicated a turn to the east northeast at less than 10 kts. The NMC surface analysis closely matched this location.

Near noon on February 7, the SIM mentioned that it was difficult to correlate the cloud patterns and weather features with the NMC forecast guidance. By this time, the storm was centered near 40N 71W (Figure 8) and had moved in an east southeast direction at about 15 kts. (Later inspection of the film loops indicated a strong upper ridge northeast of the storm, which may have had a role in pushing the storm in this direction.) Clouds showed signs of dissipating.

Film loops through 11:30 a.m. gave an overall movement towards the northeast of 10 kts. Also noted was a second surge of moisture wrapping halfway around the low center and passing across the southern portions of New England (Figure 9).

The SFSS continued monitoring the storm's movement, and the 6 p.m. February 7 SIM described the direction as heading out to sea with a speed of 15 kts. Later that evening, around 9 p.m., the low was positioned on satellite imagery at 40N 66W and moving eastward 20 to 30 kts (Figure 10). This correlated well with the LFM guidance which forecasted the storm's path away from the Northeast United States.

SHORT RANGE PROGNOSES

The current version of NMC's Limited-Area Fine Mesh Model (LFM 2) became operational on August 31, 1977. Prognoses from the LFM 2 valid throughout the 2-day storm period consistently predicted details of the development. The prognoses made from initial data for 7 a.m., February 5, 1977, constitute a representative sample.

The 12-hour prognosis for 7 p.m., February 5, forecast the initial cyclogenesis off the South Carolina coast (Figure 11). While the forecast position was approximately 120 miles south of the actual development location, it was an exceptionally good forecast. The 24-hour (Figure 12) and 36-hour (Figure 13) prognoses forecast both the northward movement of the sea-level low; however, the storm's intensification was somewhat faster than the model predicted. The 36-hour forecast position of the storm center was about 120 nautical miles south of the observed position and the forecast central pressure of 991 mb was 7 mb higher than observed. At 48 hours, the LFM no longer lagged behind as the forecast low position was northeast of the observed (Figure 14). These deviations

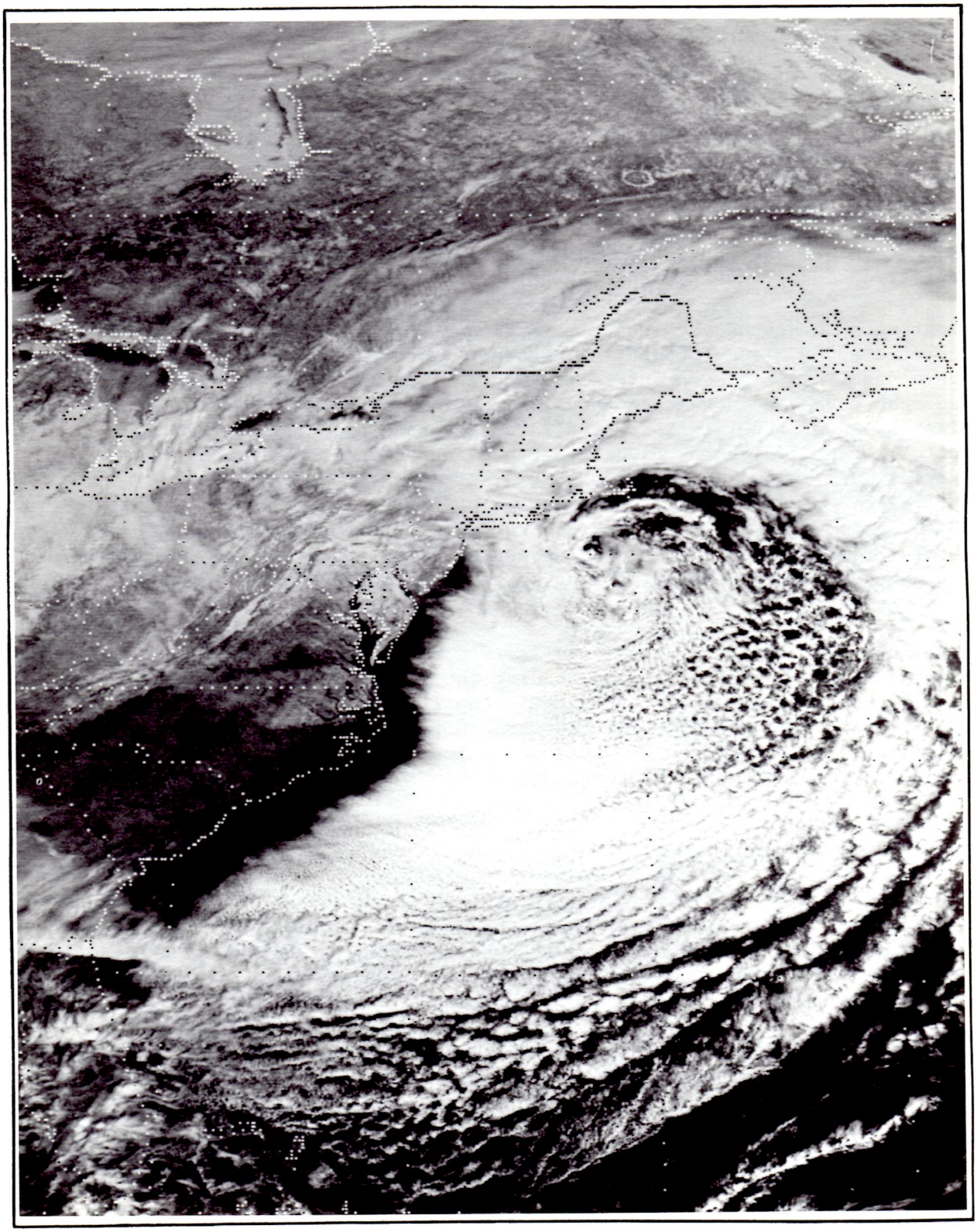


Figure 8. 10:30 a.m., February 7, 1978, visual GOES satellite picture.

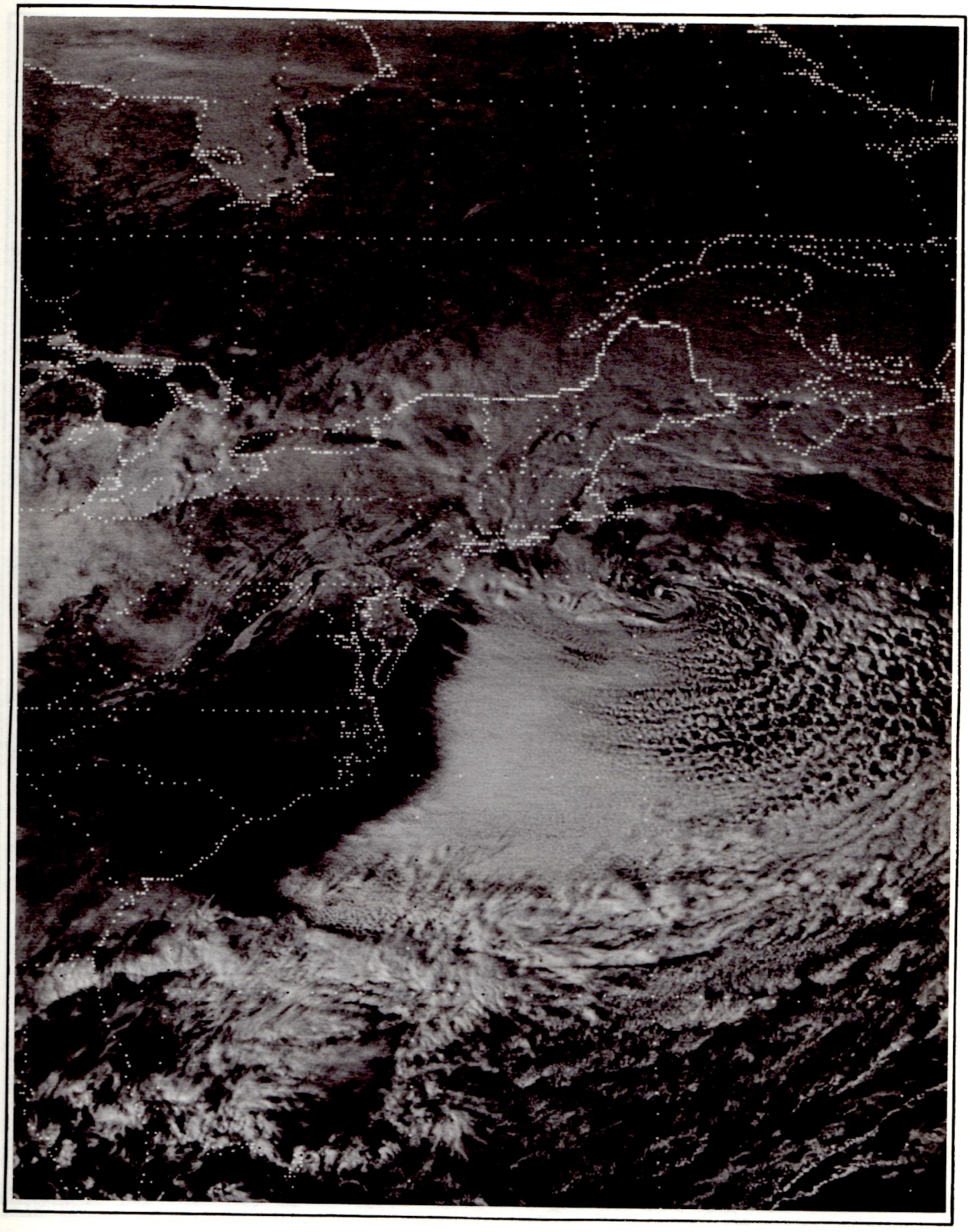


Figure 9. 3:30 p.m., February 7, 1978, visual GOES satellite picture.

