NATIONAL WEATHER SERVICE EASTERN REGION

DISASTER SURVEY REPORT

THE GREAT NOR'EASTER OF DECEMBER 1992

Cover: Left photograph--Property along the Long Island Sound in Rocky Point, NY on the north shore of Long Island shows heavy erosion in the aftermath of **The Great Nor'easter of December 1992.** Aerial photograph by Susan F. Devin. Special thanks to the New York Army National Guard Aviation Brigade for providing transportation.

Right photograph--The barrier beaches along Long Island's south shore were no match for the coastal storm's heavy surf and high tides. Over the next few months, the newly-formed Pikes Inlet, connecting Moriches Bay and the Atlantic Ocean in Westhampton Beach, grew to almost a mile wide destroying a portion of Dune Road and dozens of beachfront homes. Photograph by Bob Chartuk with transportation provided by the National Guard.

PREFACE

Nor'easters are nothing new to residents along the East Coast of the United States. However, the **Great Nor'easter of December 1992** occurred less than fourteen months after the **Halloween Nor'easter of 1991.** Consequently, with the increased vulnerability of coastal regions, it was not surprising to see so many coastal areas devastated by this powerful storm.

Due to the efforts of NOAA/National Weather Service (NWS) meteorologists/hydrologists and meteorological/hydrological technicians from many NWS offices, the populace of the United States affected by this storm was again well served. I congratulate all concerned on their expertise and professionalism in foreseeing and responding to this situation.

Susan F. Zevin
Director, Eastern Region

June 1994

FOREWORD

This report on the **Great Nor'easter of December 1992** was prepared by the NWS Disaster Survey Team following on-scene assessments and interviews conducted during the week of December 14, 1992. Such surveys are conducted at the direction of the Eastern Region Director whenever significant storms occur.

NWS Eastern Region employees; Federal, state, and local emergency services and other public officials; media representatives; and members of the general public from New Jersey to Massachusetts were contacted and questioned specifically regarding the meteorological and oceanographic conditions that occurred, the timeliness and accuracy of NWS actions in response to these conditions, and the appropriateness of responses to these actions.

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

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ACRONYMS AND ABBREVIATIONS

AFOS	Automation of Field Operations and Services
AM	Area Manager
ASOS	Automated Surface Observing System
AVN	Aviation Weather Forecast Model
AWIPS	Advanced Weather Interactive Processing System
AWOS	Automated Weather Observing System
CJIS	Criminal Justice Information System
CMAN	Coastal Marine Automated Network
COLLECT	Connecticut Local Law Enforcement Network
DMIC	Deputy Meteorologist in Charge
DST	Disaster Survey Team
EBS	Emergency Broadcast System
EOC	Emergency Operation Center
EST	Eastern Standard Time
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
ft	Feet/Foot
HIC	Hydrologist-in-Charge
kt	Knots
LFM	Limited-area Fine Mesh Model
MAPSO	Microprocessor-Aided Paperless Surface Observation
mb	Millibar
MEMA	Massachusetts Emergency Management Agency
MIC	Meteorologist in Charge
MLLW	Mean Lower Low Water
mph	Miles Per Hour
MRF	Medium-Range Forecast Model
MRPECS	NMC Marine Product, East Coast Storm Surge
MSD	Meteorological Services Division
NAWAS	National Warning System
NGM	Nested Grid Model
NGWLMS	Next Generation Water Level Measurement System
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWR	NOAA Weather Radio
NWS	National Weather Service

NWSO	NEXRAD Weather Service Office
NWWS	NOAA Weather Wire Services
NYSPIN	New York Statewide Police Information Network
ODM	Office Duty Manual
OIC	Official-in-Charge
OEM	Office of Emergency Management
PIL	Product Inventory List
TDL	Techniques Development Laboratory
USGS	United States Geological Survey
UTC	Universal Coordinated Time
WSFO	Weather Service Forecast Office
WSO	Weather Service Office

DISASTER SURVEY TEAM MEMBERS

The **Great Nor'easter of December 1992** Natural Disaster Survey Team (DST) is listed below. To more effectively investigate the storm, the Team Leader split the team into three groups. One group consisting of Graff and Budd covered Massachusetts, Rhode Island, and Connecticut; Dorr and Kramper traversed the Long Island and New York City areas; Shaffer, Kane and Thurm investigated the New Jersey area. The remaining DST members provided invaluable input and specific write-ups in their respective areas of expertise.

TEAM MEMBERS

Team Leader, **Russell A. Dorr, Jr**, Chief, Meteorological Services Division (MSD), NWS/Eastern Region, Bohemia, New York

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Field Representative, **Richard Kane**, Meteorologist, WSFO Washington, Sterling, Virginia

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The survey team is also grateful to Ed Heidelberger, Regional Public Service Meteorologist, MSD, Jeff Waldstreicher, Science and Operations Officer, NWSO Binghamton, New York, and to Joan Aybar, MSD Secretary, for their valuable assistance before, during, and after the storm.

EXECUTIVE SUMMARY

Beginning on December 10 and lasting until December 14, 1992, a succession of meteorological events resulted in a devastating coastal storm now known as the **Great Nor'easter of December 1992**. Driven and maintained by hurricane force wind gusts, very high tides and waves severely impacted locations along the Atlantic coast from New Jersey through Massachusetts. Record water levels were reached at Sandy Hook, New Jersey and Reedy Point, Delaware. Coastal sections of Maine, Delaware, Maryland, Virginia, and North Carolina were less seriously impacted by the Nor'easter. Inland, extremely heavy snows posed numerous problems.

This Nor'easter was challenging to forecast given its long duration. Particularly difficult decisions faced by forecasters included forecasting rain versus snow as depicted by "borderline" boundary layer temperatures, and determining the northern edge of the heavy precipitation shield. Nevertheless, feedback on warning services was overall very positive with good lead times provided for the more critical aspects of the storm.

This storm presented a myriad of estuarine complexities. For example, unprecedented waters levels, such as occurred along the FDR Drive in Manhattan and even inland along the Hudson River were vivid testimony to the storm's power. Extremely high waves coupled with elevated tidal levels resulted in wave battering in areas usually not vulnerable to these phenomena. Bayville, along the north shore of Long Island was a vivid example of how the **Great Nor'easter of December 1992** forever changed the attitude of local residents to these type of storms.

The many NWS offices involved in dealing with this storm recognized the threat early and did yeomen work in keeping federal, state, and local emergency officials; the media; and the public informed with clear, concise, and timely products. However, user response in the region of greatest impact was mixed - Excellent response was noted in some areas; but at other sites, user actions were delayed until necessitated by the storm's ferocity.

During the course of its investigation, the NWS DST traveled along the East Coast from New Jersey to Massachusetts. It is this area that experienced the most serious effects from the **Great Nor'easter of December 1992**, which will be the primary focus of the Disaster Survey Report.

Despite the overall positive nature of the findings, the Team feels there are continuing problems in forecasting and warning effectively for Nor'easters. Some of these findings and recommendations have not been resolved, since they were identified in the **Halloween Nor'easter of 1991** Disaster Survey Report, and in some instances, identified 15 years previously in the **Blizzard of 1978** Natural Disaster Survey Report.

There are five areas that require the most attention: real-time data availability; guidance inadequacy; communications; systems performance; and public response.

Real-time Data Availability

All NWS warning products must begin with reliable and timely observations. As addressed in the **Halloween Nor'easter of 1991** Natural Disaster Survey Report, the Team found a lack of water level observation sites along the East Coast. Where these sites do exist, forecasters often did not have adequate real-time access to the data. Further, the Team found a disturbing and continuing paucity of basic marine weather observations.

Specifically, there are too few Coastal Marine Automated Network (CMAN) units and data buoys along the East Coast. Two U.S. Coast Guard Large Navigational Buoys off the Delaware coast were replaced with smaller buoys unable to support marine observations, resulting in fewer observations than before. Buoy equipment outages off the New England coast presented a similar loss of data. In many cases, the forecasters were not able to evaluate existing marine conditions over large expanses of ocean critical to monitoring the storm's progress.

Guidance Inadequacy

The various available numerical models provided forecasters with very good guidance on the movement and intensity changes of the storm. However, the guidance predicting the potential for coastal flooding was not adequate. Current development activities on an extratropical coastal storm surge model and a coastal wave prediction system need to be accentuated so that this new and improved guidance is available to the field soon. This pending new model in conjunction with evolving local-scale models should result in the required guidance enhancement for future Nor'easters.

Communications

A factor critical to successful coordination efforts between the NWS, state and federal agencies, and the public is good communications. Automation of Field Operations and Services (AFOS), NOAA Weather Wire Service (NWWS), NOAA Weather Radio (NWR), and the telephone are the primary methods of NWS field communications. During the storm, there were a few instances of communications breakdown where the urgency of the evolving situation did not filter down to the public and local emergency management officials **despite** the strongly-worded warnings and statements from local NWS offices.

During watch and warning situations, the present and anticipated future volume of transmitted information requires frequent and well-coordinated communication between the NWS and external agency systems for rapid exchange of information. Additionally, these systems **must** be tested on a regular basis to ensure that they are ready when called upon during storms.

Systems Performance

The NWS relies on its facilities, data collection, and dissemination systems in the performance of its mandate. When these systems fail to function effectively at crucial times, the operations of a NWS office are significantly affected.

In some instances, there were problems with emergency power sources, tide gage data access, computer hardware, wind and dewpoint sensors, and NWR transmissions.

Public Response

Excellent warnings and statements were disseminated by the NWS to state and local emergency officials and to the media. In general, user response was appropriate. The media emphasized the significance of the dual threats of heavy snow and coastal flooding. The emergency service personnel were ready ahead of time to take appropriate actions.

Along the Massachusetts and New Jersey coasts, the public response to coastal flood watches and warnings was markedly better compared with response to the October 1991 Nor'easter. The public response in coastal regions of New York City and Connecticut was, however, not nearly as satisfactory. Many coastal residents did not perceive this storm as a threat to them. As was found with the **Halloween Nor'easter of 1991**, it was apparent to the DST that a public education campaign is still needed to assure that coastal residents understand the significance of coastal flooding. Such a campaign needs to include the utilization of the NWR.

The following section on "findings and recommendations" represent the DST's "bottom line" for this epic storm. It is the hope of the DST that these individual items will be acted on in a timely manner so that the entire system will be even better prepared to meet the challenges of future Nor'easters.

The individual sections of this report will expound, where needed, on those additional details required to provide a better understanding and background to the DST's "findings and recommendations." Additionally, Appendix A provides a detailed scientific analysis of the **Great Nor'easter of December 1992.**

FINDINGS AND RECOMMENDATIONS

Some of the recommendations are national in scope, while many require local action. It is hoped that this report and its recommendations will assist NOAA and NWS officials in taking full advantage of the experiences gained through this storm to further enhance public service efforts during future events.

DATA ACQUISITION AND AVAILABILITY (SECTION II)

Finding II-1:

Real-time, 24-hour access to coastal tidal heights is crucial in determining the magnitude and timing of any storm surge. The lack of real-time tide data along the coast and in back-bay areas once again hampered the ability of the NWS to monitor and forecast the extent and degree of tidal flooding.

It was disconcerting to the DST to see that little progress has been made in improving this data sparsity in key locations. This ongoing problem was also highlighted in the **Halloween Nor'easter of '91** and the **Northeast Blizzard of '78** Natural Disaster Survey Reports.

Recommendation II-1:

Automated and accessible tidal data must be made available to coastal NWS field offices from designated coastal locations. Additionally, the phaseover from the Water Level Telemetry System (WLTS) to Next Generation Water Level Measurement System (NGWLMS) technology must be accomplished as soon as possible so that coastal NWS offices can gain real-time access to this critical set of water-level data from the National Ocean Service (NOS). These data will replace the much-used TIDES_ABC data set to be decommissioned by NOS.

Finding II-2:

Coastal and offshore data (eg., wind, seas) are especially important to forecasters during coastal flood events for the determination of storm surge and wave battery. Limited observational data were available from a large area of the ocean off the northeast U. S. coast at the time the storm occurred. This lack of data coverage was also addressed in the **Halloween Nor'easter of '91** and the **Northeast Blizzard of '78** reports. The loss of the Coast Guard's Large Navigational Buoys just off the Delaware coast barely a month prior to the **Great Nor'easter of December 1992** proved to be a particularly great handicap to forecasters.

Recommendation II-2:

The NWS should supplement the present marine observational network in order to fill the gaps which presently exist and to provide the minimum coverage necessary for the reconfigured forecast areas in the modernized NWS. This network should include shoreline/shallow water wave height measurements. Towards this mandate, the National Marine Observation Network (MAROB) initiative must continue to be pressed forward.

Finding II-3:

Statistical output from the National Meteorological Center (NMC) Limited-area Fine Mesh Model (LFM)-based Marine Product-East Coast Storm Surge (MRPECS) program was, in retrospect, too conservative for this storm. However, the Nested Grid Model (NGM)-based MRPECS output, which was not yet operational and available via AFOS to field offices during the storm, was closer to actual tide height values. This latter output was telephoned by the Techniques Development Laboratory (TDL) to WSO Atlantic City late Thursday, and provided confidence for the WSO's subsequent dire tide height forecasts.

Recommendation II-3:

Completion of an extratropical storm surge model, presently under development by TDL, should be encouraged so better guidance will be available for future episodes. In the interim, the change to the MRPECS program (from LFM- to NGM-based) should be of some utility to forecasters.

Finding II-4:

The important Automated Weather Observing System (AWOS) observation from Block Island, Rhode Island was unavailable during the storm (and in previous storms) after the airport lost commercial power.

Recommendation II-4:

The Federal Aviation Administration (FAA) should connect an emergency power source to AWOS.

Finding II-5:

The Boston Harbor tide gage calibration of real-time data available via telephone was too high. As a result, the storm tide forecasts for that site were also too high.

Recommendation II-5:

Efforts to calibrate this gage should continue so it will be in line with NOS readings.

Finding II-6:

There was a noticeable absence of real-time snowfall reports from the higher elevation locations of Massachusetts. The SKYWARN amateur radio network was activated in Massachusetts for this storm, and it provided current information on coastal flooding.

Recommendation II-6:

Field offices should organize snowfall collection or coastal observation networks, preferably automated, involving spotters and/or cooperative observers. Encourage greater use of SKYWARN volunteers to assist with real-time feedback during major coastal flood events, including the placement of SKYWARN personnel in local Emergency Operation Centers (EOC) where approved and appropriate.

Finding II-7:

The Microcomputer-Aided Paperless Surface Observation (MAPSO) program was disabled at WSO Providence, and there was difficulty using the backup method of manual calculations and the paper forms.

Recommendation II-7:

The Office Duty Manual (ODM) should contain detailed operational procedures for both the primary and backup surface observation programs. Office drills should include the backup procedure for observing personnel.

Finding II-8:

The generator at WSO Bridgeport performed erratically prior to failing, leaving the office without power until commercial power was restored to the airport. An assessment determined that the oil level was too low.

Recommendation II-8:

Eastern Region, SOD, in conjunction with local offices, must ensure that emergency generators (including fluid levels) are maintained in accordance with Regional policy.

Finding II-9:

The dewpoint sensors at WSFO Boston and WSO Providence were unreliable during the event as a result of ice deposits.

Recommendation II-9:

Modified sensors have been developed and will be installed as a component to the Automated Surface Observing System (ASOS) at the above locations.

PREPAREDNESS (SECTION III)

Finding III-1:

Standard operating procedures varied from one office to another. In some cases, guidance materials were not complete or clear enough for an office's most inexperienced members to carry out their duties with the confidence that they had enough information to make the best decisions possible. At one location, many recent changes were "penciled in" or done by attaching an office memorandum, with old instructions still in place. Fortunately, the staff was well-versed on current operational procedures such that there were no resulting negative impacts on service during the storm.

Recommendation III-1:

Eastern Region, MSD must ensure that all local managers review their Office Duty Manual (ODM), checklists, emergency procedures, etc., regarding coastal flooding to ensure they are complete, clear, concise, and up to date.

Finding III-2:

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

Recommendation III-2:

Drills should be scheduled at all offices with a frequency that will keep coastal flood procedures fresh in the minds of all watchstanders.

Finding III-3:

There seems to be a lack of public awareness concerning the threat posed by coastal flooding in the coastal areas of New York City and Connecticut. However, many residents indicated that if a hurricane were coming, they would consider advance evacuation. Additionally, even though the NWS and local emergency managers in New York City and Connecticut were prepared for coastal flooding, they were not prepared for the severity of what occurred.

Recommendation III-3:

Awareness should be increased through public education and outreach initiative involving the media and local emergency managers. The NWS should explain the coastal flood watch/warning program to emergency management at workshops. A "Coastal Storm Awareness Week" should be scheduled and publicized.

Finding III-4:

At WSFO New York, information on individual counties, such as telephone numbers of county officials, spotters, and the media, was incomplete or lacking. Fortunately, there were no resulting negative impacts on services during the storm.

Recommendation III-4:

A file on each individual county that contains all necessary information and a brief history of preparedness activities in the county should be established.