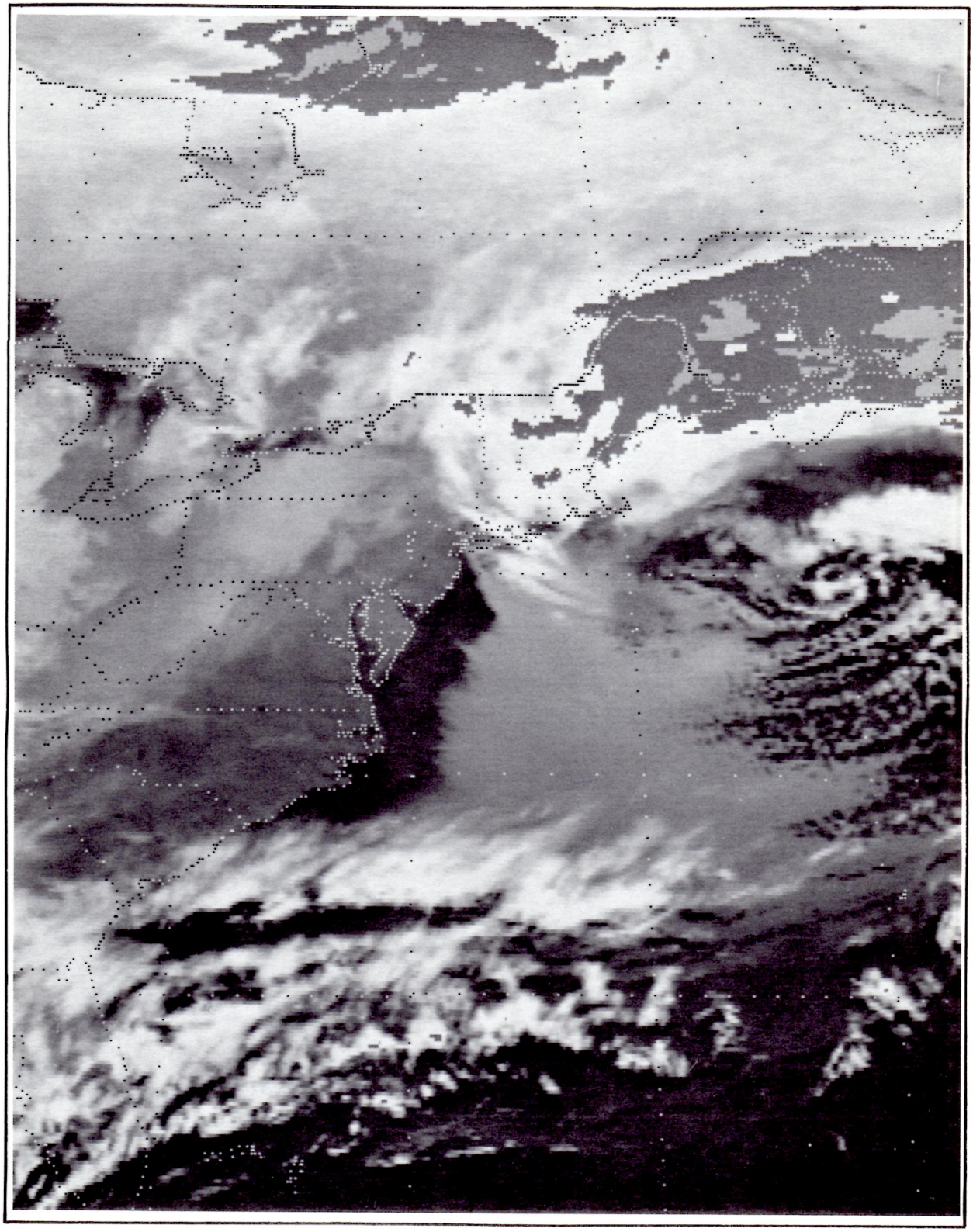


Figure 10. 9 p.m., February 7, 1978, Infrared (IR) GOES satellite picture.

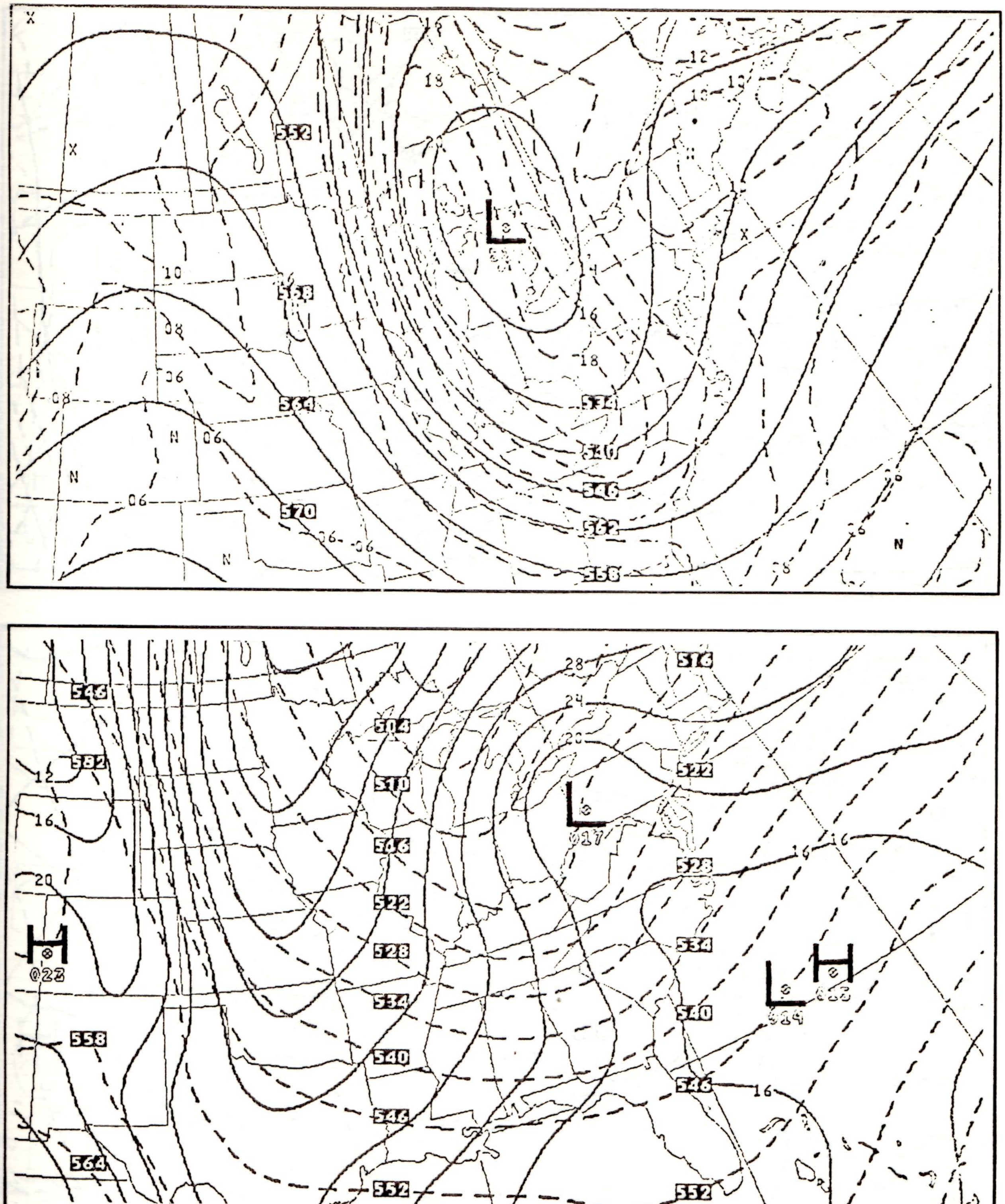


Figure 11. LFM 2 12-hr forecast derived from 7 a.m., February 5, data. The valid time for the prognoses - 500-mb (top) and sea-level (lower) - is 7 p.m., February 5, 1978.

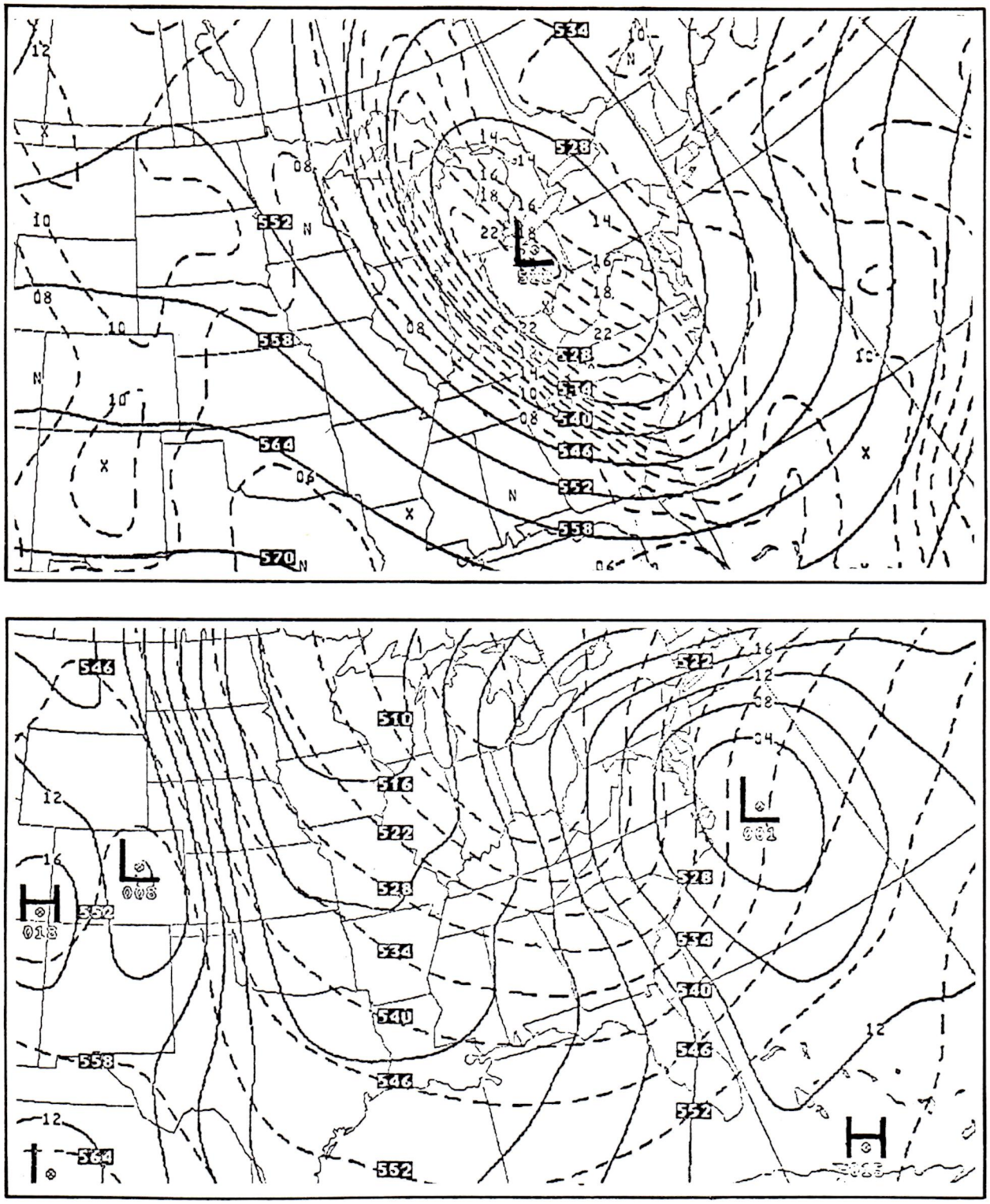


Figure 12. LFM 2 24-hr forecast derived from 7 a.m., February 5, data. The valid time for the prognoses - 500-mb (top) and sea-level (lower) - is 7 a.m., February 6, 1978.

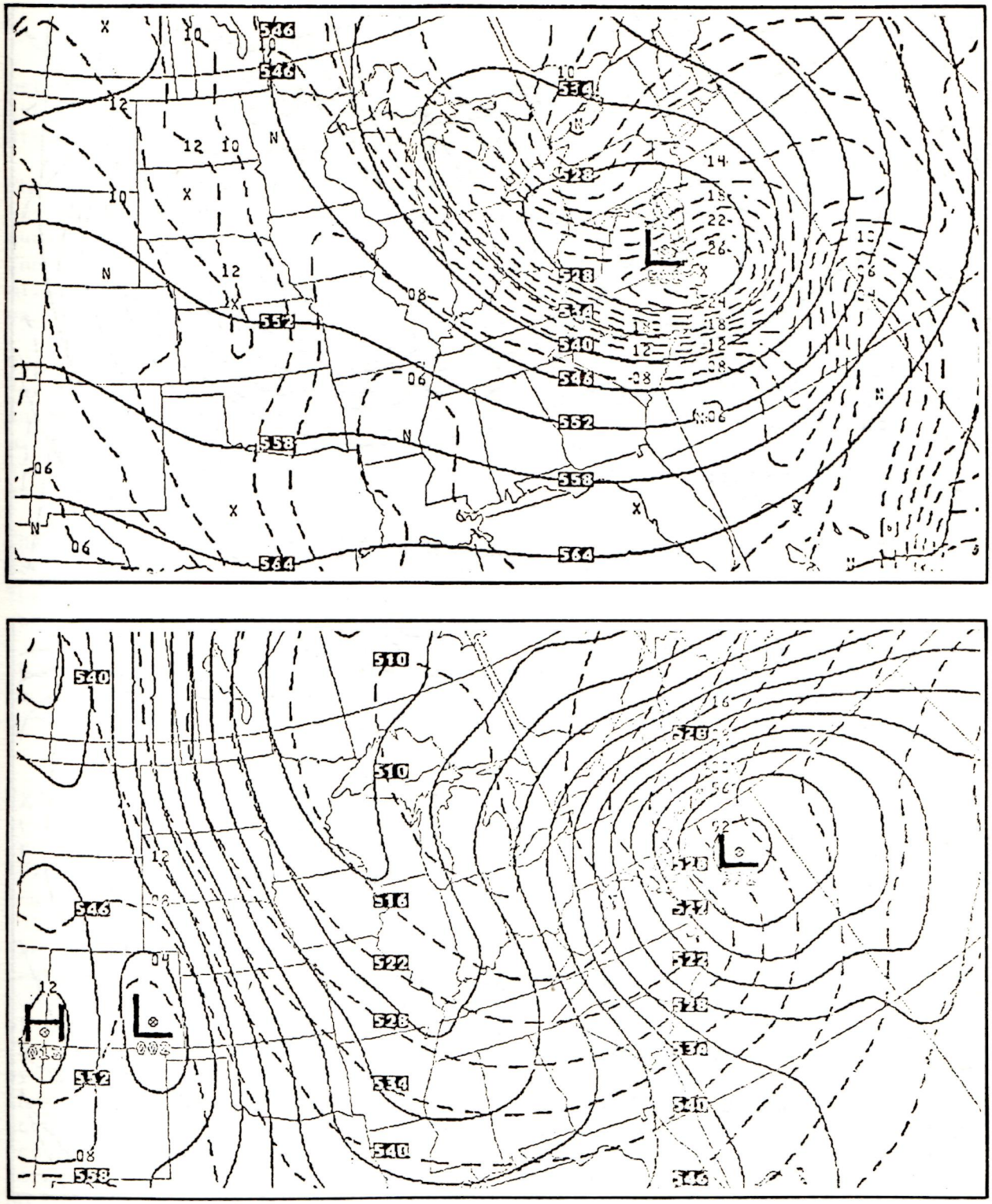


Figure 13. LFM 2 36-hr forecast derived from 7 a.m., February 5, data. The valid time for the prognoses - 500-mb (top) and sea-level (lower) - is 7 p.m., February 6, 1978.