Finding III-5:

In Massachusetts, preparedness actions, implemented since the October 1991 storm, contributed to the successful coordination concerning this storm. WSFO Boston in cooperation with Federal Emergency Management Agency (FEMA) and Massachusetts Emergency Management Agency (MEMA), conducted a series of six public workshops on hurricanes and nor'easters along the coast during the latter part of 1992.

Recommendation III-5:

As opportunities occur, coastal WSFOs should conduct similar public workshops on hurricanes and nor'easters.

WARNING SERVICES (SECTION IV)

Finding IV-1:

There were significant usage problems with the new AFOS Product Inventory List (PIL) designator WSW. Separate categories in PIL usage (WSW/SPS/NPW), identifying the same type of weather event, puts an unnecessary burden on the forecaster to determine which communication header needs to be used for a statement issuance. It is more efficient to have information available in as few communication headers as possible.

Recommendation IV-1:

A separate/single product issued for emergency managers and other users may be preferable to the continued use of multiple product headers for sequential issues of winter weather statements. Specific hazards can be highlighted through the use of sub-headings within the body of the statement.

COORDINATION AND DISSEMINATION (SECTION V)

Finding V-1:

NWWS does not have sufficient state and particularly, local emergency managers subscribers. In New York, the dissemination of critical weather products to state and county levels, primarily through the NOAA Weather Wire and state run communication systems, such as the New York Statewide Police Information Network (NYSPIN), worked very well. However, there were breakdowns in communication to the community level, specifically to the local police or fire departments who would be involved in evacuations. In contrast, more local emergency managers in Massachusetts received NWS statements during this event than in the past. This improvement was a result of more aggressive efforts undertaken by MEMA's state and area personnel to transmit copies of NWS statements to local jurisdictions.

Recommendation V-1:

The NWS needs to encourage strongly those states subscribing to the NWWS to install automatic systems for distributing emergency information to appropriate local officials. Other alternatives for delivering such information to key state decision makers, such as the NYSPIN, need to be explored and developed. Additionally, the NWS should continue to work with and encourage county and local officials to have adequate notification procedures. These procedures could be evaluated during annually conducted drills sponsored by the NWS.

Finding V-2:

A few Coastal Flood Statements (CFS) and the Coastal Flood Warning (CFW) from WSO Atlantic City were not available initially in Systems Monitoring and Coordination Center's (SMCC's) database. This problem was recognized early enough so that successful "work-arounds" were effected.

Recommendation V-2:

Eastern Region MSD, in concert with local NWS offices, should periodically check the comprehensive AFOS (SMCC) and NWWS lists to ensure that long/short fused watches, warnings, and statements are in the appropriate databases.

Finding V-3:

Early notification of a potentially serious weather event provided to the emergency managers was a key factor in their successful response. Coordination with emergency managers by telephone is valuable, but it is not always an efficient method of passing information during times of high demand in warning episodes.

Recommendation V-3:

Automate the information exchange between the NWS and emergency management centers to maximize efficiency and reliability. The goal is to enhance the flow of information and not simply to eliminate telephone contacts.

Finding V-4:

On cable TV in Rhode Island, an inland zone forecast transmitted on **The Weather Channel** plays for a coastal area because the cable company is located inland. Valuable coastal warning information is excluded from the broadcast.

Recommendation V-4:

Solutions are being explored with the cable TV company and The Weather Channel.

Finding V-5:

Commercial power fluctuated at WSO Providence and caused system failures, but the airport was unwilling to grant the NWS' request to switch to emergency power due to the possible degradation of runway lighting.

Recommendation V-5:

Negotiate a new emergency power policy and procedure with the FAA and T.F. Green Airport operations or install a portable generator for limited use by NWS systems.

Finding V-6:

NWR transmission from the Camp Edwards transmitter site on Cape Cod (one of two sites driven by WSFO Boston) was lost during the storm. The Worcester NWR transmission ceased when commercial power was lost.

Recommendation V-6:

Review the procedure for the response to problems at the Camp Edwards site so that improvements in obtaining timely results can be made. Establish access to an emergency power source for the Camp Edwards and Worcester transmitter sites, and other vulnerable coastal locations.

Finding V-7:

NWS watches, warnings, and statements received by the Connecticut State Police State Warning Point via the NWWS can only be transmitted on the Connecticut Local Law Enforcement Network (COLLECT) system by manual entry. Similarly, in Massachusetts, there is no direct interface between the NWWS and the Criminal Justice Information System (CJIS).

Recommendation V-7:

Continue to pursue efforts to obtain an automatic data link between NWWS and the state police networks, COLLECT and CJIS, so that the transmission of NWS products will be timely and streamlined.

Finding V-8:

All Connecticut towns along Long Island Sound are susceptible to coastal events and should update their existing Emergency Operations Plans.

Recommendation V-8:

There should be coordination between the towns and the NWS on coastal flood watch/warning procedures. A test drill should be conducted annually at the start of the winter storm season by the state, NWS and local officials.

Finding V-9:

The Connecticut Office of Emergency Management (OEM) wants to obtain the actual predicted tide heights at high tide for susceptible locations along the coast and have it made available to their local EOC managers.

Recommendation V-9:

WSFO Boston transmits this product with limited locations but other locations should be added and made available over NWWS.

Finding V-10:

Many members of the New York media use private meteorologists for weather forecasts. The DST found that NWS watches and warnings are not always passed along to the public.

Recommendation V-10:

Work with private meteorology companies and the media to impress upon them the importance of passing along NWS watch and warning information to their users.

Finding V-11:

While numerous "special statements" were issued by WSFO New York during the event, gaps to four hours were found between statements.

Recommendation V-11:

To supplement special statements and to increase the flow of information to the media, the NOWCAST program should be implemented as quickly as possible, where it does not already exist.

Finding V-12:

The use of facsimile was effectively used by WSO Atlantic City to disseminate critical warnings and statements to key emergency managers in New Jersey. The procedure, though, is very time-intensive to an already burned staff. Also, a telephone facsimile machine at WSO Hartford provided a backup link to the Connecticut OEM when they lost their NWWS capabilities during the storm.

Recommendation V-12:

Eastern Region, MSD is examining semi-automated notification procedures.

USER RESPONSE (SECTION VI)

Finding VI-1:

Response by the emergency management community and by the various media was generally excellent. However, in a few instances, emergency management and public response in preparing for this storm, and to coastal flood watches and warnings was poor, **despite** timely and detailed NWS products.

Recommendation VI-1:

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

Finding VI-2:

A number of residents contacted by the DST said that they did not think the storm would be as devastating as it was and took no action to protect their property or to evacuate. On the other hand, comparison to "historical" storms such as the recent **Halloween Nor'easter of 1991** proved very effective in highlighting the danger and prompting emergency managers and the public to action.

Recommendation VI-2(a):

NWS offices are strongly encouraged to continue the practice of comparing potentially damaging storms with noteworthy storms of the past, thereby increasing the sense of urgency to the general public. However, this should not be the sole method used to invoke the desired user response since individual storms often affect areas quite differently.

Recommendation VI-2(b):

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

Finding VI-3:

NWR is not widely used by the general public as its chief source of weather information for two apparent reasons; 1. Lack of knowledge of the system, and 2. Problems with the system, such as coverage and the lack of an alert feature for specific areas and warnings.

Recommendation VI-3:

The existence of NWR needs to be more highly publicized. This must be done on a local and National level. It must be noted that the NWS cannot depend on Public Service Announcements. Many of the broadcast media contacted said they would not play such an announcement since it was, in a sense, "a competitor." Additionally, the NWS should encourage manufacturers of weather radios to advertise their products more aggressively.

Finding VI-4:

Response and cooperation by the New York media was generally very good. An excellent relationship exists between the majority of the media and local NWS offices. However, it was found that some members of the media did not have an NWS telephone number.

Recommendation VI-4:

Personal contacts and a regular exchange of information must be maintained to keep strong relations with the media. These interactions should also ensure that all parties have the appropriate telephone numbers.

Finding VI-5:

In New York, the Emergency Broadcast System (EBS) was activated for some of the NWS warnings, while not for others. It was found that the messages placed on warnings to alert users to either "EBS Activation Requested" or "Immediate Broadcast Requested" were similar in nature and often overlooked.

Recommendation VI-5:

The NWS should explore a way of highlighting the "Bulletin - EBS Activation Requested" message so that it is easily distinguished from similar statements.

SECTION I - THE EVENT AND ITS IMPACT: THE GREAT NOR'EASTER OF DECEMBER 1992

The **Great Nor'easter of December 1992** was one of the epic storms of all time. At some locations along the northern New Jersey, New York City, and Long Island coasts, it produced record tides, even exceeding those produced by the hurricanes of 1938, 1944, 1954 and 1960, and the great historical extratropical storms, including the **Halloween Nor'easter of 1991**. At many other locations from northeastern Massachusetts to Maryland, it produced tides within one or two feet (ft) of record values.

High tides and subsequent coastal flooding, excessive rainfall with river and stream flooding, and heavy snowfall were all produced by this storm. In addition, a band of very strong easterly winds developed just north of the surface center. As the low moved northward, this very tight pressure gradient propagated from northern Virginia, Maryland, and Delaware to New Jersey, eastern Pennsylvania and New England. During the early morning hours of December 11, wind gusts were reported between 60 and 90 mph across parts of southeastern Pennsylvania and southern New Jersey. Ambrose Tower just outside of New York Harbor recorded sustained winds of 81 mph with gusts to 93 mph.

The diversity and quantity of adverse weather associated with this storm system covered nearly the entire spectrum of NWS warnings, watches, advisories, and statements. Likewise, the entire population of the northeastern quarter of the United States was affected in some way by this Atlantic nor'easter.

Table I provides a snapshot view, by state, of the direct storm-related fatalities and **insured** damages associated with the **Great Nor'easter of December 1992.** Insured losses totalled nearly $850 million, while news media accounts for the storm, which also included **non-insured** losses, ranged up to two billion.

Figures 1 and 2 are courtesy of the American Red Cross (ARC) and depict how truly devastating this storm was in the hardest hit areas. The number of dwellings affected by this storm is compared to the two previous major storms; The Halloween Nor'easter of 1991 and Hurricane Bob of 1991. The number of dwellings affected by the **Great Nor'easter of December 1992** is nearly three times that of the combined total for the Halloween Nor'easter and Hurricane Bob.

TABLE I

FATALITIES + INSURED DAMAGE ESTIMATES (MILLIONS OF DOLLARS)

STATES	FATALITIES	AIA*	NFIP**	SUM#
NY	1	220	54	274
NJ	2	150	115	265
MA	0	75	10	85
PA	3	70	-	70
CT	1	40	20	60
RI	0	30	-	30
MD	0	25	-	25
DE	0	20	0.25	20.25
VA	1	10	-	10
NC	1	-	-	-
WV	0	10	-	10
TOTAL	9	650	199.25	849.25

* Derived from statistics provided by the **American Insurance Association** (AIA). Claims represent **insured** losses primarily from water damage.

** Derived from statistics provided by the **National Flood Insurance Program** (NFIP). Claims represent **insured** losses from tidal inundation.

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

\# **Non-insured** losses on private or public property are not included in this list. "Public" denotes such items as cleanup costs, beach erosion, boardwalk, seawall and pier damage, lighthouse damage, etc. Also not available are specific tourist dollar losses.

Note: Fatalities are **directly** storm related

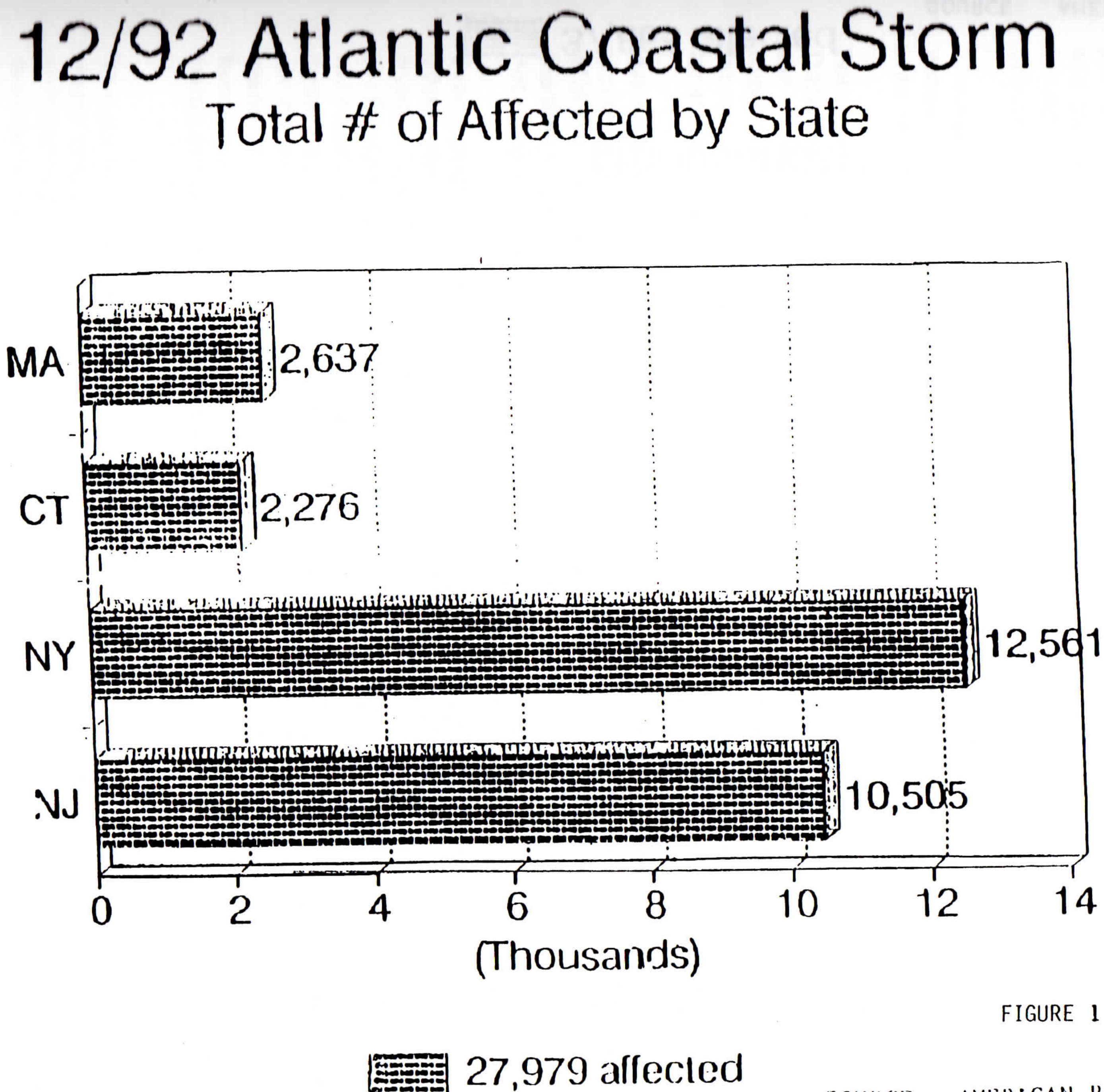


FIGURE 1

SOURCE: AMERICAN RED CROSS

Comparison: Latest N. Atlantic Storms

Total # of Affected by Storm

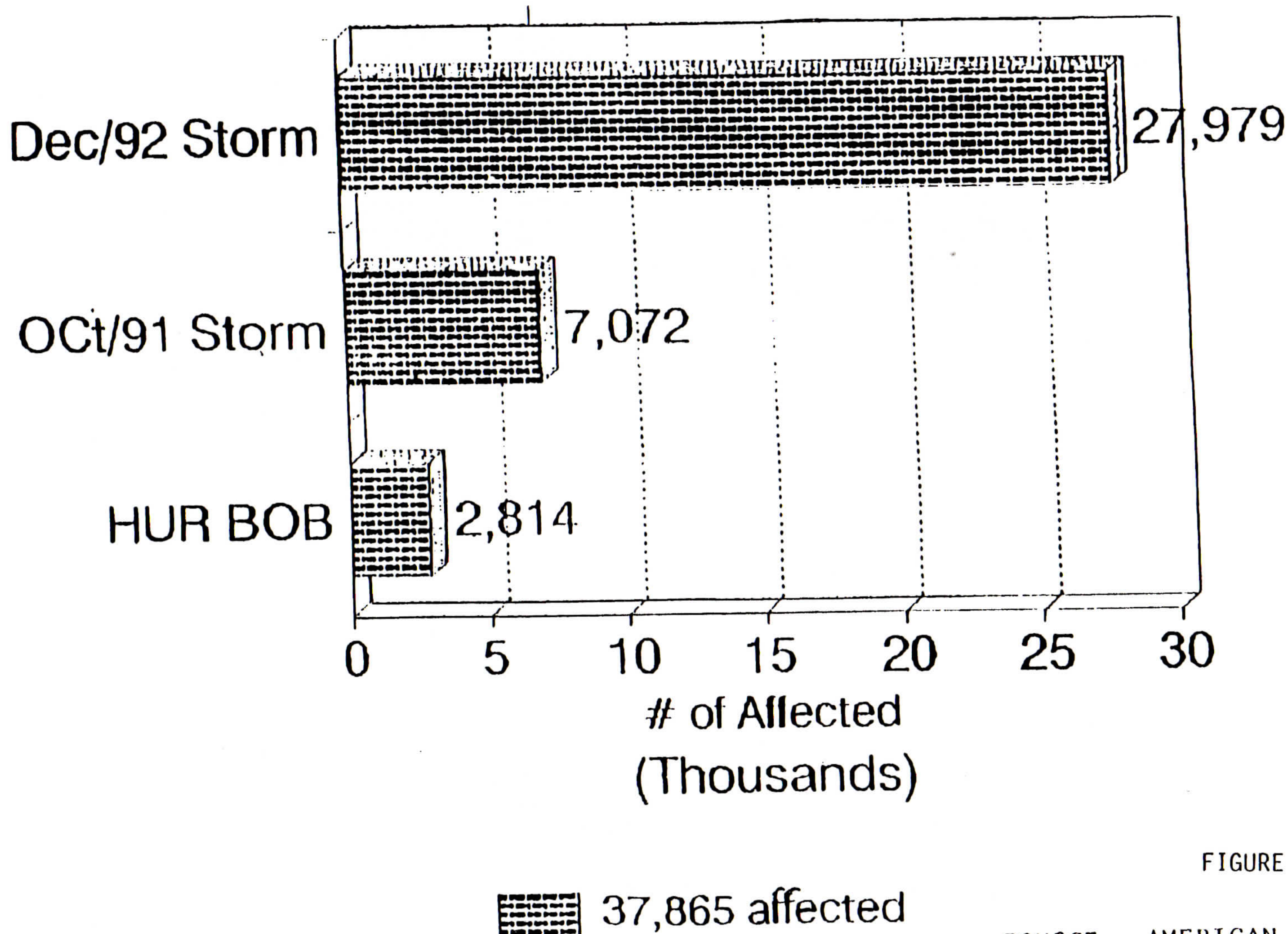


FIGURE 2

SOURCE: AMERICAN RED CROSS

Historical Comparison

An preliminary assessment was that the coastal flooding along the New York City, Long Island, and Connecticut coastlines will be considered the worst in many years, perhaps at least since Hurricanes Donna (1960) and Carol (1954). The very strong and persistent easterly gradient piled water into New York Harbor and Long Island Sound during high tide and hampered the normal release of that water during the low tide cycles.