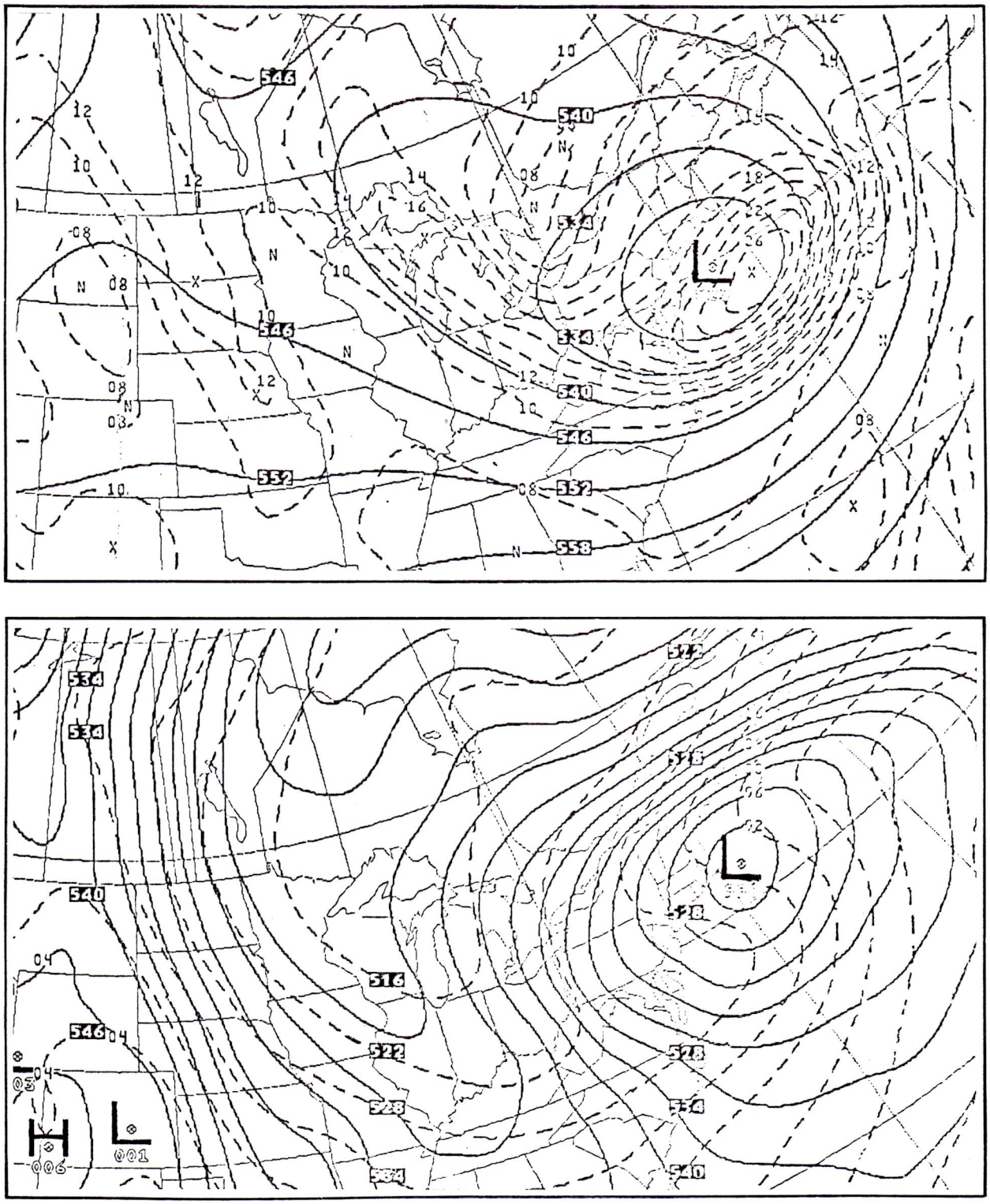


Figure 14. LFM 2 48-hr forecast derived from 7 a.m., February 5, data. The valid time for the prognoses - 500-mb (top) and sea-level (lower) - is 7 a.m., February 7, 1978.

between model and actual atmosphere did not detract significantly from the public forecasts and warnings. Over the entire Northeastern United States, the forecast sea-level circulation closely resembled the observed.

The 500-mb prognoses, extended through 48 hours, successfully forecast the plunge of the cold low from Lake Huron to Eastern Virginia and the subsequent turn towards the east-northeast (Figures 11 through 14). The 36-hour 500-mb low position in Virginia was forecast only 100 nautical miles west of the observed position. The forecast 48-hour low position was within 40 nautical miles of the observed position.

The LFM 24-hour prognoses made from successive initial analyses and valid for the days of the storm were consistent throughout. Differences between successive 24-hour forecast and observed positions were about 90 nautical miles for all four forecasts. Corresponding differences between forecast and observed positions of the 500 mb low were greater than at sea level and varied from 60 to 120 nautical miles.

The LFM 2 forecasts for occurrence of measurable precipitation for 12-hour periods were as successful as the circulation prognoses (Figure 15). The timing of the onset of precipitation in the Mid-Atlantic States was very good. The 12- to 24-hour area of forecast precipitation valid 7 a.m., February 6, indicated an increase in the Mid-Atlantic region from that of the 00- to 12-hour forecast. However, the model was slow in indicating the subsequent spread of precipitation into New England, as might be expected from the lag noted in the sea-level prognoses.

EXTENDED RANGE PROGNOSES

The 7-Layer Primitive Equation model (7LPE) became operational on January 19, 1978. This model made excellent 84-hour prognoses valid during the 2-day storm period and very large changes were successfully predicted.

The 84-hour 500-mb prognoses were available to field forecasters, but the sea-level prognoses were not, because they are not regularly transmitted. However, the field did receive 72-hour manual prognoses which are modifications of the 7LPE 84-hour, i.e., the 72-hour is a modification of the 84-hour. The manual modification decreased the magnitude of the position error by half and lowered the forecast central pressure by at least 12 mb so that the 72-hour forecast central pressures were within the limits of accuracy of the analysis. The manual prognoses made a day earlier were accurate enough to enable the forecaster on February 3 to issue a general forecast indicating surface development near the New Jersey shore in 60 hours with rapid and strong intensification generating moderate to heavy precipitation in the northeastern States.

Figure 16A shows the 72-hour manual prognostic and observed sea level isobars valid at 7 a.m. EST, Tuesday, February 7.