The **Ash Wednesday Storm** of March 1962 remains as the benchmark storm for the central and southern New Jersey coastline. The **Great Nor'easter of December '92** was very comparable to the **March 1984 Nor'easter** in that area.

For the Massachusetts east coast, comparisons between the October 1991 and December 1992 storms are inevitable. The overall impact from coastal flooding along the Massachusetts east coast will probably not be considered as severe as experienced in the **Halloween Nor'easter of 1991** and the **Northeast Blizzard of 1978** storms. Compared to the October 1991 storm, water levels were lower at most locations.

Although there were high seas with this storm, wave battery was estimated to be worse with the October 1991 storm when 30 to 40 foot seas were reported just offshore. Unlike the October 1991 storm, the strongest winds did not coincide with the time of the highest tide along the Massachusetts coast, and the wind direction did not remain constant (backing from east to northeast during the event).

Even though this storm moved rather slow and brought coastal flooding over several tidal cycles, the October 1991 scenario appeared to have focused stronger winds over a longer fetch for a greater time period along the Massachusetts coast. Furthermore, the October 1991 low pressure center had a significant westward propagation, which may have helped drive huge seas from the outer continental shelf areas onto the coastline. Still another important difference is that the October 1991 storm destroyed (or caused the eventual razing of) a number of structures that simply weren't left standing to be damaged by the December 1992 northeaster. Also, a number of homeowners and public officials took mitigation measures after October 1991 to better fortify homes and public facilities.

MASSACHUSETTS, RHODE ISLAND, AND CONNECTICUT

The storm brought record snowfall to parts of interior southern New England and major coastal flooding along much of the coast. The impact of the storm was sufficiently great for the governors of Connecticut and Massachusetts to request presidential disaster assistance for a number of counties, especially those hit hardest by coastal flooding.

Fatalities
There was **one** known **direct** storm-related fatalities in New England. A 50-year old man from Harwinton, Connecticut was killed while he was under a homemade carport roof which collapsed from the weight of heavy snow on Saturday. Some of the people rescued from the flood waters and emergency response personnel were treated for hypothermia.

Coastal Flooding
Although heavy snow severely impacted portions of interior southern New England from late Friday through Saturday, the greatest damage wrought from this storm was due to coastal flooding. Major coastal flooding struck the Connecticut coast around the time of high tide Friday. Lesser, but still serious, coastal flooding occurred along the Connecticut coast Saturday and Sunday. Serious coastal flooding occurred along the Massachusetts coast as well, Friday through Sunday. For the Massachusetts coast, the most damaging storm tide occurred early Saturday afternoon. Pockets of coastal flooding persisted at times of high tide as late as Monday along parts of the southern New England coast.

Storm tides Friday, December 11, ran about 4 to 5 ft above normal along the western Connecticut coast, 3 to 4 ft above normal along the rest of the Connecticut shoreline, and 2 to 3 ft above normal along other parts of the southern New England coast. Saturday's high tides ran 3 to 4 ft above normal along much of the Massachusetts east coast and western Connecticut coast, and 2 to 3 ft above normal elsewhere. Tides continued to run 2 to 3 ft above normal along much of the southern New England coastline Sunday.

Waves as high as 23 ft were reported along portions of the Massachusetts east coast Saturday. The pounding from the waves during several consecutive above-normal tides took their toll. A 350-ft breach of Hull's Nantasket Beach seawall occurred during the Saturday night/early Sunday morning high tide, which was not as high as the Saturday afternoon tide. Another phenomenon observed along portions of the Massachusetts coast was the observation of peak water levels along a few back bays and marshes well after the predicted time of high tide along the nearby open shore.

Damage...Connecticut
Property damage caused by the wind and coastal storm surge was extensive. The state declared 18 towns in Fairfield and New Haven counties disaster areas.

Hardest hit locations were the coastal communities of the Connecticut counties of Fairfield and New Haven, including Greenwich, Norwalk, Westport, Stratford, and Milford. Many motor vehicles were trapped in flood waters and rendered inoperable. Metro North rail service was interrupted for several hours Friday.

Punishing high tides occurred twice Friday and near midday Saturday, exacerbating storm damages. Snow and rain added to the damage caused by wind-driven sea water. A peak wind gust of 53 mph was recorded Friday morning at WSO Bridgeport and a wind gust of 72 mph was reported at Mason's Island.

Hundreds of people were evacuated from their homes Friday throughout the coastal areas in the western part of the state. Additional evacuations occurred Saturday in the town of Fairfield. At least 40 Connecticut National Guardsmen helped in the evacuations from flooded areas of Milford, Fairfield, Westport, and Norwalk.

Much of the public sector impact was concentrated in Bridgeport, Greenwich, Norwalk, and in the state parks (primarily Sherwood Island and Hammonasset Beach). The coastal flooding caused the following types of damage to public facilities: broken seawalls; undermined and washed out roads; exposed, cracked, and undermined sewerage lines; damaged electrical systems of sewerage pumping stations; and eroded beaches. The storm deposited tremendous amounts of sand and silt upon local roads.

Old Greenwich was pounded by four successive flooding tides. There were 195 homes damaged and numerous others affected. The homes with the most serious structural damage were located at the end of a small bay where its shape funneled the high water and waves toward it. Power had to be cut to 600 homes for safety reasons. Natural gas and home heating equipment will need to be replaced in many homes.

Two islands just offshore were severely impacted. Great Captain's Island lost 20 ft of shoreline and a 60-ft dock off its western end. Little Captain's Island, developed for recreational use, lost a 50-year old bathhouse, a boat landing area, and 1000 ft of seawall. "No one knew the event was going to be as bad as it was," said Captain Keegan of the Greenwich police. "At 10:20 am, a tidal surge inundated the area with high winds and surf." According to Chief Moughty, unnecessary rescues had to be made because people did not heed the evacuation orders.

In Norwalk, at least 100 residents were carried to high ground by firefighters during the worst flooding in 40 years to strike the city. A man had to swim out of his car after water swept over a seawall and submerged the car to its hood. In the Rowayton section, the flood waters were a foot higher than any storm since the '38 Hurricane.

The effects of the flooding on businesses was most severe in the town of Westport, where a commercial center was flooded, causing the loss of inventory by approximately 24 businesses. In Bridgeport, a city landmark, the recently-remodeled Black Rock Yacht Club, was significantly damaged. In the shorefront section of Milford, homes took a beating, as severe flooding turned streets into muddy rivers and sent residents scurrying to higher ground. Meanwhile, West Haven suffered serious flooding and erosion in at least three sections of the city.

The U.S. Coast Guard responded to numerous calls for assistance. In Fairfield, a helicopter rescued 12 people, including six college students stranded on a roof. In Stratford, a boat rescued five adults and two children at a beachside motel.

The Sikorsky Memorial Airport in Stratford was directly impacted by the flood waters. Late Friday morning, the power had to be shut off to the Federal Aviation Administration's (FAA) instrument landing system building due to rising waters, thereby closing the field. All runways and their access roads became flooded. The Automated Flight Service Station was abandoned except for essential personnel. Airport operations were plagued with a commercial power outage Friday evening, and a small fire in the terminal building Saturday, affecting their emergency power generator. Power was not satisfactorily restored until late Sunday afternoon. The NWS office was directly affected by the outages and was forced to curtail operations due to its emergency generator problems.

Northeast Utilities reported a peak of 63,000 electrical outages between Friday and Sunday, while United Illuminating reported an additional 1,250 outages for its service area. By Sunday, most customers were back on line with most recovery done by Monday.

Damage...Massachusetts
All coastal counties except Bristol were declared eligible for presidential disaster relief.

The most significant damage along the Massachusetts coast was reported from Chatham to Provincetown on Cape Cod, from Plymouth to Marblehead, around Gloucester and Plum Island, and on Nantucket Island. The heaviest hit communities included Nahant, Revere, Winthrop, Quincy, Hull, Scituate, Chatham, and Nantucket. The northeast shore appeared to have escaped the worst damage. Less tangible, but no less significant, was the ecological impact from beach erosion and saltwater intrusion. Dunes were washed away in Hull and Duxbury. Ten foot dunes in Marshfield had a vertical scarp loss of five feet. As much as 20 ft of dune was lost in Sandwich and up to 25 ft lost at Crane's Beach in Ipswich.

Selected residents were evacuated from the following coastal communities: Newburyport, Rockport, Manchester-by-the Sea, Swampscott, Lynn, Nahant, Winthrop, Revere, Hull, Quincy, Marshfield, Scituate, Wareham, Falmouth, and Barnstable.

The Weather Service Meteorological Observatory (WSMO) at Chatham on Morris Island was cut off from the mainland by flooding from 2 pm on Saturday until 6 am on Monday. The office observatory recorded 60 mph wind gusts, but the anemometer is shadowed from the northeast by the radar dish. The Official-in-Charge

(OIC) believed the wind gusts were higher. The direction indicator became inoperative on Saturday. At Otis Air Force Base in Falmouth, a peak gust of 74 mph was reported.

Cape Cod and the Islands were especially vulnerable to flooding and beach erosion. Hard hit areas included Falmouth with coastal road closings, Edgartown and Tisbury on Martha's Vineyard, where the business districts were under 2 to 3 ft of water, and much of Nantucket Town (Brant Point area), where boats were floating in the roadways. In many areas, high-tide peak flooding marks recorded on Friday were exceeded up to an hour or more before Saturday's high tides, between 12:30 pm and 3 pm. There was no ferry service between the mainland and any of the Islands and the area airports were closed.

A 600-ft freighter went aground Thursday night just after exiting Cape Cod Canal, but it floated free on Saturday's record high tide. Even though the grounding was not storm related, its flotation was supported by the tidal anomalies. On Friday, the U.S. Coast Guard rescued eight crewman from a sinking fishing boat, the scalloper *Betty Ann*. The boat was lost in gusty winds and heavy seas off Chatham.

On Saturday, pilot whale strandings were reported along Cape Cod Bay from Brewster to Truro. About 30 pilot whales swam up the Pamet River to near Truro Center. In Truro, there was a breach of Ballson Beach on the outer Cape Cod shore that reached the headwaters of the freshwater Pamet River, turning it into a salt marsh and turning Provincetown into an island. The historic Highland House near Cape Cod Light in North Truro was severely damaged, but the problems in Provincetown seemed to be limited.

On Nantucket Island, wind-driven tides claimed six cottages and left two more severely damaged. Waves ripping through the harbor tore away 60 ft of the town dock. Up to 3 ft of sea water surged through Brant Point, a neighborhood of large beach houses and expensive hotels. Although this area is considered to lie within a 100-year flood zone, dozens of homes have been surrounded by sea water twice in just over a year.

Damage...Rhode Island

The Rhode Island coast suffered significant coastal flooding but escaped the magnitude of damage incurred along sections of the Connecticut and Massachusetts coasts. Nevertheless, portions of the Rhode Island coast experienced major beach erosion.

The Meteorologist-in-Charge (MIC) of Weather Service Office (WSO) Providence assessed the damage in Misquamicut on the southwest coast and found that there was extensive beach erosion (up to 50 ft inland), but the impact on structures was not as severe as in the **Halloween Storm**. There were flooded basements and roadways, with wooden decks and walkways washed away, including the porch on the Atlantis restaurant which was smashed to pieces. Several houses on Green Hill Beach Road near Charlestown sustained structural damage when high tides and wave action smashed porches and eroded sand around pilings that supported the houses.

Electrical power was knocked out to half the homes on Block Island during the height of the storm. Statewide, power failures initially affected about 77,000 customers. A peak wind gust of 46 mph was recorded at WSO Providence. The City of Providence closed its hurricane barrier in preparation for the Friday morning high tide.

The lobster industry in Rhode Island and Massachusetts was devastated by the added losses of equipment in wake of losses suffered during the **Halloween Storm**. The estimated cost of the lost gear was close to $14 million.

A 75-ft sloop, bound for Bermuda from Newport, was sunk by a rogue wave from the storm early Friday morning, 250 miles east of the Virginia coast. The crew of five had a dramatic rescue by a tanker which was called to the scene by the U.S. Coast Guard. The crew was then taken by helicopter to the Naval Air Station in Virginia Beach, Virginia, and treated for hypothermia.

Snowfall

Storm snowfall totaled as high as 4 ft over higher elevations of the Berkshires in Massachusetts (48 in at Beckett, Savoy, and Peru). Snow totals were 1 to 2 ft in much of northern Connecticut and northern Rhode Island, with up to 30 inches in portions of northeast Connecticut, 18 to 32 inches over the higher elevations of central Massachusetts, and 6 to 20 inches over much of interior eastern Massachusetts.

The combination of wind and snow produced near blizzard conditions over much of central and interior eastern Massachusetts Friday night and Saturday. Even in East Boston, Logan Airport curtailed operations due to wind-blown snow from 10:30 am until 1:30 pm on Saturday when one runway was reopened.

Snow drifts to 10 ft were reported over the higher elevations of the Berkshires, and blowing/drifting snow was significant for awhile across exposed higher terrain in central Massachusetts (e.g., Worcester Airport). Elsewhere, the water content of the snow was higher and blowing/drifting was not a factor. However, strong winds combined with the wetter, heavier snow caused considerable tree damage and widespread power outages. The weight of the new fallen snow taxed snow removal equipment in many communities and may have instigated a number of insurance claims for roof damage. Local forecast snow amounts were conservative due to the variability of the rain/snow line.

Snow accumulations of 30 inches were reported by the Connecticut Department of Transportation in northeastern sections of the state and accumulations in excess of 24 inches were reported in the northwest hills. Road use was severely restricted in many areas in the northwest and northeast due to accidents, heavy snow,and downed trees and wires. For a time, Bradley International Airport and all other small airports were closed. There were many localized cases of serious drifting snow and access problems at the higher elevations from blowing snow, especially in Tolland, Litchfield, and Windham counties. Locations in western Connecticut with the greatest amounts of snow in inches were: Harwinton-26, Wolcott-25, Winstead-24, Torrington-23, Bethlehem-22, and Prospect-21. In the northeastern part of the state, Union had 27 inches while Putnam had 17 inches of snow.

Berkshire County, Massachusetts, declared a state of emergency as the higher elevations were buried under nearly 4 ft of snow that in places swirled into 12-foot drifts. Longtime residents called this storm among the worst in half a century. The mountain community of Sandisfield, near the Connecticut border, was isolated by snow drifts for more than 24 hours. In the town of Savoy, school was called off because snow reached to within a foot of the top of one classroom building.

There were 135,000 customers without power in Massachusetts during the storm. The central part of the state suffered the brunt of the outages where 30,000 households were without power, just in Worcester County. WSO Worcester operated on emergency power, but there was no back-up source to supply power for the NWR transmitter.