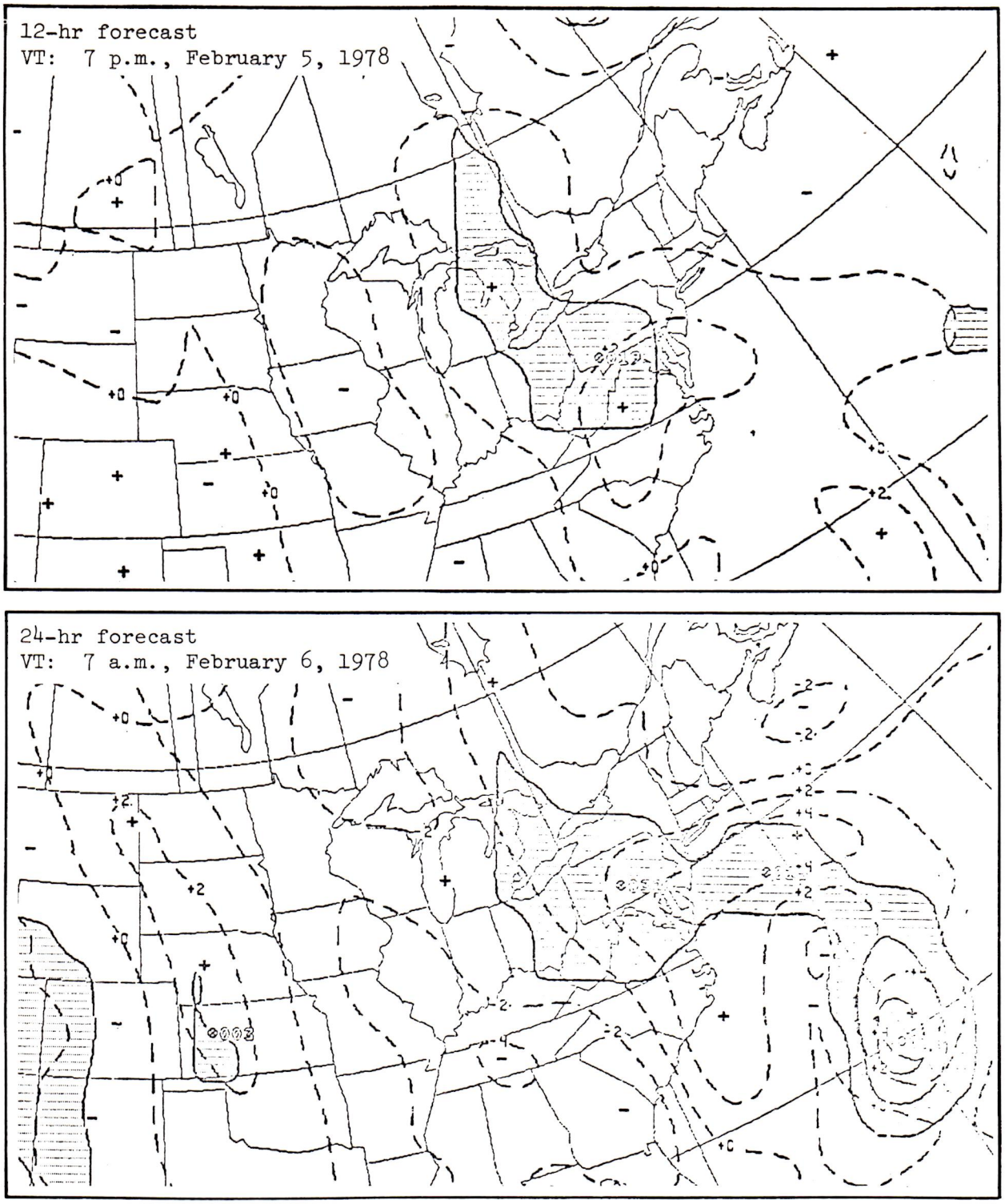


Figure 15A. LFM 2 Precipitation forecast derived from 7 a.m., February 5, data. Solid lines are isohyets (lines of equal precipitation amounts) drawn at intervals of 1/2 inch accumulated precipitation. Precipitation maxima are indicated by encircled "X" and accompanied by a three-digit number representing units, tenths, and hundredths of inches of accumulated precipitation.

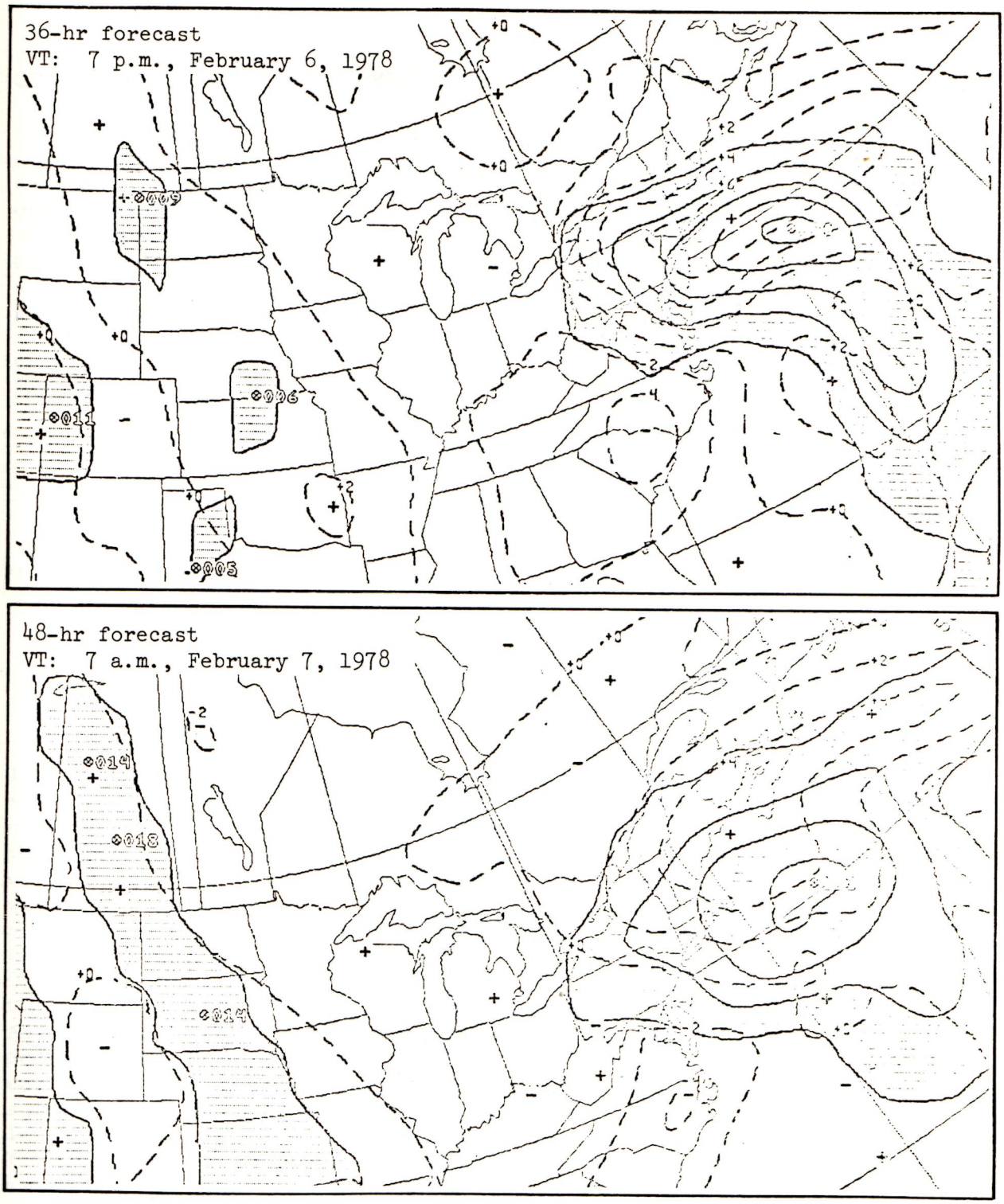


Figure 15B. LFM 2 Precipitation forecast derived from 7 a.m., February 5, data. Solid lines are isohyets (lines of equal precipitation amounts) drawn at intervals of 1/2 inch accumulated precipitation. Precipitation maxima are indicated by encircled "X" and accompanied by a three-digit number representing units, tenths, and hundredths of inches of accumulated precipitation.

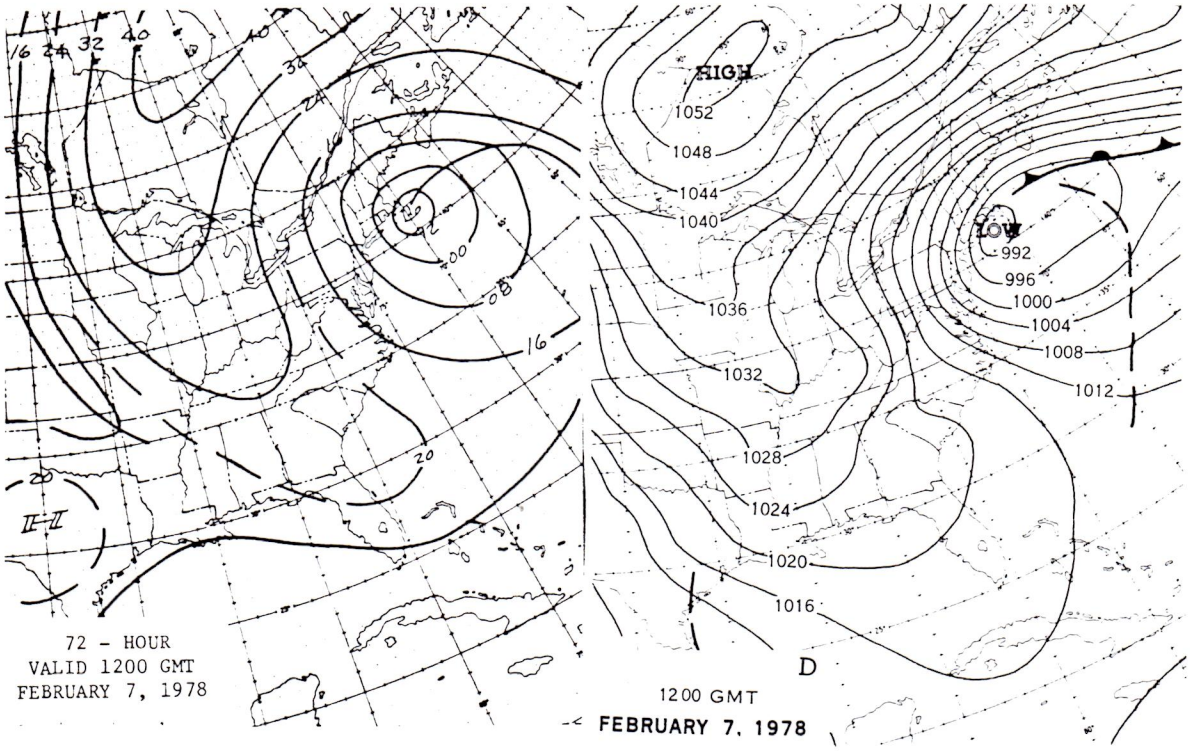


Figure 16A. 72-hour manual prognostic and observed sea level isobars (millibars) valid at 7 a.m. EST, February 7, 1978.