Worcester registered its all-time greatest storm-total snow record of 32.1 inches from 1:00 pm on Friday to 2:30 am Sunday. A 24-hour maximum snow record of 28.0 inches was set from 1 pm Friday until 1 pm Saturday, as well as records for a December snowfall and total snow for the month. During the 24-hour maximum snowfall period, the visibility was one quarter of a mile or less in snow with the wind blowing at a sustained 25-30 mph and occasional gusts in excess of 50 mph. The peak wind gust recorded at WSO Worcester was 54 mph.

Precipitation
Precipitation totals for this storm were extraordinary. Much of southern New England received up to 5 inches of liquid-equivalent precipitation during a 2- to 3-day period, with locally close to 8 inches recorded in parts of southeast Massachusetts. Along coastal sections and in some southern interior valleys, much of the precipitation fell as rain or mixed rain and snow. This caused considerable ponding and localized flooding in poorly drained areas. As impressive as the heavy rains were, the precipitation fell during an extended period of time, and any inland fresh water flooding appeared to have had considerably less impact than the heavy snowfall, high winds, and coastal flooding.

NEW YORK AND NEW JERSEY

In the worst-affected areas of New York City, Long Island, and New Jersey, several successive high tides from early Friday, December 11 through Monday, December 14 resulted in unprecedented flooding and coastal erosion, which may have permanently changed the coastline.

In response to the rapidly worsening conditions, New York's Governor Cuomo declared a "State of Emergency" in New York City, Long Island, and in Westchester and Rockland Counties. New Jersey's Governor Florio declared a "Limited State of Emergency" in 10 coastal counties.

On December 18, 1992, parts of New Jersey were declared disaster areas by President Bush. On December 21, 1992, New York City and Long Island were declared disaster areas by President Bush.

Fatalities

Three people died within WSFO New York's forecast area (two in New Jersey and one in New York).

A 65 year old woman was killed in a traffic accident along Route 47 in Deptford. Her auto swerved to miss a falling tree but then was struck head-on by a tow truck. A 38-year old woman was struck and killed by a piece of roof blown off a building in Jersey City. A man drowned in a flood in Mamaroneck, Westchester County, New York. He attempted to reach safety, holding onto a tree for as long as he could, while his car was submerged.

Numerous injuries occurred during the storm. A 33-year old man was hit by a falling tree limb outside a store where he had parked his car in Yonkers. Forty-five fire fighters and 10 police officers in New York City were treated for hypothermia after rescuing people from flooded cars. At least 17 motorists were treated for hypothermia at two sites along FDR Drive in New York City on Friday, December 11 when they were overcome by flooding.

Coastal Flooding

Successive astronomically high tides coupled with tidal surges produced flooding and wave battery during a four day period from December 11-14. The worst flooding occurred on December 11 and 12. The storm was an "equal opportunity destroyer," equally affecting both the north and south shores of Long Island, an unusual turn of events.

Damage...New York and New Jersey

The effects of coastal flooding and high winds caused significant damage to coastal New York and New Jersey. Widespread moderate and scattered severe coastal erosion, flooded beaches, and significant erosion of dunes occurred. Also evident was widespread damage to houses, cars, and boats.

On Long Island's north shore, the coastal areas that were hit hardest included Bayville, Northport, Centerport, and Port Jefferson. On the south shore, the communities of Long Beach, Lindenhurst, Freeport, Babylon, and Mastic Beach were severely impacted.

In New Jersey, among the communities and areas hardest hit were Union Beach, Atlantic Highlands, Sea Bright, Monmouth Beach, Sea Girt, Long Beach Island, Harvey Cedars, and Longport.

In New York City, the FDR Drive and Battery Park (Manhattan), and Sea Gate (Brooklyn) were particularly impacted by tidal inundation. On the FDR Drive, police cut through the guardrails at 79th Street to let northbound motorists exit across the southbound lanes. More than 50 cars were abandoned on the FDR Drive from 60th to 96th Streets. On the Battery Park underpass, police used rafts and scuba divers to rescue 19 trapped motorists. Their cars were abandoned.

Staten Island's east-facing beaches south of the Verranzano Bridge and north of the Outer Bridge Crossing experienced severe coastal erosion. Several boats were sunk or washed ashore. Significant damage occurred at Oakwood and Huguenot Beaches. There was also significant tree damage at Wards Point.

Thousands of people evacuated their homes along the New Jersey and New York shores. In north coastal New Jersey, more than 5,000 people evacuated from about 20 towns, including Sea Bright, Union Beach, Monmouth Beach, and Manasquan in Ocean County. On the north shore of Long Island, up to 1,000 people evacuated their homes in Bayville (Suffolk County). In New York City, more than 600 people evacuated their homes in Broad Channel, Jamaica Bay (Queens County). Hundreds of people were evacuated from 675 homes in Edgewater Park (Bronx County). From 150 to 200 people evacuated their homes in Sea Gate, Brooklyn, between 8 am and 9 am Friday, during high tide.

Long Beach, Long Island, was typical of many of the south shore communities with flooding occurring from **both** the bay and ocean. In Long Beach, severe flooding occurred in the canals area, with Long Beach Hospital experiencing basement and first floor flooding. Along the beachfront, Friday morning's high tide left many cars submerged in salt water. Severe erosion occurred along the oceanfront in this community, particularly along the boardwalk section which lacked a protective dune system.

The community of Sea Gate, located adjacent to Coney Island, consists of about 840 homes, most of which are owned by older people. Sea Gate was not prepared for this storm. When the tide came in early Friday morning, the order of the day went from a voluntary to a forced evacuation. One hundred fifty to 200 people were evacuated along Atlantic and Ocean View Avenues. Water came through a wooden sea wall and destroyed at least two houses. A number of other houses were extensively damaged in this hard-hit community. In adjacent Coney Island, a pier collapsed, and sea water went under the boardwalk and out onto adjacent public streets causing extensive damage to cars.

The north shore Long Island community of Bayville suffered great damage and personal hardships from this storm. Bayville has a population of about 8,000 people. Flooding began at 10:45 am on Friday. Voluntary evacuation was recommended. Although there were no forced evacuations, from 600 to more than 1000 people had to evacuate their homes. Several cars afloat in the community interfered with recovery efforts. Eastern sections of Bayville near the beach were impacted the most. Western sections, where the ground was higher, experienced only minor inconveniences (interruptions in telephone and electrical services). The water in Bayville became land-locked, waiting for successive high tides to reinforce the high water levels already there. Third Street and Pine Lane to 8th Street were under 2 ft of water.

Eighteen to 24 Bayville homes along the immediate shore facing Long Island Sound suffered severe structural damage. Many homes were defaced. These homes were built just above the beach and were not protected by a sea cliff. A very shallow sea wall of stone was completely inadequate and ineffective. Based on the damage pattern, waves broke over the roofs of these homes with wave heights estimated at 15 to 20 ft. The Bayville marina was totally destroyed. At its peak, up to 6 ft of water was in the streets. According to an individual that was there during the Great Hurricane of 1938, this was about two ft lower than the water level experienced during that hurricane.

In Westhampton Beach on Long Island's south shore, Dune Road was breached in two locations, creating two new inlets across Dune Road. In Mastic Beach, water levels of 2 to 4 ft above the streets in this area were common. Some areas experienced water levels up to 6 ft. Eyewitness accounts mentioned that waves were breaking clear over Fire Island, which served little protection to mainland shore communities such as Mastic Beach.

In New Jersey, several "dredging" barges were sunk east of South Amboy. Along New Jersey's shoreline, there was significant damage to houses, boats, boardwalks, and piers caused by the combination of high winds, tidal flooding, and wave action. Most beaches were under water. In Keyport, there was severe damage to boats, many of which had been thrown together in heaps similar to what had occurred in Massachusetts during **Hurricane Bob** and in South Carolina during **Hurricane Hugo**. The area from Pt. Pleasant to Asbury Park (including Manasquan, Belmar, and Bradley Beach) witnessed large sections of boardwalk and some piers partially to totally destroyed. Areas of severe coastal erosion and wind damage were also evident in this area.

The community of Sea Bright in north coastal New Jersey experienced severe flooding. The dune system at Sea Bright was breached in more than one spot. About 700 people were evacuated. There was extensive damage to parts of houses and structures along the immediate shore. High winds caused widespread power outages. More than three-quarters of the new sand placed in the Sea Bright area during the Spring of 1992 was washed away. The sea wall was eroded, although it adequately withstood high water on its seaward side. However, water trapped on the landward side eroded the sea wall from the base. Much of the home flooding experienced was the result of water rising in the streams and bays behind the dune/seawall system.

During the storm, the community of Union Beach witnessed 300 cars totaled from the effects of sea water, 690 houses damaged, and 200 people sheltered. Nearby, in Atlantic Highlands, over 95% of the boats in and near the municipal piers were destroyed. Public property damage was estimated at $4.2 million dollars.

The high winds accompanying the storm downed numerous trees and power lines, causing extensive power outages. At the height of the storm, about 450,000 Long Island Lighting Company (LILCO) customers, 91,000 from Jersey Central Power and Light Company, 28,000 from Consolidated Edison in New York City and 15,500 in Westchester County were without power.

Mass transportation across the New York City metropolitan area was crippled during the height of the storm. Numerous roads were flooded, and cars were submerged. Many bridges were closed due to the high winds. All bus traffic in and out of New York City was delayed, including New Jersey Transit buses.

LaGuardia Airport in Queens was closed due to flooded runways from 10:22 am, Friday, until about noon Saturday. There were also significant delays at John F. Kennedy and Newark International Airports.

Most trains, including the New York City subway system were delayed. Some systems were partially or entirely closed, including the PATH Commuter Rail System between New York and New Jersey, some branches of the Metro-North Commuter Rail System, and some branches of the Long Island Railroad. The New Jersey Transit Coast Line was shut down due to flooding and debris over its tracks.

All boats coming into and leaving the New York City area were delayed. Some boat services were closed entirely. The Staten Island Ferry was closed between 7:50 am and 1:30 pm Friday, then closed again at 5 pm. The Governors Island Ferry was canceled. Boat service on the Port Imperial Ferry, which carries about 16,000 passengers daily between Manhattan and Hoboken, NJ, was delayed.

The DST found an extensive amount of beach erosion from Long Beach Island, New Jersey, south to Cape May. Many sections of the dune system were breached with a large amount of sand deposited in streets and residential areas. The DST found sporadic structural damage such as roofs blown off and siding, porches, steps, bulkheads, and piers damaged. Undoubtedly, beach restoration efforts in response to earlier nor'easters in October 1991 and January 1992 helped to prevent much more damage.

Precipitation
Heavy rains produced small stream and urban flooding across much of WSFO New York's area of responsibility. Over 6 inches of snow occurred over northwest New Jersey and interior southeast New York from late Thursday night through Friday night. As the storm moved offshore, "backwash" (ie., wrap-around) heavy snowfalls occurred again over the interior sections during Saturday. "Backwash" snowfalls of 2 to 5 inches occurred over Long Island's north shore and central sections from late Friday night through early Saturday afternoon.

Fatalities Outside the Areas of Greatest Impact

There were **three** known **direct** storm-related fatalities in western Pennsylvania during the storm where roofs collapsed from the weight of the snow. The roof of a printing company collapsed in the Allentown section of Pittsburgh killing three workers.

In northern Virginia, **one** homeless person drowned from flooding along the Rappahannock River in Stafford County, and there were 7 water rescues in Fauquier County. In North Carolina, **one** man was killed by a falling tree in Swannanoa of Buncombe County.

SECTION II - DATA ACQUISITION AND AVAILABILITY

Table II depicts selected maximum waters levels along with historical comparisons as compiled by the NOS for the **Great Nor'easter of December '92**. Table III is a similar depiction from the **United States Geological Survey (USGS)** for their crest gages located in New Jersey.

Storm Tide Readings - Connecticut
Preliminary statistics from the NOS indicated that the midday Friday, December 11 storm tide at Bridgeport reached 12.14 ft above Mean Lower Low Water (MLLW), which was just below the 12.44 ft above MLLW reading registered during the 1938 Hurricane. The reading from the previous tide cycle around midnight Thursday, December 10 was 8.85 ft, about 2 ft above normal, which produced local flooding of low-lying areas. At 6:20 am Friday, the tide was 4 ft above normal, but at 7 am the tide gage reading was unavailable and the gage remained out of service for duration of the storm.

The peak tidal height reading of 13.56 ft above MLLW at the Stamford Hurricane Barrier occurred Friday at 11:40 am. This reading exceeded the highest tide of record (since the late 1960s), and was second only to the 1938 Hurricane tidal height of 13.84 ft MLLW, reached at that location prior to the construction of the barrier.

Storm Tide Readings - Massachusetts
At Boston, the NOS recorded a Saturday, December 12 storm tide of 14.21 ft above MLLW, just under the 14.29 ft reading recorded during the October 1991 storm, and about a foot below the record of 15.25 ft established during the Blizzard of February 1978. On Sunday, the midday high tide was about a foot lower than the tide recorded Saturday, but it was still 3 ft above normal.

The amplitude of the storm surge varied along the Massachusetts coast. In contrast to the Boston tide gage reading for Saturday, the Metropolitan District Commission reported a near record 15.1 ft above MLLW at the Amelia Earhart Dam (near the mouth of the Mystic River) and 14.7 ft above MLLW at the Charles River Dam site (well after the predicted time of high tide).

At Nantucket, the NOS reported a preliminary peak storm tide of 6.89 ft above MLLW versus the record 8.11 ft above MLLW recorded during the October 1991 storm. However, the Nantucket harbormaster estimated the Saturday high tide at just 4 inches shy of the October 30, 1991 mark.

TABLE II
NOS
MAXIMUM WATER LEVELS - THE GREAT NOR'EASTER OF DECEMBER '92
WITH HISTORICAL COMPARISONS

STATION	DATE/TIME (EST)	OBSERVED (Feet) MLLW/NGVD	RECORD DATE	ELEVATION (Feet) MLLW/NGVD
Portland, ME	12/12/92 12:12	12.30 / 7.71	2/7/78	14.17 / 9.60
Boston, MA	12/12/92 12:42	14.21 / 9.35	2/7/78	15.25 / 10.40
Nantucket, MA	12/12/92 13:30	6.89 / ---	10/30/91	8.11 / ---
New London, CT	12/11/92 10:12	6.36 / 5.31	9/21/38	10.76 / 9.69
Montauk, NY	12/11/92 9:48	6.04 / 5.45	8/31/54	8.68 / 8.10
Bridgeport, CT	12/11/92 11:00	12.14 / 9.22	9/21/38	12.44 / 9.52
Willets Pt., NY	12/11/92 11:00	14.44 / 11.25	9/21/38	16.90 / 13.74
Battery, NY	12/11/92 8:42	9.55 / 7.68	9/12/60	10.23 / 8.35
Sandy Hook, NJ	12/11/92 8:30/9:24	**10.47 / 8.69** New Record	9/12/60	10.33 / 8.56
Atlantic City, NJ	12/11/92 7:54	8.99 / 7.35	9/14/44	9.20 / 7.56
Cape May, NJ	12/11/92 9:24	8.86 / 6.86	9/27/85	9.09 / 7.09
Lewes, DE	12/12/92 10:12	8.07 / 6.33	3/6/62	9.49 / 7.76
Reedy Pt., DE	12/11/92 14:24	**9.45 / 6.96** New Record	10/25/80	9.19 / 6.68
Philadelphia, PA	12/11/92 14:42	10.01 / 7.72	11/25/50	10.79 / 8.50
Wachapreague, VA	12/12/92 10:00	7.68 / ---	10/25/80	8.33 / ---
Chesapeake Bay Bridge Tunnel, VA	12/12/92 9:30	5.94 / ---	4/26/78	6.36 / ---
Kiptopeke, VA	12/12/92 9:30	5.64 / 4.20	3/7/62	7.41 / 5.99
Gloucester Pt., VA	12/12/92 10:12	5.18 / 4.04	3/7/62	6.63 / 5.47
Lewisetta, VA	12/11/92 17:30/19:30	2.89 / 2.62	3/19/83	3.62 / 3.34
Solomons Island, MD	12/11/92 6:30/19:30	3.08 / 2.76	8/13/55	4.53 / 4.18
Annapolis, MD	12/11/92 9:30	3.08 / 2.92	8/23/33	6.40 / 6.24
Baltimore, MD	12/11/92 9:30	4.07 / 3.79	8/23/33	7.93 / 7.65

TABLE III
USGS
MAXIMUM WATER LEVELS - THE GREAT NOR'EASTER OF DECEMBER '92
WITH HISTORICAL COMPARISONS

STATION	DATE	OBSERVED (Feet) NGVD	RECORD DATE	ELEVATION (Feet) NGVD
Raritan River at Perth Amboy, NJ	12/11/92	**10.4** New Record	11/7/53	9.50
Luppatatong Creek at Keyport, NJ	12/11/92	**9.77** New Record	3/29/84	8.03
Cedar Creek at Lanoka Harbor, NJ	12/11/92	5.54	2/18/36	6.45
Manahawkin Bay near Manahawkin, NJ	12/11/92	**6.02** New Record	3/29/84	5.36
Little Egg Harbor at Beach Haven, NJ	12/11/92	**6.93** New Record	3/29/84	6.19
Batsto River at Pleasant Mills, NJ	12/11/92	**7.77** New Record	3/7/62	7.2
Mullica River near Port Republic, NJ	12/11/92	7.13	3/6/62	7.90
Absecon Creek at Absecon, NJ	12/11/92	7.58	3/29/84	7.77
Great Egg Harbor Bay at Ocean City, NJ	12/11/92	**7.85** New Record	3/29/84	7.53
Great Channel at Stone Harbor, NJ	12/11/92	7.12	3/29/84	7.33
Cohansey River at Greenwich, NJ	12/11/92	6.68	11/25/50	8.80
Delaware River at Burlington, NJ	12/11/92	8.78	8/20/55	10.8

Storm Tide Readings - Rhode Island/Maine
The high tide at Providence, Rhode Island peaked slightly above flood stage Friday morning and again Saturday morning, or about 2 ft above normal.