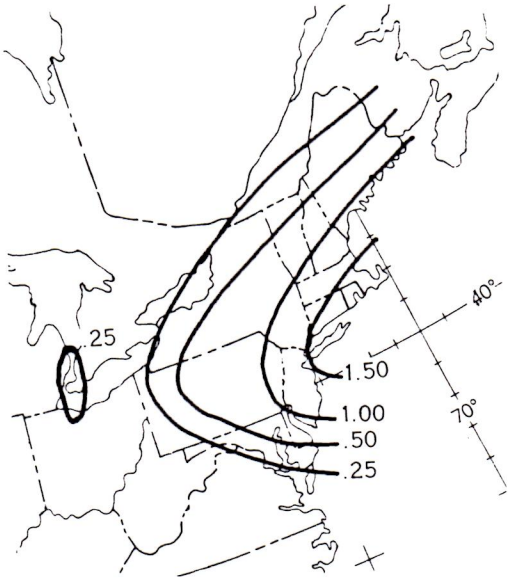


Figure 16B. The 48-hour combined QPF (in inches) from 7 a.m. EST, February 5, through 7 a.m. EST, February 7, 1978.

QPB SNOWFALL GUIDANCE FORECASTS

Snowfall guidance predictions are produced by the NMC Quantitative Precipitation Branch (QPB). These predictions are a blend of information from the numerical model prediction and interpretation of latest data with the individual forecaster's knowledge and expertise.

Daily at 7 a.m., the QPB forecaster prepares and issues via teletypewriter a technical reasoning discussion of amounts of precipitation and snow anticipated for the next 48 hours. Prior to the onset of this storm a couple of these were especially noteworthy: On Saturday morning, February 4, about 48 hours prior to the onset of the intense snowfall, the QPB discussion read (in part):

> "Digging short wave southern Canada holds threat of major snowstorm for New England and possibly northern portions of mid-Atlantic states beginning Day 2 as cutoff upper low forms Great Lakes."

On Sunday morning, the discussion stated (in part):

> "Major surface development East Coast seems assured, however, location and timing uncertain. This will be a slow moving system...Severe snowstorm likely New Jersey and Eastern Pennsylvania northeastward through southern and central New England."

In conjunction with these discussions the QPB forecaster prepares specific forecasts of precipitation amounts for the next 48 hours for transmission over facsimile. These two 24-hour forecasts contain implicit snowfall forecasts in that a dashed line is entered to delineate that portion which is expected to be frozen (snow). On Sunday morning this product was particularly valuable. The LFM was not available, and the 7LPE, although making credible circulation prognoses, was very deficient in terms of precipitation. Despite this, the QPB forecaster made an excellent QPF, with over 1.00 inch of precipitation forecast over New Jersey and the southern half of New England for the combined 2-day total (see Figure 16B). Amounts in excess of 1½ inches--all snow--were indicated for southern New England. The 24-hour QPF verifying at 7 a.m. on Monday morning called for 0.50 inch over eastern Pennsylvania and New Jersey. This was somewhat overforecast, for, although 5 inches of snow had fallen in some locations by 7 a.m., the 24-hour precipitation was closer to 0.25 inches. The remainder of the forecast verified quite well. Subsequent forecasts maintained excellent consistency and continuity.

Specific 12-hour snowfall predictions are issued via facsimile four times per day, about 4 to 5 hours prior to the start of the valid period. These depict the QPB-predicted snowfall amounts in increments of 4 inches or more per 12 hours. Of note in this series of forecasts is the timing and location of the "8-inch or greater per 12-hour" area as it moves up the

coast. This is best seen by comparing the forecast to the official reporting point 12-hour snowfall. (See Figure 17).

According to unofficial reports, even more snow fell at other locations. Although the coastal maximum was well forecast, a second maximum in western New York was not, although the 24-hour QPF did suggest good snowfall there. Some of this may have been due to some unexpected enhancement from "Lake effects." Once the storm was in progress, the LFM provided the QPB forecaster with excellent numerical precipitation guidance for the important coastal maximum.

MODEL OUTPUT STATISTICS (MOS) GUIDANCE

Snow, high wind, and cold temperatures combined to cause the devastation, deaths, and hardship wreaked by this storm. NMC prepares and issues Model Output Statistics (MOS) forecast guidance on each of these elements; as discussed below.

Temperature Guidance

The preparation of NMC's objective guidance for temperature is completely automated for the first 60 hours. Temperature forecasts for 3 - 5 days are based on subjective techniques, however. Temperature forecasts, while not as critical as wind and snow, were adequate.

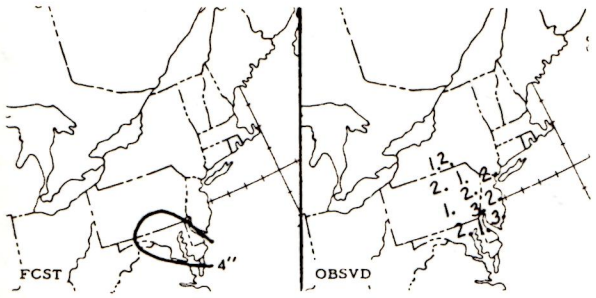
Wind Guidance

NMC wind forecasts are issued in the form of predicted sea-level circulation patterns (from which wind may be inferred) and the fully automated MOS surface wind guidance. The MOS surface wind forecasts are available in 6-hour increments, beginning at 12 hours and ending at 48 hours after the LFM 2 cycles.

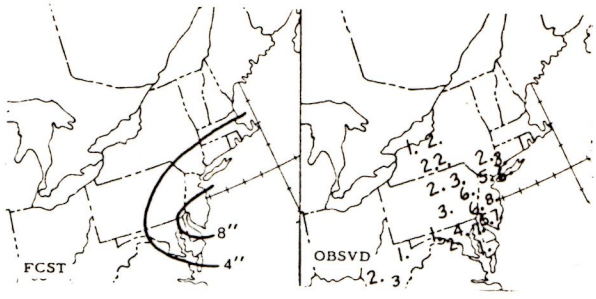
Figure 18 shows the 24-hour surface wind speed forecasts valid at 7 a.m., February 7, 1978, for selected coastal stations. The performance of these MOS forecasts were generally typical for the entire storm. The MOS forecasts underestimated the sustained wind in the Boston area by a significant amount but were generally quite good for coastal stations in Rhode Island, Connecticut, New York, New Jersey, Delaware, and Maryland.

Snowfall Guidance

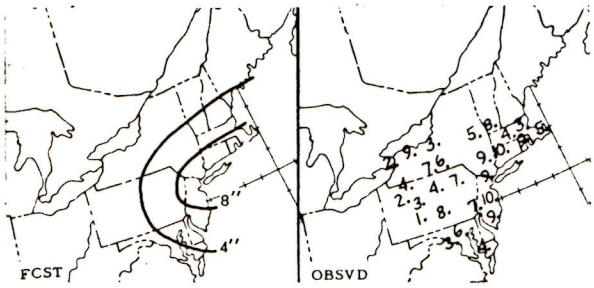
The MOS heavy snow forecasts, available this season for the first time, are labeled "PoSH" (Probability of heavy snow). Heavy snow is defined as the occurrence of $\geq$ 4 inches in a 12-hour period at a station. The PoSH system gives both probabilistic and categorical forecast of heavy snow for the 12-hour period starting at 12 hours after the 7 a.m. and 7 p.m. LFM 2 cycle times.



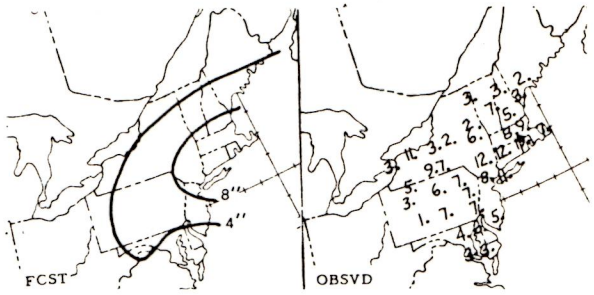
A. Valid for 12-hour period ending 7 a.m., February 6.