The high tide at Portland, Maine for the midday storm tide Saturday, as recorded by the NWS was 12.54 ft (1.7 ft above normal). The high tide on Sunday was 12.19 ft which was 1.5 ft above normal.

Storm Tide Readings - New York/New Jersey
The extratropical storm of December 11-12, 1993 caused some of the highest water levels ever recorded along the New Jersey, New York City and Long Island coastlines.

Record water levels were reached at Perth Amboy on the Raritan River, where water reached 10.4 ft above NGVD (National Geodetic Vertical Datum, the mean sea level of 1929). Record levels in New Jersey were also recorded at Keyport, Manahawkin, Beach Haven, and Ocean City. Reedy Point in the Delaware Bay reached 9.45 ft above MLLW, exceeding its previous all-time high of 9.19 ft.

Water levels are a combination of the wind-driven surge plus the astronomical tides. This particular storm occurred during a period of spring tide - the higher periods of monthly tides which occur around the new- and full-phases of the moon. New moon occurred on December 9, just before this storm. Tide tables show that the highest astronomical tides would occur on December 11 and 12.

Tides along the East Coast are semi-diurnal in character, having two maximums and two minimums each day. On December 11 and 12, the maximum tide that occurred between 9 and 10 am was the higher of the two, reaching 5.7 ft above MLLW at Sandy Hook, NJ. This "natural" high astronomical tide coincided with the storm reaching its peak and resulted in record water levels at Sandy Hook. According to NOS, Sandy Hook's tide reached 10.47 ft above MLLW at 8:30 am and again at 9:24 am Friday. This exceeded Sandy Hook's previous record of 10.33 ft above MLLW set during Hurricane Donna on September 12, 1960.

Tide Gage Performance
Tide gage information was crucial during this storm. The gages themselves appeared to work well, but issues regarding the availability of real-time information surfaced. WSO Bridgeport lost communications to the local tide gage early in the event due to a chafed power cable and the submersion of key components.

The Boston tide gage appeared to function as intended, but the appropriate calibration of real-time data available via telephone was in doubt. Just prior to the storm, there was concern that the Boston gage may have been reading higher than the expected astronomical tide. After having noticed values that were obviously too high, the gage was adjusted to read near values available from the Charles River Dam (which has run close to the Boston NOS tide gage in past storms). Both gages registered a maximum tide height of 14.2 ft on Friday and 15.1 ft on Saturday.

Additional post-storm investigation indicated that the real-time data available by telephone was still too high when compared with on-site NOS data. Additional efforts have been taken to recalibrate this gage. The error in calibration resulted in storm tide forecasts for Boston that were too high, but not to the point where the usefulness of the forecasts were compromised, as indicated by feedback from various organizations and the observed impact of coastal flooding.

Tide Gage Data Availability
Real-time access to coastal tidal heights is mandatory to determine the magnitude and timing of any storm surge. Due to the limited number of tide stations and difficulty in retrieving data in real-time, large areas of the coastline subject to significant flooding are not well-represented, including Long Island, the back-bay areas of New Jersey, the southern New England coastline, Cape Cod, and all of Maine east of Portland.

The acquisition of real-time tidal information is critical to the NWS mission. This requirement is all the more crucial given the ever-increasing development of the shoreline. The lack of real-time tide data once again hampered the ability of the NWS to forecast and monitor the extent and degree of tidal flooding. This ongoing problem was also referenced in the **Halloween Nor'easter of '91** and **Northeast Blizzard of '78** reports.

Storm Surge Prediction
Extratropical storms, in general, are slow moving and impact the coastline for an extended period, giving high surge values through several tidal cycles. In contrast, hurricanes usually generate higher surge values, but their scale is smaller so the impacted geographical areas are smaller. Also, hurricanes impacting the northeast are generally fast moving, with forward speeds of 30 kts and faster.

NWS offices along the coast were aware of the predicted tide levels and that this storm would cause flooding. Coastal flood watches were issued well in advance of the event. The main question for forecasters was how high the surge would be. The primary guidance for extratropical storm surge forecasting available to forecasters is the AFOS product MRPECS. This guidance product is available for twelve sites along the East Coast.

The MRPECS is a statistical forecast product derived from a "perfect prog" statistical technique. In such a technique, a dependent variable, such as the surge level, is related to meteorological conditions which occurred **at the same time.** In the forecast mode, this derived equation is applied, not to observed meteorological values, but to forecast values. For the MRPECS, the surge level was related to observed pressures along and off the coast and a simple regression equation was derived. These equations were then applied to pressure forecasts from the LFM.

The NWS has been moving most of its forecast products to a newer atmospheric forecast model, the Nested Grid Model (NGM). Although the MRPECS product was running operationally with forecast fields from the LFM during this event, an experimental version based on the NGM was run at the TDL. Results from this model were made available to NWS offices at Sterling, VA, Atlantic City, NJ, and New York, NY. During several previous cases, this guidance product was transmitted to Atlantic City for performance evaluation during significant events. In general, the NGM version performed better than the older LFM version.

The actual predicted tide anomalies were somewhat conservative for the Connecticut coast and a little too high for the Massachusetts east coast. Even so, local NWS office statements correctly forecast major flooding along both coastlines for the right tidal cycles. It is important to communicate to users the fact that there is usually a degree of uncertainty in such predictions for an event of this type. It is expected that completion of an extratropical storm surge model by the TDL will provide the NWS additional valuable guidance for such events.

In the case of the Massachusetts east coast, problems with accurately calibrating the Boston tide gage tended to skew WSFO Boston's storm surge predictions a little high. However, that did not seem to pose a significant problem in the long run to users, given the extent of the flooding as determined by post-storm feedback.

To assist in determining expected storm surge, WSFO Boston forecasters ran a software program, called "TIDES1", which produced a table of high tide times, astronomically predicted high tide, flood stage, and predicted storm tide based on the provided storm surge forecast. WSFO Boston personnel also plotted a running graph of observed versus astronomically predicted tide data. NOS-produced software, called TIDES_ABC, does essentially the same operations automatically, but it could not be successfully implemented on WSFO Boston's computer systems. TIDES_ABC was also inoperative during the storm at WSFO New York. The TIDES_ABC system is in the process of being replaced with a new software version that accesses the NOS NGWLMS.

Coastal and Offshore Marine Observations

Coastal and offshore data (e.g., wind, seas) are especially important to forecasters during coastal flood events. The existing network, even when totally operational, leaves large areas of the ocean almost totally devoid of real-time data for forecasters. The unavailability of a number of key buoys during the storm only served to compound the problem.

The loss of the Coast Guard's Large Navigational Buoys just off the Delaware coast barely a month prior to the storm proved to be a particular handicap to forecasters. Specifically, the absence of the buoys made forecasting the seas and winds very difficult, since the storm re-curved in the vicinity of the buoys previous locations. Additionally, the buoys positions with respect to the surface low pressure system would have given forecasters a more precise indication of both storm strength and movement.

The data from the Georges Bank buoy (NOAA-44011) was not available for the storm and left a significant gap in wind and seas information. These data are important in the determination of storm surge and wave battery along the southeast New England coast. The Nantucket buoy (LNB-44008) had a wave data failure on December 8 and was adrift on December 11 during the storm.

AWOS Observations

The Automated Weather Observing System (AWOS) observations from Block Island, Rhode Island, ceased during the storm when the power went out at the airport. The observation from this site is often an excellent indicator of coastal weather conditions, and its loss at critical times during recent significant storms caused a data void. This AWOS site should be tied into an emergency power source.

Federal AWOS sites at the Waterbury-Oxford Airport (OXC) in Oxford, Connecticut, the North Central State Airport (SFZ) in Pawtucket, Rhode Island, and the Provincetown Municipal Airport (PVC) in Provincetown, Massachusetts, provide continuous observations in locations where data is needed. The highest wind gust at the Provincetown AWOS obtained by telephone was 59 mph.

Snowfall Observations

Water equivalent precipitation values were considerably less than what might have been expected in areas of heavy snow, especially in western Massachusetts. Cooperative observers in that region stated the wind was sufficiently strong so the snow fell horizontally and was not all caught in the gage.

During the heavy snow event, state police, the department of transportation, and private meteorologists were helpful in providing snow amounts to the NWS. Nonetheless, both WSFO Boston and WSO Hartford would like to obtain better real-time snowfall information. An improved snowfall collection network involving spotters or cooperative observers should be established. The Hydrologic Service Area office serving these offices could receive the snowfall data and transmit the information via AFOS.

SECTION III - PREPAREDNESS

Disaster Preparedness is one of the most important, and time consuming, functions of the National Weather Service. If the public is to be adequately warned of impending dangerous weather, they must fully understand the hazards that may strike, and how the NWS will try to alert them.

To alert and educate the public, "external" preparedness is conducted by work with the media, the emergency management community, state and local officials, and the general public.

CONNECTICUT

Preparedness workshops have demonstrated value in facilitating the cooperation of emergency management agencies, weather spotters, and the NWS. A media workshop concerning NWS modernization was conducted at WSO Hartford on Thursday, one day prior to the onset of the storm. Besides NWS managers from Connecticut, Massachusetts, and New York, there were representatives from the media and from state agencies. The storm potential and its serious implications were discussed at this gathering and given public dissemination.

The responsibility for disseminating NWS watches and warnings throughout Connecticut resides with the state police. As a matter of policy, initial notifications of watches and warnings are transmitted over the National Warning System (NAWAS) and the state law enforcement network (COLLECT). Follow-up statements are not transmitted. The restricted disbursement of this information during the event prevented users from obtaining significant information on the storm's progress and calls to action. The OEM is in the process of changing the policy to include statement transmissions and to provide training for the dispatchers in the use of NWS terminology and products. They are also investigating methods of improved communications of meteorological information with another public safety organization, the Department of Environmental Protection (DEP).

The labor-intensive retransmission of NWS products on the COLLECT network can be eliminated by automatically linking it to NWWS. Efforts have been underway for several years to accomplish this connection, but they should be renewed in view of the fact that manual transmission physically limits the amount of storm-related information that can be transmitted to the local user.

All towns along Long Island Sound are susceptible to coastal events. We endorse OEM's requirement that these towns update their existing Emergency Operations

Plans to better prepare for coastal flooding. These plans should be coordinated with the NWS on flood watch and warning procedures. A test drill should be conducted annually at the start of the hurricane season by the state, NWS, and local officials.

MASSACHUSETTS

WSFO Boston and other NWS offices in the management area have had recent coastal flooding experience associated with the **Halloween Storm** and **Hurricane Bob** in 1991. The forecast office issued its written Winter Storm Drill in late November 1992 and it was ongoing during the mid-December event. The drill is a review of operational procedures for winter weather and coastal flood events.

Several preparedness actions, implemented since the October 1991 storm, contributed to the successful coordination concerning this storm. The Area Manager (AM) and Deputy Meteorologist-in-Charge (DMIC) of WSFO Boston initiated and coordinated with FEMA and the MEMA a series of six public workshops on hurricanes and northeasters. The focus was on hurricanes at the forums in Wareham and Hyannis in July 1992 and at the two sessions in Marshfield in August. The workshops in Gloucester and Revere in October focused on northeasters. The AM also gave a talk to MEMA's Area II (southeast Massachusetts) local emergency managers several weeks before the storm. WSFO Boston personnel have also stressed coastal flood preparedness at other presentations. Also, meetings with media representatives may have helped promote the flow of information to the public (or at least its importance) via the local media.

As a result of prior preparedness activities for weather spotters, the SKYWARN amateur radio network was activated for this storm for periods during Friday, Friday night, and Saturday. In particular, real-time SKYWARN reports provided useful and current information on coastal flooding along the Massachusetts coast.

WSFO Boston's relocation to Taunton, Massachusetts, means that the forecast office will eventually assume warning and coordination responsibilities for Rhode Island, parts of Connecticut and New Hampshire, as well as most of Massachusetts. There will then be a need for a quick and efficient method of communicating with the emergency management structure of these four states at the same time, if necessary. Consequently, it is important for NWS operations that the modes of communication involve a minimum number of telephone calls and transmissions from the NWS office.

RHODE ISLAND

According to the MIC of WSO Providence, the state director of the Rhode Island Office of Emergency Management, Joe Canavali, stated they were adequately notified, pleased with the lead time of the warnings, and prepared for the storm. It was noted, however, that there was only limited feedback from the state agency during the event.

In the northern part of the state, some weather spotters provided snow depth readings, while along the coast, a spotter provided information about the fury of the storm and about voluntary evacuations in Westerly at the height of the storm. As a preparedness function, the office is in need of more observers at the coast who can provide critical information about the effects of a coastal storm as they are occurring.

NEW YORK AND NORTHERN NEW JERSEY

The number and range of situations that an NWS forecaster may face are limitless. In order to function properly during each situation, "common sense" is needed, together with documented instructions and procedures available for quick reference. In NWS offices, these instructions and procedures are part of the office duty manual (ODM).

WSFO New York has a rather elaborate ODM, with separate volumes covering virtually all weather situations and duties that may arise.

While there were no major problems found with the ODM, it must be noted that some sections are in need of a good "cleaning." It was found that many changes were either "penciled in" or made by attaching an office memorandum. In some cases, the old instructions were still in place, even though they had been changed by an attached memorandum.

A "spotter" book was also found at the WSFO. This book contained the names and telephone numbers of various emergency management personnel, spotters, and the media. For the most part, the book was up-to-date; however, some of the media names and telephone numbers were incorrect.

No other preparedness files were found. It is recommended that a file on each county be established. The file would contain all necessary information (names, telephone numbers, media, etc.) from that county. It should also contain a brief history of preparedness activities in the county and the type of response received from NWS initiatives.

Office drills also provide a good forum for performing internal preparedness. It was found that the WSFO conducts drills on various weather hazards; however, it must be noted that not all drills were held on an annual basis.

The county warning area of WSFO New York presently consists of 23 counties covering New York and New Jersey. While the area is rather compact, the tremendous population and urbanization of the region present many challenges.

The preparedness program at the WSFO has undergone great improvements during the last couple of years. The number of weather spotters in the WSFO's county warning area has tripled in three years, growing from 300 to nearly 1000.

Annual "Severe Weather Awareness Weeks" were held for a variety of weather hazards. These awareness weeks include mailing information to the media, schools, and emergency management personnel. Interviews for the various media were also done upon request. Of particular note was the Winter Weather Awareness Week held two weeks before the storm. This awareness campaign covered all hazards associated with winter-time storms, including coastal flooding and high winds.

DST interviews held with local emergency managers were generally positive in nature. All managers interviewed said they felt they had good relations with the local NWS office and could call upon them at any time for more information. The media interviewed responded in much the same manner, although some indicated they did not have current telephone numbers.

Conversations with the general public revealed that a wide range of knowledge exists, ranging from the very informed and knowledgeable to people who only know what "they say on television." Preparing the public for weather hazards is primarily done by trying to get the media to pass along safety information. However, the DST found that this is not usually done by the media. None of the media representatives interviewed by the DST indicated they did any special stories concerning the recently held Winter Weather Awareness Week.

CENTRAL AND SOUTHERN NEW JERSEY

NWS personnel must be ready to respond to all types of weather related events in a timely and efficient manner. While experience continues to be an irreplaceable commodity, many personnel are new, and many phenomena are seasonal or infrequent. A storm like the **Great Nor'easter of December 1992** falls under this latter category. Consequently, clearly written, easily obtainable comprehensive instructions and procedures for NWS personnel are critical.

The DST found that the Weather Service Office (WSO) in Atlantic City does have an ODM covering coastal flooding and other types of severe weather. However, enhancements and updating should be periodically performed to maintain an up-to-date manual. The DST found that the staff of the WSO not only possesses an elevated and keen knowledge of tidal effects on its county warning area, but extensive experience, expertise and precision in handling coastal flooding events.

The DST recommends that periodic drills covering all phenomena be conducted at both WSOs and their parent WSFOs. As modernization continues and offices reorganize, it will be critically important for personnel at many new offices to obtain or maintain the existing level of expertise and involvement. This will require knowledge and proficiency in all aspects of weather phenomena within the prospective county warning area.

As noted earlier, preparing state and local officials, the media, and the general public for the eventuality of severe weather is a continuing, essential, and difficult job. It is the NWS' mission to warn the public about weather which has the potential to threaten life or property. Disaster preparedness work is crucial to that mission.

The DST found excellent rapport between emergency management officials and WSO Atlantic City. Significant strides have been made, and continue to be made, in preparedness work across the area. Emergency management and media representatives felt that they were well informed and prepared for this event. They also stated that statements issued by the WSO provided both excellent coverage of the event and a good lead time. Responses from the general public were quite favorable.

The general populace often underestimates the power of mid-latitude cyclones and East Coast storms. Many perceive these storms as posing a lesser danger because they are not tropical in nature. As one resident put it, "this one caused a good bit of damage for a storm without a name."

The DST found three aspects of the Atlantic City WSO's methodology in preparing statements to be rather effective, resulting in a high level of awareness and favorable user response by the general public, the media, and emergency management officials.

First, comparisons were made with the **Halloween Nor'easter of 1991** and the **January 4 1992 storm**. "Historical storm" comparisons, particularly those still fresh in the minds of all concerned, frequently serve as a barometer for expected damage with an ongoing event. Secondly, strong terminology was used in statements denoting the potential for structural damage and the severity of the flooding. These factors heighten user awareness and result in a higher level of user response. Lastly, tidal heights referenced to MLW have provided local emergency management officials with reference levels allowing comparison between storms of varying intensities.

Another factor which plays an important role in disaster preparedness activities within the WSO's county warning area is the "home-rule" approach to emergency services in New Jersey. Emergency management is run at the municipality level, with each local government having the authority to conduct evacuations and construct its own emergency plans. This approach to emergency services can greatly increase the workload for the staff at WSO Atlantic City simply due to the number of agencies involved.

SECTION IV - WARNING SERVICES

The **Great Nor'easter of December 1992** was a storm which will undoubtedly be remembered for its intensity, as well as the amount and diversity of the attendant severe weather. Diverse forms of adverse, and in many cases "severe," weather conditions were confronted by many Eastern Region offices from Raleigh-Durham, NC, to Portland, ME, and points inland. This section will focus on those offices from Massachusetts through New Jersey where the impact of this storm was the greatest.

Overall, NWS warning services were effective with a plethora of quality statements from the involved offices. In general, watches and warnings were issued with ample lead time to respond. A few watch or warning decisions might have been made differently given the advantage of hindsight, but the **crucial** watch and warning issuances gave excellent notification on the what, where, and when of the more serious aspects of the storm - coastal flooding, heavy snow, and high winds.

WSFO BOSTON

The storm potential was discussed in the Tuesday afternoon (December 8) State Forecast Discussion. The first Special Weather Statement (SPS) regarding this storm was issued early Wednesday morning. The first Winter Storm Watch (WSW) for mainly western parts of Connecticut and Massachusetts and a Coastal Flood Watch (CFA) were issued early Thursday morning. In addition to a continuing series of special weather and coastal flood statements, Public Information Statements (PNSs) were issued Wednesday, Thursday, Friday, and Saturday to list precautions and actions people should take for coastal flooding and winter storms. The content of each public information statement was tied to the applicable watch or warning in effect.

Winter storm and coastal flood watches were upgraded to warnings early Friday morning. The coastal flood warnings were valid through Saturday. High wind warnings were added to coastal areas early Friday morning. In addition to the existing warnings Friday, winter storm watches were issued for northeast coastal Massachusetts and northern Rhode Island to reflect the potential for a change from heavy rain to heavy snow. Blizzard warnings were issued for eastern Massachusetts early Saturday morning.

By late Saturday night and early Sunday morning, winter storm warnings and advisories had been discontinued. However, it was necessary to continue a coastal flood warning for the Massachusetts east coast through the Sunday afternoon high tide. In retrospect, enough coastal flooding occurred along the western Connecticut coast again Sunday, although of much lesser magnitude than Friday's event, to have warranted extending the coastal flood warning through Sunday. Minor coastal flooding occurred in places (especially in heavily eroded areas) along the Massachusetts east coast again Monday.

Of all the many important and wise decisions made, the issuance of a winter storm watch Friday afternoon encompassing the Boston metropolitan area was perhaps the most bold. Against the advice of some meteorologists at other NWS facilities and the private sector, the Boston Lead Forecaster, relying upon years of New England forecast experience, predicted a change-over to heavy snow for much of eastern Massachusetts. Conventional wisdom is that heavy rain rarely changes to heavy snow along the southern New England coastal plain. However, it was recognized that not only was this storm an exception to the rule but that the area would receive another round of significant precipitation, contrary to some of the guidance from NMC.

Assessment of Selected Watch/Warning Decisions

It would have been desirable to expand the winter storm watch, perhaps sometime Thursday, to include central and northeastern Massachusetts. This area never came under a watch, but ended up with record snowfall. Uncertainty in the northeastward extent of the heavy precipitation shield caused forecasters at WSFO Boston to "wait and see." Even so, the winter storm warning issued early Friday morning provided at least eight hours lead time for that zone. Also, the number and character of statements made it clear that all of Massachusetts would likely be struck by a major storm.

Blizzard warnings were issued in lieu of winter storm warnings for eastern Massachusetts and coastal Rhode Island early Saturday morning. They did not verify and snowfall predictions along portions of the immediate Rhode Island and Massachusetts coasts were too high; most of the precipitation was rain. Although the backing of surface winds from east to northeast brought colder air into southeast sections of Massachusetts, the influence of relatively warm sea surface temperatures could not be fully offset near the coast. This was a tough forecast call since a drop of a few more degrees in the boundary layer mean temperature likely would have resulted in rapid snow accumulations accompanied by strong winds, even along the immediate coast; and probably would have resulted in substantially greater snowfall a short distance inland with potentially paralyzing blowing and drifting snow problems. Even for east coastal Massachusetts, this event came precariously close to matching the **Northeast Blizzard of '78.**

In retrospect, an upgrade from a coastal flood watch to a warning for the Connecticut coast might have been helpful with the Thursday afternoon or evening forecast package, since it had become apparent that there was a strong likelihood of a major event. This might have stimulated a stronger response by people in an area that had not faced the potential for such severe coastal flooding in many years. Nevertheless, the upgrade to a warning early Friday morning provided several hours lead time to complete evacuations and other preparations.

Product Heading Designators
There were problems with the use of the correct PIL in the heading. For example, coastal flood and high wind warnings were initially included with winter storm warnings under the WSW PIL at WSFO Boston Friday morning. To be consistent with Weather Service Operations Manual (WSOM) Chapters C-42 and C-44, the coastal flood warning should have been issued under CFW and the high wind warning under NPW. The coastal flood warning was reissued under CFW a little later Friday morning.

At WSFO Portland, most statements were under the WSW PIL because a change in the status of a watch or warning prompted the issuance of a statement. The coastal flood warning issued in a WSW statement at 4 pm Friday should have been issued separately under CFW. Another statement issued as a WSW early Saturday morning should have been issued as a SPS.

The experience with this event was a good example of the complexity and difficulty presented by NWS PIL guidelines for field operations. Separate PIL usage categories describing portions of the same weather event puts an additional burden on the forecaster, and ultimately the user, to determine which communication header needs to be used/stored for issuances.

A separate/single product issued for emergency managers and other users may be preferable to the continued use of multiple product headers for sequential issues of winter weather statements. Specific hazards can be highlighted through the use of sub-headings within the body of the statement.

In Massachusetts, a local emergency manager voiced his need for a product tailored for just emergency management use and not for public dissemination. A separate product issued for emergency managers, and other users may be preferable to the continued use of multiple product headers for sequential issues of winter weather statements. It is recognized that the solution to this issue may take time as the NWS must balance the needs of key users with what is operationally feasible. Future systems such as the Advanced Weather Interactive Processing System (AWIPS) will help forecast offices correctly and reliably "package" various products for optimum use.

WSFO NEW YORK

The New York City Weather Service Forecast Office issued a spate of watches, warnings, and weather statements during the event.

The WSFO highlighted the potential for a BIG storm with coastal flooding as early as 2 pm Monday, December 7 in its state forecast discussion (SFD). The first special weather statement (SPS), which highlighted the potential for a major winter storm starting Thursday night and Friday, was issued at 5 am Wednesday, December 9.

A Coastal Flood Watch (CFA) was issued at 3 pm, Wednesday, December 9 for New York City, Long Island, and north-coastal New Jersey, effective late Thursday night and Friday. A Coastal Flood Warning (CFW) was issued at 3 pm, Thursday, December 10 for New York City, Long Island, and north coastal New Jersey for late Thursday night and Friday. The first report of coastal flooding was at 6:15 am, Friday, December 11 in the northeast New Jersey communities of Union Beach and Keyport in Monmouth County, giving a lead time of about 39 hours for the watch and 15 hours for the warning.

Numerous, timely updates and extensions to the original coastal flood warning were subsequently issued by the WSFO with the final warning disseminated for the entire area at 4 am, Monday, December 14.

A Winter Storm Watch (WSW) was issued at 3 pm, Wednesday, December 9 for interior northern New Jersey and interior southeastern New York for Thursday night and early Friday. The first report of 6 inches of snow was at Pine Bush, Orange County, NY at 3:15 am, Friday, December 11, affording a lead time of about 36 hours.

A Winter Storm Warning (WSW) was issued at 4:30 am, Thursday, December 10 for interior northern New Jersey and interior southeastern New York for late Thursday and Friday, giving a lead time of about 23 hours for the six inch snowfall at Pine Bush, Orange County, NY. Lead times for the other counties ranged from 23 to 31 hours. Various changes in the WSW area occurred from Thursday afternoon through Saturday morning when remaining warnings were changed to advisories at 4 am, Saturday, December 12. However, events warranted the reissuance of a WSW for portions of interior New York and New Jersey at 9:45 am Saturday.

A Flood Watch (FFA) for urban and small stream flooding was issued at 3 pm Thursday, December 10 for northeast and central New Jersey, southern Westchester County, Long Island, and New York City, for late Thursday night and Friday. A flood warning (FFW) for urban and small stream flooding was issued at 11 am, Friday, December 11 and extended until 9:30 pm (in effect about 10 1/2 hours) for east central New Jersey (Monmouth County); northeast New Jersey (Bergen, Essex, Hudson, Middlesex, southeast Passaic, and Union Counties); and southeast New York (Bronx, Kings, Nassau, New York, Queens, Richmond, Suffolk, and southern Westchester County) and again from 10 pm, December 11 until 5 am Saturday, December 12.

The WSFO issued a flood warning (FLW) for northern Westchester County at 10 pm, Friday, December 11 which was extended until 5 am, Saturday, December 12.

A high wind watch (NPW) was not issued by the WSFO for its area of responsibility, although winds reaching the high wind warning category occurred. However, a high wind warning (NPW) was issued at 3:30 pm, Thursday, December 10 for New York City, Long Island, and north coastal New Jersey for late Thursday night and Friday, which was updated at 9:30 pm to include Rockland and northern Westchester County for late Thursday night and Friday and again at 3 pm, Friday, December 11, extending through Friday night. The first report of damaging winds (roofs blowing off) was received at the New York WSFO at 6:37 am, Friday, December 11 from Keyport, NJ, giving a lead time of about 15 hours.

The WSFO received many compliments from the media and emergency management officials on the services provided during the **Great December Nor'easter of December 1992**. On the flip-side, the WSFO also received "second-hand" criticism, from the newspapers, that its warnings were inadequate. This resulted from some communication lapses at the local government level.

WSFO PHILADELPHIA/WSO ATLANTIC CITY

WSFO Philadelphia is responsible for issuing coastal flood watches for central and southern New Jersey. The Atlantic City weather service office is unique in that they are the only WSO in the Eastern Region of the NWS which has a coastal flood warning responsibility. At other locations, coastal flood warnings are issued by the parent WSFO. As a consequence, close coordination between the two offices must be maintained to insure proper procedures, avoidance of a conflict in information, and a smooth efficient flow of information to the users.

The first Special Weather Statement from WSFO Philadelphia suggesting the potential for a storm to develop was sent at 10:35 pm Monday, December 7. This was five days ahead of the event. Likewise, WSO Atlantic City issued a very strongly worded statement at 10 pm Tuesday, December 8 with the first high tide of consequence occurring 8 am Friday, December 11. The coastal flood watch from the WSFO was initiated at 2:40 pm Wednesday, December 9, a full 41 hours ahead of the reported flooding. Meanwhile, the WSO issued a coastal flood warning at 8:52 am Thursday, December 10. This was 23 hours ahead of any flooding.

It is interesting to note that the model guidance for storm surge was advertising tides in the 2 to 3 ft above-normal range for sections of the New Jersey coast. During the storm, the guidance was LFM-based; as noted earlier, it has since been modified to NGM-based. The staff at WSO Atlantic City, however, did have limited access to the NGM-based values, which was forecasting higher surge heights. These values were used to reinforce and build confidence in the decision to forecast higher tide amounts augmented by hourly gage readings which turned out to be correct.

In New Jersey, Flood Warnings were issued early on December 11 for the Cooper River, Assunpink Creek, Rancocas Creek, and the Raritan River basin. Flood Warnings for the Rancocas Creek basin were correctly extended until late in the evening December 14.

SECTION V - COORDINATION AND DISSEMINATION

Early Notification
The first notification to emergency managers of a potentially serious weather event was given by the area NWS offices on Tuesday, December 8, three days before the storm significantly impacted the area from New Jersey to southern New England. Indeed, a number of NWS forecast offices issued state forecast discussions the day earlier (December 7) calling attention to the potential of a "big event" later in the week.

WSFO Philadelphia's initial special weather statement was disseminated at 10 pm, Tuesday, December 8. At 5 am the following morning, WSFO New York issued its first special weather statement on the upcoming storm.

WSFO Boston issued a winter storm outlook statement for the public at 5:55 am Wednesday. Public information statements containing a description of NWS winter weather products and term usage were transmitted by WSO Hartford and WSFO Boston later that day. Subsequent statements about the storm were issued periodically by NWS offices for what were to be the hardest hit areas.

Frequent phone coordination kept federal and state emergency managers better informed so they could make decisions on projected weather developments. However, such coordination takes time and is dependent upon sufficient staffing.

The perception of the AM at WSFO Boston was that the investment of some reasonable amount of external coordination via phone for such major events was warranted, given the service and real-time feedback benefits generated. Even so, efforts to automate the exchange of information between the NWS and the emergency management community are very valuable and should be rigorously pursued.

CONNECTICUT

The OIC, of WSO Bridgeport exclaimed that the state of Connecticut's response to the storm was the best he had ever seen. Even so, there are some coordination and dissemination problems that need to be addressed. There was a problem in New London County, where information pertaining to coastal flooding was not being relayed from the Groton public safety dispatch center to the New London Emergency Operations Center.

The OEM in Hartford had difficulty receiving NWS products over their NWWS receiving link. Their inability to receive complete messages caused personnel at WSOs Hartford and Bridgeport to dedicate precious time providing this missing information by telephone and facsimile. Fortunately, facsimile capability was made available at WSO Hartford early in 1992, partly as a result of past problems in communicating with the OEM. WSO Bridgeport did not have that capability, however they were able to use an airport facsimile, courtesy of the airport manager.

The Connecticut OEM wants to obtain the actual predicted tide heights at high tide for susceptible locations along the coast and have them made available to their local EOC managers. WSFO Boston produces this listing with limited locations but it should be expanded and made available over NWWS.

The Northeast River Forecast Center (NERFC) in Hartford were not directly involved with the more damaging aspects of storm. However, they did handle a substantial volume of precipitation and snow reports in their capacity as the Hydrologic Service Area Office for Southern New England. There was some tidal flooding of the lower stems of the major rivers at the times of high tide, but inland river flooding was not a factor. The acting Hydrologist-in-Charge (HIC) stated there was good coordination with WSFOs Albany and Boston during the event.

MASSACHUSETTS

The transmission and receipt of NWS warnings and statements throughout the state's emergency management structure can be streamlined by the interfacing of the NWWS with the Criminal Justice Information System (CJIS). This linkage may eventually be accomplished via the National Law Enforcement Telecommunications System (NLETS). Until that avenue becomes a reality, work should continue on the interface within the state.

MEMA used facsimile, radio, and telephones (including cellular) to disseminate weather information to cooperating agencies and local emergency managers. They did activate the public Emergency Broadcast System (EBS) for the storm; Connecticut and Rhode Island did not.

RHODE ISLAND

A problem was noticed in the display of the forecast on cable television in this state, which may apply to other states as well. A television cable company that supplies service for Newport (at the coast) is located in the northern part of the state. The NWS zone forecast that is transmitted on **The Weather Channel** for Newport is the interior (northern) zone and not the coastal zone, which is applicable for Newport. Therefore, the coastal flood warning information for the storm was not contained in the forecast. Similarly, there is a cable company near the coast that provides the interior portion of the state with the coastal zone forecast information. Prior to, and during this storm, their viewers were denied winter storm warning information about heavy snow. The problem of unrepresentative zone forecast transmissions is being investigated with the cable company and **The Weather Channel.**

NEW YORK

WSFO New York efficiently and effectively used every type of media available to disseminate accurate warnings in a timely manner. This included the effective use of NWR, numerous commercial radio and TV interviews, and the print media.