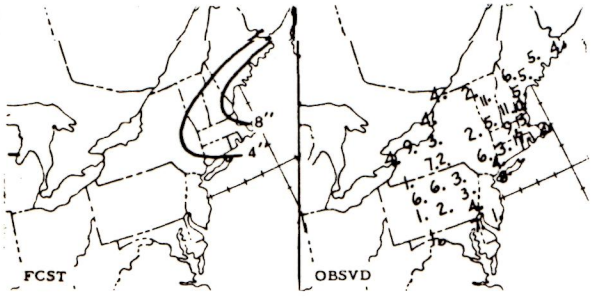
B. Valid for 12-hour period ending 1 p.m., February 6.



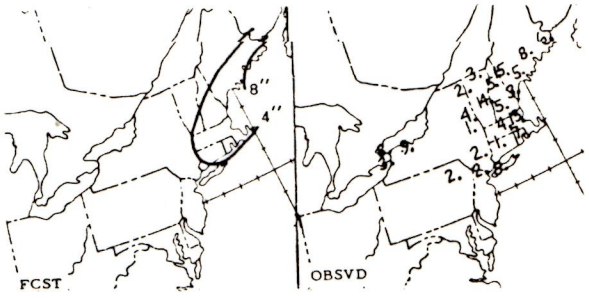
C. Valid for 12-hour period ending 7 p.m., February 6.



D. Valid for 12-hour period ending 1 a.m., February 7.



E. Valid for 12-hour period ending 7 a.m., February 7.



F. Valid for 12-hour period ending 1 p.m., February 7.

Figure 17. 12-hour heavy snowfall (in inches) forecasts and corresponding snowfall observations for height of storm.

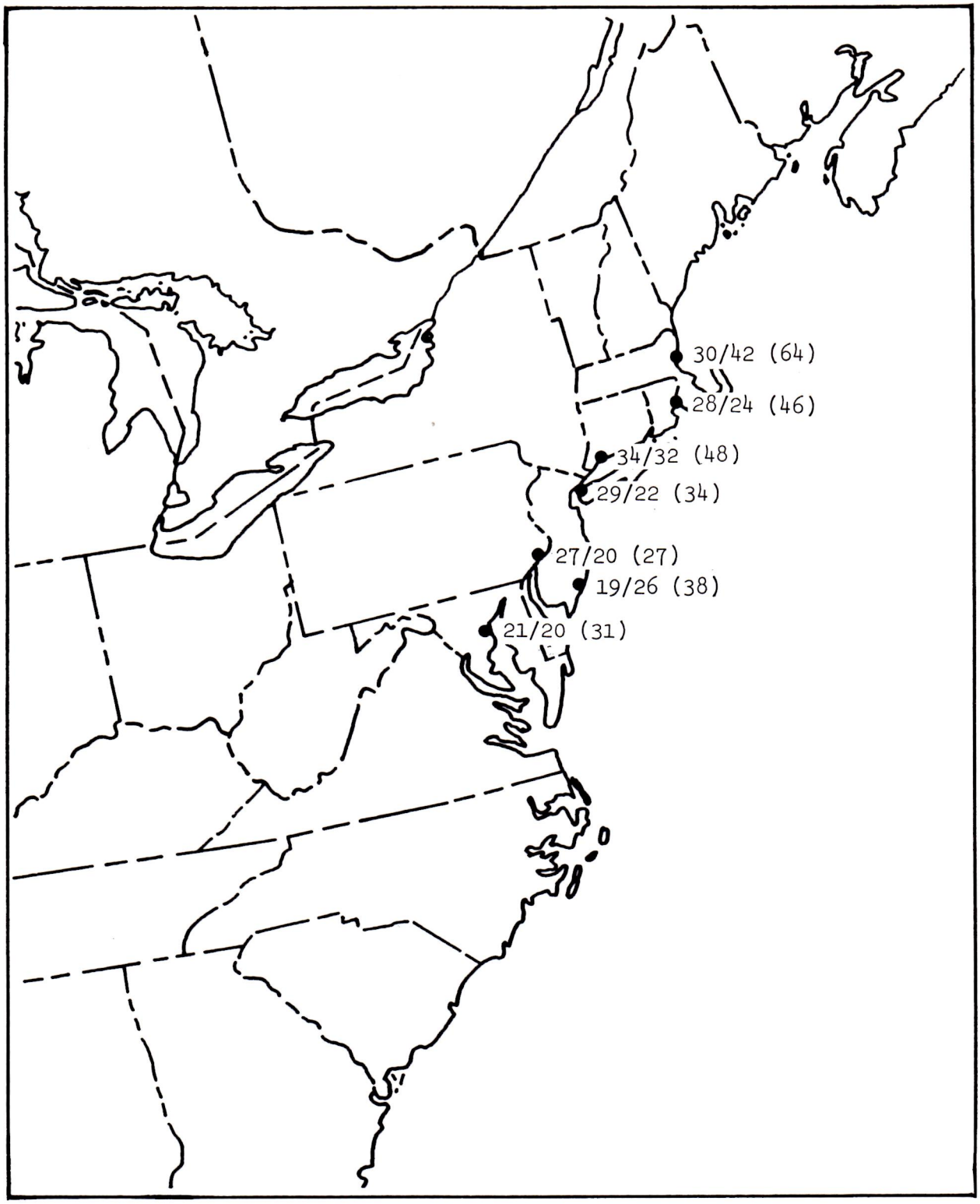


Figure 18. MOS 24-hr surface wind speed forecasts valid at 7 p.m., February 6, 1978, for selected coastal stations. For each station plotted, the first number is the forecasted wind speed, the second number is the observed wind speed, and the third number is the observed gust.

In Figure 19, the area bounded by the dashed line and the coast includes the MOS station for which the PoSH system categorically forecasted heavy snow. The area represents a composite of three successive 12-hour forecast periods starting at 7 a.m., February 6, and ending at 7 p.m., February 7. The approximate area where heavy snow was observed during this period is enclosed by the dotted line. The PoSH forecasts did very well except for western New York, central Pennsylvania, and the Maryland-Virginia border area.

STORM SURGE

High winds, large waves, higher than normal spring (astronomical) tides, and large storm surges combined on February 6 and 7, 1978, to batter the coast from New Jersey to Maine. Environmental buoys located off the coast of New York and Massachusetts measured 40 to 45 kt winds from the east-northeast. These winds were accurately predicted by the MOS 24 to 36 hours in advance for the coastal areas from New York to Maine. The 24-hour, computer-produced, forecast of a 18-foot wave center agreed well with ship observations of 14 and 20 feet (Figure 20).

20-hour computer forecasts indicated that storm surge heights would be 2.5 to 4.7 feet at coastal locations from New York to Massachusetts. The maximum observed storm surge (4.1 feet) at Boston was underforecast by about 1 foot. Severe beach erosion was reported along the Massachusetts coasts, while major erosion was reported along the New Jersey coast. Computerized beach erosion forecasts made 24- to 36-hour in advance indicated major erosion for Massachusetts; moderate erosion at other locations between New York and Maine; and only minor erosion along the New Jersey coast. The amount of erosion was underforecast, especially for Massachusetts and New Jersey.

CONCLUSIONS ON ADEQUACY OF METEOROLOGICAL GUIDANCE

A. The potential for an unpredicted storm affecting the northeastern United States existed on February 4-5, 1978, because the initial cyclogenesis was far off the coast and the storm had no history as a typical Cape Hatteras low.

B. The combination of NMC's LFM 2 prognoses for short range, the 7LPE and manual prognoses for extended ranges, and the manual modification of the model precipitation forecasts resulted in field forecasters being advised 2 1/2 days in advance and receiving consistent guidance thereafter.

C. The numerical prognoses were consistent throughout. The lack of some of these products due to power outages at NMC on February 4 had no adverse affect on the total performance of the forecast system.

D. Forecasts from the short range LFM 2 were superior to those from the short range 7LPE.

E. Although longer range (36-60 hour) explicit numerical QPFs were deficient, circulation prognoses were sufficient for preparation of timely and accurate subjective QPFs. These, when converted to snowfall amounts, enabled forecasters to give exceptional warnings of a major snowstorm.