In New York, automated information flows to the State OEM Headquarters via the NYSPIN communications circuitry. It is interesting to note that WSFO New York received copies of all watches, warnings, advisories, and statements that were received on NYSPIN before, during, and immediately after the storm. This confirmed successful communication and dissemination of weather products over the NYSPIN and AFOS systems.

The dissemination of critical weather products to state and county levels, primarily through NWWS and NYSPIN, worked very well. However, there were some breakdowns in passing this information to the community level, including local police or fire departments who were involved in evacuations.

The media commented that the flow of information from the NWS was good, but could have been better. Several commented that they wanted more statements during the height of the storm, "at least one per hour." The NWS Eastern Region Nowcast program will help assure that a steady stream of information is available to users during future significant weather situations.

Private forecasting firms have a rather large presence in New York City, and they essentially view the NWS as a competitor. Several broadcast meteorologists pointed out to the DST that private forecast firms are not always diligent in passing along NWS products. This was confirmed during an interview with a meteorologist who works for a cable channel on Long Island that contracts with a private meteorology firm. Another meteorologist who works for a private firm verified this.

The Mastic Beach Volunteer Fire Department received no "official notification," but heard of a "flood alert" on the county fire communication frequency Friday morning, just prior to their receiving calls for help. Otherwise, the local TV news was their main source of information. However, one member of the department stated he received adequate warning through access to the NYSPIN. A voluntary evacuation was recommended, starting at 7 am, Friday, December 11.

The Sea Gate community, adjacent to Coney Island, normally receives emergency weather information from the 60th Precinct of the New York City Police (Coney Island area). This time they received **no warning** of the coastal flooding, even though the NWS had issued one. They knew of an impending storm from hearing about it on the local news but did not pay too much attention because of a lack of official notification.

They knew about NWR, "that channel on the scanner," but did not think to monitor it. They had no knowledge of the NWR tone alert feature. They indicated they would quickly buy a tone-activated NWR.

The DST spent considerable time with the Bayville Fire Department. Normally their only notification of watches and warnings is on the county fire communications frequency. This time, the Fire Department received no warning about the impending disaster.

Bayville does not have its own police department but is served by the 2nd precinct in Woodbury which has a NYSPIN drop. Woodbury does not pass information to non-police agencies. A "Fire Comm" representative staffs the Nassau County EOC in Mineola and passes information to the Bayville Fire Department. Apparently, the Mineola facility did not pass warning information to the Department.

NORTHERN NEW JERSEY

As stated earlier, the State of New Jersey applies the "home-rule" approach to emergency services. While the State Police has the overall program responsibility, emergency management is essentially run at the municipality level with each local government having the authority to conduct evacuations and to construct its own emergency plans.

Judging from the relatively poor public response in coastal Monmouth County, despite all the strongly-worded warnings and statements from WSFO New York, the flow of information within the county needs to be improved. Monmouth County's emergency manager noted that weather information is normally acquired from Trenton, via the State Police emergency management function. As back-up, a facsimile is transmitted. The manager maintains liaison with WSFO New York and monitors **The Weather Channel.**

From his office, the emergency manager directly contacts the affected municipalities, either by phone or facsimile. He felt that NWS products for this storm were good and used them frequently when relaying information to other people.

CENTRAL AND SOUTHERN NEW JERSEY

The DST found that there were no significant coordination problems despite the fact that the "home-rule" approach to emergency services in New Jersey greatly increases the workload for the staff at WSO Atlantic City simply due to the number of entities involved.

To prevent coordination problems, the WSO staff maintained close and constant contact with the forecasters at WSFO Philadelphia. During the storm, the WSFO's staff had a wide variety of severe and adverse weather occurring across its forecast area. Consequently, it was particularly advantageous for the WSO to focus on the coastal flooding aspects of the storm.

Both NAWAS and NWR were used during the storm. However, it appeared that the primary and preferred method of communication between the WSO and most emergency management and police officials was the facsimile and telephone.

While the "home-rule" approach is cumbersome and in some ways rather inefficient, there are benefits. At least in one case, local officials were riding through the streets with a bull-horn, instructing local residents of high water and safety procedures. This is a service not attainable at higher levels of government. In addition, several individual car dealerships were notified and were able to relocate large numbers of new and used cars, saving them from salt water inundation and resultant great financial loss.

Local emergency management officials stated the need to possess a hard copy of individual warnings, watches, and statements rather than just receiving "the word" by telephone. Hard copy made for more accurate, thorough, and responsive dissemination.

The staff of WSO Atlantic City regularly provided hard copies (via facsimile) of all critical statements, watches, and warnings to many municipalities and specific users. This proved to be quite time consuming and tedious. In fact, during the storm, once the high tide projections were finalized, every county and OEM was notified, a very labor-intensive procedure. We are presently examining semi-automated notification procedures.

The DST did find a problem with the dissemination of coastal flood statements (CFS) and coastal flood warnings (CFW) via AFOS. During the storm, the staff at WSO Atlantic City issued CFSs and CFWs under both the PHLCFSACY and PHLCFSPHL headers. This procedure was initiated during the **Halloween Nor'easter of 1991** when SMCC notified the WSO that there was a problem with the CFS and CFW distribution. The DST found that there was still a problem with the CFS and CFW products issued by the WSO. The PHLCFSACY product, along with several other Eastern Region CFSs, were not in the SMCC data base. Even more importantly, these products were not in the GATEWAY database. As a result, these products could not be distributed to users via vendors such as the Family of Services. This problem has since been rectified.

SECTION VI -- USER RESPONSE

The goal of the NWS's warning preparedness program is to invoke the proper response by people to various weather hazards. The NWS issues warnings to alert the public to the hazards. The public determines what actions to take to properly protect themselves.

An important part of instilling a sense of public urgency regarding weather hazards is through the work of the emergency management community and the media. In order to judge public response, actions taken by emergency management and the media must be examined.

The response by users to both the heavy snow and coastal flood components of this storm appeared to be very effective. There were areas where user response was not commensurate with the seriousness of the evolving situation.

<u>Emergency Management Response</u>
The importance of early notification was underscored by the Deputy Director of FEMA Region I. He received a telephone call from the NWS Southern New England Area Manager on Tuesday, December 8 alerting him that a major weather event was expected. This early notification was crucial to the success of FEMA's role in New England. The Deputy Director was able to retrieve all his disaster relief assessment teams from Florida and Georgia in time for them to handle the New England post-storm assessment.

On Wednesday, December 9, his office received a facsimile message concerning the storm from NWS Eastern Region Headquarters. He, in turn, retransmitted it to his national headquarters where the FEMA Director acknowledged the receipt with a phone call of appreciation. The Deputy Director stated that he was "very happy" with the NWS coordination effort, the accuracy of the weather information, and the improvement of the NWS with each successive storm.

MASSACHUSETTS

Governor Weld declared a state of emergency for selected counties late Friday, December 11 and expanded it Saturday to include the entire state except Franklin, Hampden, and Hampshire counties. About 2200 National Guardsmen were on duty by late Saturday.

It appeared that more local emergency managers may have received NWS statements during this event than previously. For two days, the MEMA Area II coordinator faxed coastal flooding information to the local EOCs. Several emergency managers commented on their value. This improvement was a result of more aggressive efforts undertaken by MEMA's state and area personnel to forward hard copies of NWS statements to local jurisdictions. There had been prior experience with the procedure, since it was the third major weather disaster in the past 16 months to affect the area.

MEMA was pleased with the early notification and subsequent coordination during the storm. An official of the State Highway Department said that "early notification was the key to being prepared for the heavy snow." The EOC coordinator from Scituate, a hard hit coastal location, while commenting on a successful response, stressed the importance of good centralized communications and the early establishment of a disaster relief center. His counterpart from Quincy had the EOC operating by 9:30 am Friday, well before the serious problems started, and he had trained student volunteers answering the phones.

CONNECTICUT

The Connecticut OEM was informed of the storm well in advance, due to good coordination with NWS offices. The director of OEM had a meeting with area coordinators on Thursday, and they notified the local emergency managers responsible for coastal locations. However, it took a report of a large storm surge with high winds at Atlantic City, New Jersey, early Friday to underscore the magnitude of this event for the director. Still, the severity of the coastal flooding was **not** anticipated.

The governor activated the State EOC at noon Friday. The EOC was staffed by representatives of the state response agencies, FEMA Region I, U.S. Coast Guard, the Corps of Engineers, the major utility companies, and the American Red Cross. The State Police and the Departments of Environmental Protection, Consumer Protection, and Health Services were also active participants in the storm response.

An hour prior to the formal activation of the state center, Old Greenwich put their Emergency Operations Plan in effect and coordinated with the public service providers in the area, including the Department of Public Works and the local Red Cross.

Statewide, a total of 28 shelters were opened to evacuees by the Red Cross and local officials as the result of the flooding, the loss of heating systems due to basement flooding, and prolonged power outages. Over 500 persons, including many elderly and individuals with special needs, were sheltered.

The State Department of Transportation had a 100% mobilization of its snow removal forces and support personnel. The National Guard assisted with the evacuation of an estimated 330 people on Friday from Fairfield, Norwalk, and Westport, which had declared a state of emergency. The U. S. Coast Guard assisted with the rescue of at least 36 individuals by helicopter and 11 by boat.

NEW YORK AND NORTHERN NEW JERSEY

Overall, emergency management officials responded very well. They were very much aware that a storm was coming and used watches and warnings issued by WSFO New York as a basis for their agency's actions. They also passed NWS information to local officials. A common response from emergency managers was "I don't know what else they (the NWS) could have done."

While emergency managers adjusted their readiness based on NWS watches and warnings, it must be noted that there were no real actions taken. One emergency manager noted that a Nor'easter does not make them, or the public, "jump." A hurricane, on the other hand, invokes a wide variety of actions, ranging from more in-depth notifications to possible forced evacuations.

Some local communities did not "gear up" at all for possible action. This was largely based on a lack of "official" advance notice from county officials. The Bayville, New York, Fire Department, in a hard hit community, noted they never received any information over their local communication systems. Their only knowledge of an advancing storm was what they heard from the local media.

Officials at the coastal Sea Gate community in New York City also stated they received no official word, thus limiting their initial response. Once the coastal flooding started, they took a very active role, invoking forced evacuations.

In northern New Jersey, one county official expressed concern about the lack of action taken by community officials. He stated that most communities in his county take little action due to poor communication and a lack of trained, emergency management personnel. The state needs to take a more active role in ensuring proper response by community officials.

CENTRAL AND SOUTHERN NEW JERSEY

Emergency managers and police officials were very complimentary of services and information provided by the Atlantic City WSO. They stated that there was an excellent and timely flow of information from the WSO which gave them plenty of lead time to perform their duties.

The emergency managers did uncover one problem. A large Hispanic population resides in the Atlantic City area. An inability to directly communicate with this sector of the population caused several problems during evacuation attempts. Disaster preparedness pamphlets should be produced in Spanish (and English).

Emergency officials stated that the hotels and casinos along the beach front are very reluctant to construct a dune system which would be used for beach preservation. Evidently, clientele prefer to have an ocean view. Existing dune systems that have walk-through paths to the ocean prematurely breach. It would be much more efficient to build walks over the dune system, thereby keeping the dune system intact for the longest possible time. (Another possibility is to build a bulkhead, similar to the one at Ocean City, Maryland, which has gates to allow beach access, but can be closed during storm events.)

Media Response

Media response is a critical part of the NWS's weather information dissemination to the public. The vast majority of people interviewed indicated they depend on the local media for weather forecasts.

MASSACHUSETTS AND CONNECTICUT

The news and electronic media emphasized the coastal flooding aspect of this storm in direct contrast to the **Halloween Storm of 1991**, where it was not given much attention. This contributed to earlier and better preparation.

In Connecticut, a front page article warning of severe coastal flooding was published in the New Haven Register on Friday, December 11. There was a lot of cooperation and coordination between NWS offices and local television meteorologists in New Haven and Hartford. One TV meteorologist in Hartford broadcasted compliments to the NWS about the early notification of the storm.

NEW YORK AND NORTHERN NEW JERSEY

Response by the media was excellent. Most commented that talk of a possible "big storm" began as early as Friday, December 4, one full week before the storm struck. They stated that the NWS watches and warnings were timely and accurate. One radio station meteorologist commented that he thought the NWS forecasts were "relatively bold, yet within bounds."

The New York broadcast media market did a fine job in relaying NWS watches and warnings. The majority of broadcasters (some are meteorologists) commented that they always pass along critical information, even if they do not agree with it.

The Weather Channel also covered the storm quite well. However, the news director from an EBS radio on Long Island pointed out a possible problem with the "Bulletin" message line on NWS warnings. The NWS currently uses two messages:

1. "Bulletin - Immediate Broadcast Requested", and
2. "Bulletin - EBS Activation Requested".

It was felt these two statements are too similar, thus causing the EBS request to be passed over by a quickly-scanning broadcaster. The EBS request needs to be highlighted more.

CENTRAL AND SOUTHERN NEW JERSEY

Officials with a local TV station in the Atlantic City area stated that they felt adequately prepared for the situation. They learned as early as Tuesday night of the possibility of flooding on Friday. Although they did not have a dedicated person on duty over the weekend, they frequently interrupted programming to keep their audience advised of the situation.

The early releases on this storm, accompanied by historical comparisons with earlier severe storms allowed the Philadelphia media to cover the storm directly from shore areas the day before Friday's devastating high tides. This coverage on Thursday further facilitated the overall excellent user response. On a negative note, the Philadelphia media left shore areas by late Friday when it became apparent that Friday evening's high tides and those following were not going to be quite as high as those experienced Friday morning.

The media, emergency management officials, and police authorities stated that the service rendered by the Atlantic City staff was very good. The recordings, phone calls, and live interviews were greatly appreciated and highly valued.

Public Response

MASSACHUSETTS AND CONNECTICUT

Along the Massachusetts coast, user response to coastal flood watches and warnings was markedly better than for the October 1991 Northeaster. The October 1991 storm probably sensitized the coastal population to the need to be more vigilant for such storms and be more respectful of their life and property threatening potential. While surveying the north shore of Massachusetts, the DST found that people were generally pleased with the forecasts, despite sustaining damage to seawalls and having their homes flooded.

The user response in Connecticut was **not** as satisfactory, in spite of the notification of significant flooding. The last coastal flood of a similar magnitude occurred nearly 40 years ago, so there was not a storm of recent memory with which to compare.

The heavy snowfall over interior southern New England certainly taxed public works departments but did not come as a surprise. The decision by WSFO Boston forecasters to issue a winter storm watch and follow through with warnings for late Friday night and Saturday for much of eastern Massachusetts may have made the difference between an effective and ineffective response by snow removal outfits in Boston's northern and western suburbs.

In the Lordship section of Stratford, Connecticut, at least one user did not take a sensible course of action. According to the OIC of WSO Bridgeport, a rescue was performed on a section of the flooded roadway around the airport perimeter. A woman drove her car around a roadblock where it stalled in the water. She got out but was swept by the current into the airport fence. She clung to the fence and had to be rescued by the fire department, which was staffing a nearby roadblock.

Along Shoreline Drive in Lordship, many houses on the beach side were severely damaged by the high water and wave action. The survey team met residents who rode out the storm. One man, who had lived at this location all his life, said he knew it was time to leave his house when he saw his neighbor's house collapse. He then put on his life vest and swam in neck deep water to another neighbor's house further inland.

On the landward side of Shoreline Drive, a long-time resident couple watched the raging sea surround their house to a depth of several feet. They were aware of an approaching storm from the media reports, including information on **The Weather Channel**. However, they had little idea of the severity of the storm and how bad it would be for them. They lost power before the water reached their house, and they watched a beachside house get swept off its foundation but still had no intention of evacuating.

Further inland on Third Street, a woman said that the basement of her home was severely flooded and everything was damaged, but she was satisfied with the accuracy of the weather information she received. She was keenly aware of the storm and followed its progress with media reports (including **The Weather Channel**) because the area floods during minor coastal flooding events. When the fire department came by to encourage evacuations, she left.

NEW YORK AND NORTHERN NEW JERSEY

The DST found that the public in many instances did **not** respond adequately to the NWS' strongly-worded warnings. In most cases, they waited until threatened, assessed the danger, and then made a decision, in essence, took a "wait and see" posture.

Another problem noted earlier by an emergency manager, and mentioned previously in this report, was that the public does not usually take advance precautions for a Nor'easter. A hurricane, with a name, demands attention. A Nor'easter, with no name or identity, usually does not. This type of attitude unfortunately still prevailed despite the fact that the previous big Nor'easter occurred just a little over a year prior to this storm, in October 1991.

The New York WSFO made many comparisons to the 1991 storm in their statements. In numerous instances, this got the public's attention. A woman from Mastic Beach who was interviewed said she kept her children home from school Friday, December 11. Her decision was based on forecasts she heard stating that the storm would be as bad, if not worse than the 1991 storm. A fisherman from the same area said that he pulled his boat out of the water and "headed inland" for the same reason.

However, the "historical comparison" meant little for some communities. Bayville, on the north shore of Long Island experienced little damage from the 1991 storm. Thus residents, upon hearing the comparison, thought conditions from this storm would be the same, when in fact the **Great Nor'easter of December 1992** turned out to have a far greater impact on the New York City metropolitan area then did the **Halloween Nor'easter of 1991**.