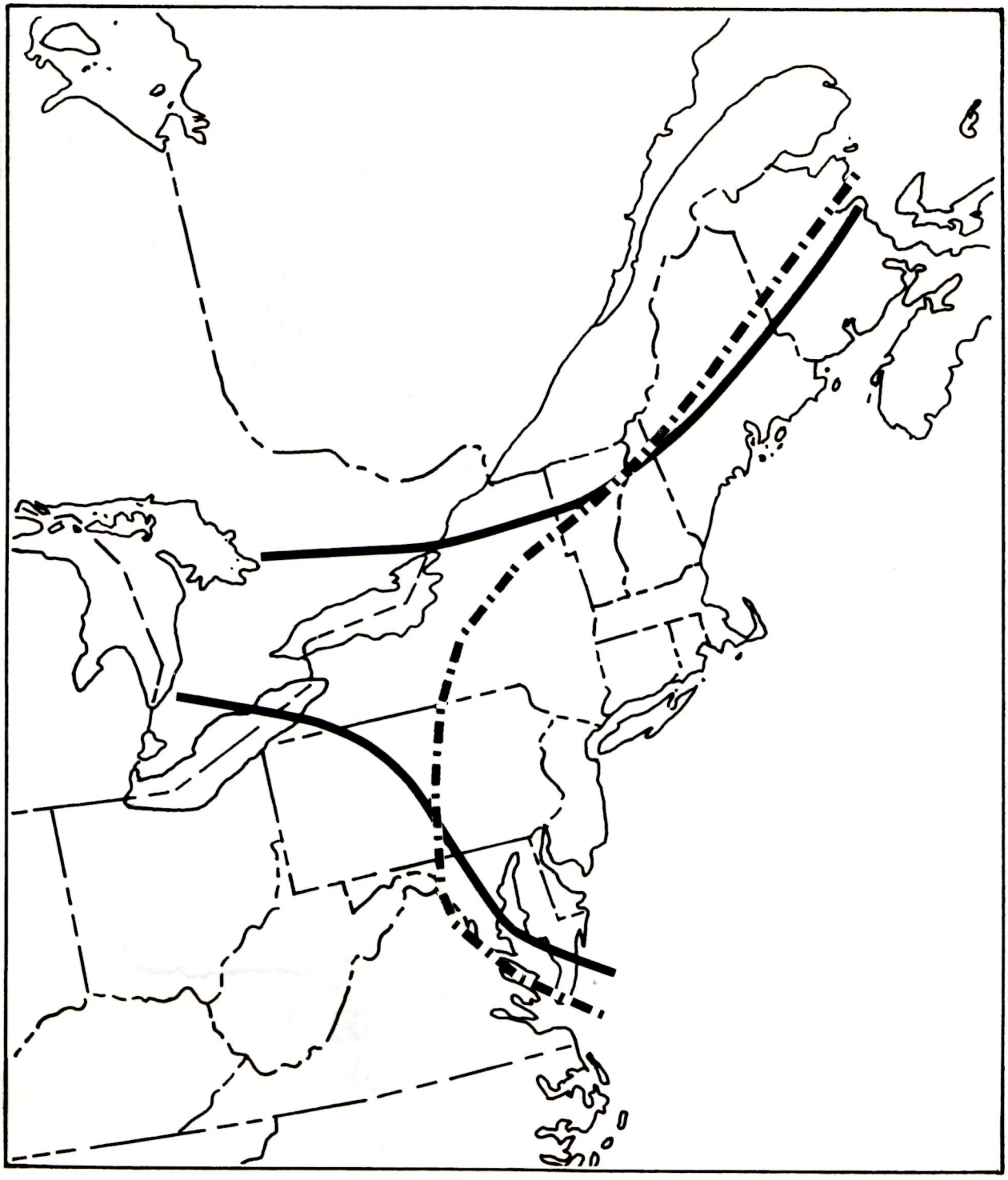


Figure 19. The area bounded by the dashed line and the coast includes the MOS stations for which the PoSH system categorically forecasted heavy snow. The area represents a composite of 3 successive 12-hour forecast periods starting at 7 a.m., February 6, 1978, and ending at 7 p.m., February 7, 1978. The solid line outlines the area where heavy snow was observed during the same period.

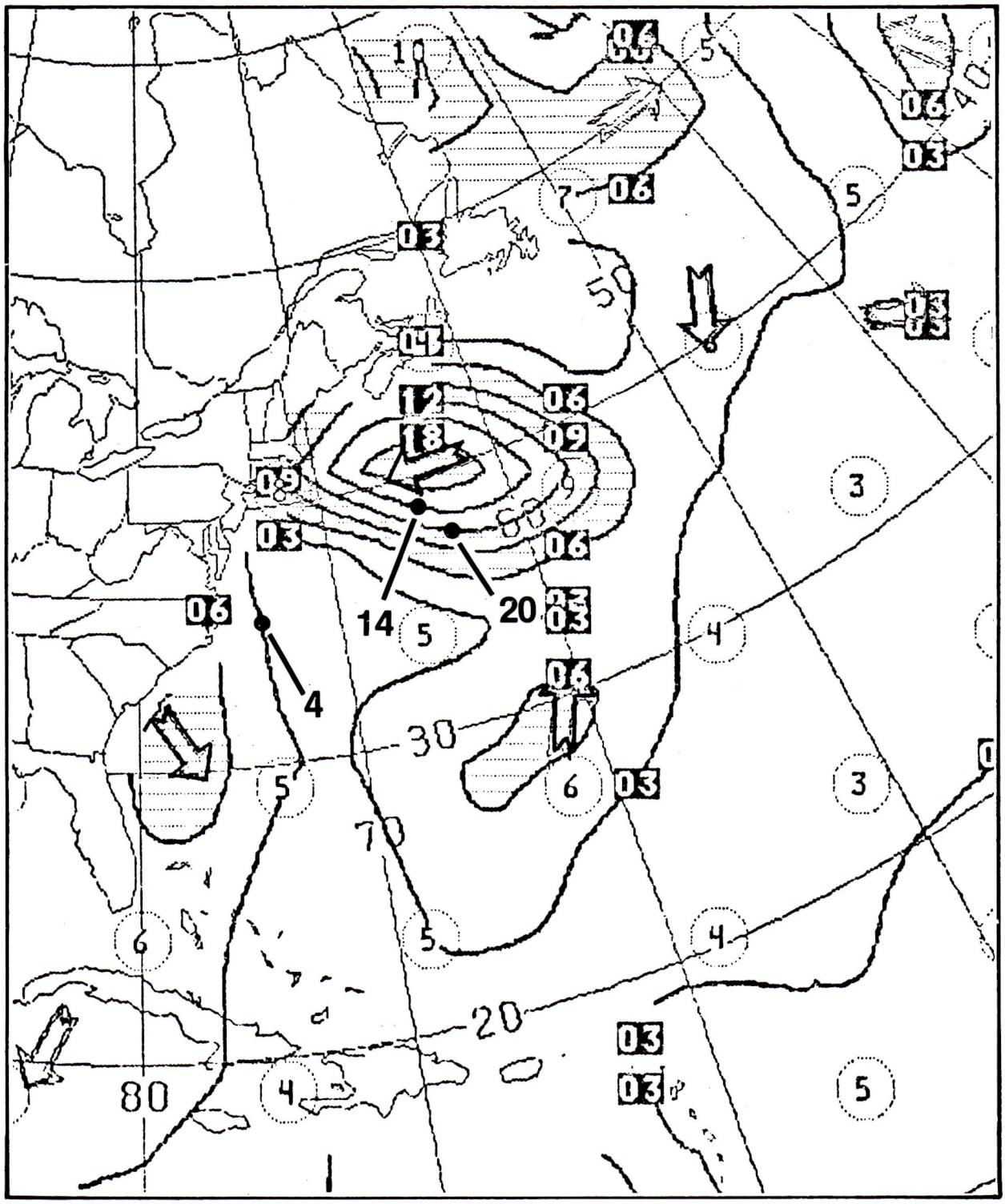


Figure 20. Computer-generated 24-hr. wind wave forecast valid at 7 p.m., February 6, 1978. Wave height contours are in feet, wave periods (circled) are in seconds, and direction of wave centers are indicated by arrows. Observed wave heights reported by ships are plotted in feet.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

CLEAN	Commonwealth Law Enforcement Agency Network
DCA SFSS	Washington Satellite Field Services Station
EBS	Emergency Broadcast System
GOES	Geostationary Operational Environmental Satellite
IR	Infrared
KCRT	Keyboard Cathode Ray Tube
LFM	Limited-Area Fine Mesh
MIC	Meteorologist-in-Charge
MOS	Model Output Statistics
NAFEC	National Aviation Facility Experimental Center
NAWAS	National Warning System
NESS	National Environmental Satellite Service
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
OAS	Oceanic and Atmospheric Services
PA	Principal Assistant
PoSH	Probability of Heavy Snow
PVA	Positive Vorticity Advection
QPB	Quantitative Precipitation Branch
QPF	Quantitative Precipitation Forecast
RAMOS	Remote Automatic Meteorological Observing Station
7LPE	7-Layer Primitive Equation
SIM	Satellite Interpretation Message
WAWAS	Washington Regional Warning System
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR-57	Weather Surveillance Radar, 1957