Quite a few people interviewed along the coast commented they knew about NWR. However, they indicated that it is <u>not</u> their main source of weather information. They noted two inherent problems with NWR. One was the warning alarm tone that would "go off in the middle of the night for something not affecting me." The other being poor reception and unreliability during storms.

CENTRAL AND SOUTHERN NEW JERSEY

All persons interviewed by the DST along the beach front commented that they felt adequately warned and informed. As stated previously, the Atlantic City staff made comparisons with the **Halloween Nor'easter of 1991** and the **January 4th Storm of 1992** in their statements. These were storms that many people remembered well. The WSO's statements also reflected the gravity of the situation through using strong language to describe damage and severity of flooding.

As mentioned earlier, for a number of years, the WSO has referenced forecast tide levels with respect to "mean low water" (MLW), in addition to "above normal" departure values. Consequently, the central and southern New Jersey coastal and back bay user communities have another frame of reference (MLW) when they receive NWS coastal flood products. A forecast of "9 ft above MLW" sets off a number of "bells and whistles" in users minds and prompts the desired user response.

Typifying the public's excellent response to this storm was action taken by local car dealers in moving their new and used cars out of "harms way" on Thursday afternoon, prior to the damaging high tides early Friday morning. This action resulted from timely warnings by the WSO, which made their way to the end user, in this particular case, the car dealerships. For these users, the system worked exceedingly well, thereby sparing them from big losses.

APPENDIX A - SCIENTIFIC ANALYSIS OF EVENT

1. Synoptic Overview

a. Surface Analyses

Twelve-hourly surface analyses are presented in Figures 1 and 2 depicting the evolution of surface weather features immediately prior to and during the storm. In Figure 1, the eastern United States was under the influence of a building anticyclone on 9 December that drifted slowly eastward across southern Canada on 10 December, immediately north of the Great Lakes and New York. The anticyclone then became nearly stationary north of Maine by 12 Universal Time Coordinated (UTC) 10 December. (To convert UTC to Eastern Standard Time (EST), subtract five hours.) This anticyclone was associated with moderately cold air across the northeastern states that supplied cold air for the snowfall that occurred later.

A complex low pressure system over Texas at 12 UTC 9 December moved northeast during the following 48 hours and consolidated into one low pressure center over the Midwest United States by 12 UTC 10 December. A separate low pressure system crossed the Gulf Coast States to be located over southeastern Georgia by 12 UTC 10 December. This southern low pressure system intensified rapidly over the next 24 hours and was associated with the high winds, heavy rain, and snowfall that marked this event.

In the 24-hour period following 12 UTC 10 December, the East Coast storm moved from Georgia to southeastern Virginia by 00 UTC 11 December and then to the Chesapeake Bay by 12 UTC 11 December. During this period, the central pressure of the cyclone dropped about 24 millibars (mb) to 985 mb. As the cyclone moved northeastward and intensified, the precipitation continued to advance to the northeast, reaching eastern New York and northern New Jersey late on 10 December. Snow changed to rain across Virginia and Maryland (except in the western mountains) and rain spread northward across eastern Pennsylvania and into Delaware and New Jersey, where 2 to 3 inches (in) of liquid precipitation were common, with isolated amounts up to 6 in. Precipitation remained as snow across much of West Virginia and central and western Pennsylvania and snow spread into central and western New York.

The surface high progressed to a position near Anticosti Island off the coast of Quebec and remained virtually stationary after 00 UTC 11 December, with its central pressure remaining near 1035 mb. The combination of the intensifying cyclone and the decreasing distance between the cyclone and anticyclone centers resulted in a significant increase in the pressure gradient between the two. Commensurately, surface wind speeds increased along the Middle Atlantic Coast. Gale- to storm-force winds spread northward from Virginia and Maryland to New Jersey and southeastern New York, where wind gusts commonly approached and occasionally exceeded hurricane force, especially along the New Jersey-New York shores on 11 December.

Six-hourly mesoscale surface analyses (Fig. 3) illustrate the movement of the surface low pressure system and accompanying pressure gradient during the period of very strong winds along the coastline from eastern Virginia to southern Maine. Winds at New York City's LaGuardia Airport remained above 45 mph for much of 11 December with occasional gusts near or exceeding hurricane force. Offshore winds were higher, as demonstrated by a peak hourly gust of 93 mph at Ambrose Light at 16 UTC, just south of New York City.

Between 12 UTC 11 December and 12 UTC 12 December, the surface low pressure center near the Chesapeake Bay weakened slowly as the storm began to redevelop to the east over the Atlantic Ocean. The heaviest snow had fallen across portions of West Virginia, the mountains of western Maryland and Virginia, and across much of western Pennsylvania, where amounts in excess of 1 to 2 ft were measured, with some locations in western Maryland and southwestern Pennsylvania reporting 3 ft or more. While heavy snow began to taper off across western Pennsylvania on 11 December, snowfall intensities increased across elevated portions of northern New Jersey, southeastern New York, Connecticut, Rhode Island, and Massachusetts.

The strong winds over the large onshore fetch continued to produce damaging surf from New Jersey northward to Maine through 12 December. Heavy snow and high winds affected much of interior Massachusetts during the night of 11-12 December, with many interior areas receiving in excess of 1 to 2 ft of snow, while heavy rain continued near the coast. Total precipitation amounts approached 8 in over southeast Massachusetts, with snowfall totals approaching 4 ft in some mountainous locations of interior Massachusetts. Rain began to change to snow in coastal locations from eastern Massachusetts to northern New Jersey, and these regions then experienced a blustery, snowy day on 12 December. By the evening of 12 December, the complex low pressure system continued to drift slowly east into the Atlantic and most of the remaining precipitation began to diminish and eventually end.

b. Upper-Air Analyses

A twelve-hourly sequence of upper-air charts, including the 500 and 300 mb levels, are presented in Figures 4 through 7 to complement the preceding surface analyses.

On 9 December, the surface anticyclone centered north of the Great Lakes was associated with an upper-level ridge that extended roughly from a position near the Gulf Coast to the Great Lakes. The ridge moved slowly east as indicated on both the 500- and 300-mb charts (Figs. 4 and 5). A confluent northwesterly flow dominated the region east of the ridge axis and was associated with a 300-mb wind maximum, or jet streak, above the Middle Atlantic Coast.

The surface low over Texas was associated with a short-wave trough moving east across that state. A jet streak with maximum winds exceeding 110 mph was located to the south of the trough axis by 12 UTC 9 December (Fig. 5a). To the rear of the short-wave trough, a band of strong upper-level winds was entering the West Coast in a diffluent upper-level flow regime across the western United States (Fig. 5a).

As the surface anticyclone progressed to a position north of New England and became stationary, the upper-level ridge moved to the East Coast but did not progress much further east. The slow eastward progression of the ridge axis occurred in association with an amplifying short wave trough east of the trough axis, as indicated by a 500-mb vorticity maximum and intensifying 300-mb jet streak. This trough propagated southeastward off the New England coast on 10 December and amplified into a slow-moving upper-level cutoff cyclone (not shown). The amplification of this feature prohibited the eastward translation of the upper ridge and associated surface anticyclone.

As the main surface cyclone began to move eastward along the Gulf Coast toward the Atlantic Seaboard, the short-wave trough over the Southern Plains began to lift northeastward toward the Ohio Valley. However, a region of cyclonic vorticity advection remained south of the center and propagated across the Southeast United States in association with the surface low pressure system, which had not yet begun to intensify.

Meanwhile, the diffluent jet flow across the Western United States moved inland and propagated southeastward toward the Central Plains. Upper-level heights rose significantly to the rear of the jet maximum, in conjunction with a developing upper-level ridge. As the ridge amplified across the western states, a new trough began to amplify, upwind of the pre-existing trough that was lifting northeastward from Texas to Ohio (see the 500 mb chart at 12 UTC 10 December in Fig. 4). The developing surface low over Illinois appeared to be the surface reflection of this amplification and was located in the left exit region of the jet streak centered over Nebraska (Fig. 5). As this upper trough continued to amplify and approached the East Coast following 12 UTC 10 December, the surface low began to intensify markedly as it moved northeastward along the Atlantic Coast. By 00 UTC 11 December, an amplifying 500-mb vorticity maximum was analyzed over Georgia and maximum 300-mb winds appeared to be reaching the base of the trough.

By the morning of 11 December, the upper-level charts (Figs. 6 and 7) showed that the East Coast storm was now associated with a highly amplified, negatively-tilted trough with a closed center over eastern Virginia at both 500 and 300 mb. The region of high wind speeds at the surface over the New Jersey and New York coasts was found to the north of the 500-mb vorticity maximum, which had swung northward from a position over Georgia at 00 UTC to a position east of the Virginia coast at 12 UTC. The area of high wind speeds was also located beneath a region of pronounced upper-level diffluence and large cyclonic vorticity advection.

By 00 UTC 12 December, the closed low had moved little and was centered near the Chesapeake Bay, directly above the primary surface cyclone. The vertical stacking of the surface and upper-level centers and rising pressures at the surface low pressure center were indications that the cyclone had occluded and ceased to intensify. The 500-mb vorticity maximum located east of the Virginia coast earlier had now rotated about the low center to a position north of the center, near southern New Jersey, and maximum winds at 300 mb progressed to the east of the upper low.

By the morning of 12 December, the 500-mb low had drifted slowly southeastward to a position east of the Virginia-North Carolina border. Several vorticity maxima were observed at 500 mb. One center just south of New England appeared to be associated with the continuing snowfall and rain that occurred across southern New England into northern New Jersey on 12 December. By 00 UTC 13 December, the closed low had begun to exit the Northeast Coast. This trend continued into the day on 13 December, as precipitation finally ended across the Northeast.

c. Precipitation and Snowfall

Daily precipitation amounts from the period 9-13 December are shown in Fig. 8. Total snowfall is shown in Fig. 9.

The daily precipitation charts show 24-hour precipitation amounts in inches ending each day at 12 UTC. By 12 UTC 10 December, precipitation had spread into the Middle Atlantic States, where most amounts were less than .5 in, except for slightly greater totals over West Virginia.

By the morning of 11 December, two areas of heavy precipitation were noted, with an area of greater than 2 in covering the coastal areas of Virginia, Maryland, Delaware, and much of central and southern New Jersey. Most of this precipitation occurred in the form of rain. Further west, 2 to greater than 3 in of precipitation fell from western Virginia into the panhandles of Maryland and West Virginia and on into southwestern Pennsylvania. Much of this precipitation fell in the form of snow.

By the morning of 12 December, the area of heaviest precipitation during the previous 24 hours shifted to the northeast, with amounts exceeding 2 in from northern New Jersey to eastern Massachusetts. Amounts exceeding 3 in were common across Rhode Island and eastern Massachusetts, and some locales measured up to 5 in of precipitation. Much of the heaviest precipitation fell as rain, but the interior sections of northern New Jersey through Massachusetts received snow.

The 24-hour precipitation totals ending at 12 UTC 13 December show .5 in totals from northern New Jersey to eastern Massachusetts, with 1 to 2 in totals common across eastern Massachusetts, much of which fell in the form of snow or as rain changing to snow.

d. Satellite Imagery

Twenty-four hour sequences of infrared satellite imagery during the period 9-12 December are shown in Figs. 10 and 11 to highlight the evolution of the cloud structure during the storm.

2. NMC Forecasts

The current operational numerical models at NMC, including the Medium-Range Forecast Model (MRF) and the Nested Grid Model (NGM), performed well in predicting the storm. There was some inconsistency in the medium-range forecasts by the MRF, with some of the earlier forecasts outperforming forecasts that were made closer to the event. The shorter-range forecasts by the NGM provided excellent guidance in forecasting the severity of the storm, especially with regard to predictions of high winds and heavy snow in the Appalachians, although the severity of the snowstorm across New England was somewhat minimized. Marine forecasts issued at NMC emphasized that gale-force winds would be a major problem with this storm as early as 9 December, with forecast winds of 40 kt or more. By 04 UTC 11 December, the High Seas Forecasts began issuing statements on the "dangerous" storm with forecast winds of 60 kt.

a. Medium-Range Forecasts

The 5-, 4-, 3-, 2-, and 1-day MRF forecasts of sea-level pressure verifying at 0000 UTC 11 December 1992 are shown in Fig. 12 to illustrate the performance of the medium-range model. The verifying analysis in Fig. 12a shows the surface cyclone over northeastern North Carolina (the actual position was closer to Richmond, VA) at the midpoint of the 24-hour period during which the cyclone was intensifying rapidly. Note that the 120-hour, or 5-day, forecast made at 0000 UTC 6 December (Fig. 12f) provided excellent guidance, indicating that a relatively intense cyclone would be located across southeastern Virginia. Furthermore, the forecast location and intensity of the surface anticyclone was close to that observed, and a strong pressure gradient was forecast from the Middle Atlantic Coast to southern New England. The manual 5-day surface forecast (Fig. 13) made on 6 December was consistent with model forecasts, indicating the potential for a major cyclone along the Middle Atlantic Coast on 11 December.

The intervening forecasts showed a poorer forecast of the cyclone at day 4 (hour 96), with an elongated low pressure system from the Great Lakes to the Southeast Coast. This forecast was slower in predicting the storm than the other simulations, but ultimately, this model simulation did produce a major cyclone along the East Coast, albeit a day too late.

Note that the forecast of the surface anticyclone north of New England appeared to be uniformly consistent from one simulation to the next. The day 3 (72-hour) and day 2 (48-hour) forecasts both predicted a dual-cyclone system, with one center over the Ohio Valley and the other over the Middle Atlantic Coast. However, the 24-hour forecast converged on the actual observation showing one primary cyclone center near the Middle Atlantic Coast. All forecasts indicated the potential for high winds from Maryland to Massachusetts. In addition, the 5400 m 1000-500 mb geopotential thickness contour, a common parameter used to estimate the rain/snow line, was consistently forecast to extend from the Appalachian Mountains to southern New England (not shown), alerting forecasters to the possibility of a major storm accompanied by high wind and heavy snow as much as 5 days in advance.

b. Short-Range Forecasts

The NGM provided very consistent short-range forecasts of the cyclone development. To illustrate, the NGM 48-, 36-, 24-, and 12-hour forecasts of sea-level pressure and the 1000-500 mb geopotential thickness fields verifying at 1200 UTC 11 December are compared to the actual analysis (Fig. 15). The four separate forecasts all indicated a major cyclone, with the earlier forecasts slightly too deep and slightly too far to the west over Virginia. The consistent forecasts of the surface anticyclone north of Maine, the strong pressure gradient north of the cyclone center, and the 1000-500 mb thickness field provided consistent guidance for forecasts of high winds along the coastline and the likelihood of snow inland.

1) Precipitation Forecasts

The NGM precipitation forecasts suggested that excessive rain and snow would accompany the storm. The 36- and 48-hour forecasts of precipitation generated by the NGM and initialized at 1200 UTC 9, 10, and 11 December (Fig. 14), provided forecasts of 24-hour precipitation amounts verifying at 1200 UTC 11, 12, and 13 December. An examination of these model forecasts with observed precipitation amounts (Fig. 8) shows that the model provided a reasonable forecast of the areas of maximum precipitation, although it slightly underforecast the excessive amounts from western Virginia to western Pennsylvania on 11 December (Fig. 14a,b). The precipitation forecast for 12 December (Fig. 14c,d) correctly forecast the maximum amounts across southeastern New England, although they were again underestimated. There was also a secondary maximum across Maryland and northern Virginia which was indicated by the NGM. The precipitation forecast for 13 December (Fig. 14e,f) was not as accurate as earlier forecasts, and heavy precipitation amounts over eastern New England were not predicted. As a result of the underprediction and uncertainties about surface temperatures, heavy snowfall across southern New England was underestimated by many local forecasters.

A comparison of the three operational model forecasts for precipitation for the 12-36 hour periods on 10-13 December, including the NGM, the Limited Fine Mesh Model (LFM), and the Aviation Run of the Medium-Range Forecast Model (AVN), with the

NMC manual forecast and observations is shown in Fig. 16. The three models are fairly consistent with each other, except on 10 December, when the models predicted too much precipitation and too far to the north, especially the LFM. The forecasts for 11 December through 13 December were all similar but underestimated precipitation in eastern New England.

2) Heavy Snow Forecasts

Manual heavy snow predictions made at NMC for 12-hour periods between 10 and 13 December (Fig. 17) were forecasting that 12-hourly snowfall amounts in excess of 8 in during the course of the storm along the Appalachian Mountains, through eastern West Virginia, western Virginia, central and northeastern Pennsylvania, and west-central New England. Comparing the forecast with the snowfall analysis shown in Fig. 9, it appears that heavy snowfall was correctly forecast along the Appalachians from western Virginia to Pennsylvania but was not forecast well from western Pennsylvania to Massachusetts.

3. Coastal Observations

As can be seen in Fig. 3, the area of maximum pressure gradient, and therefore maximum winds, advanced northward along the coast despite the surface low making little northward progress after 10 December.

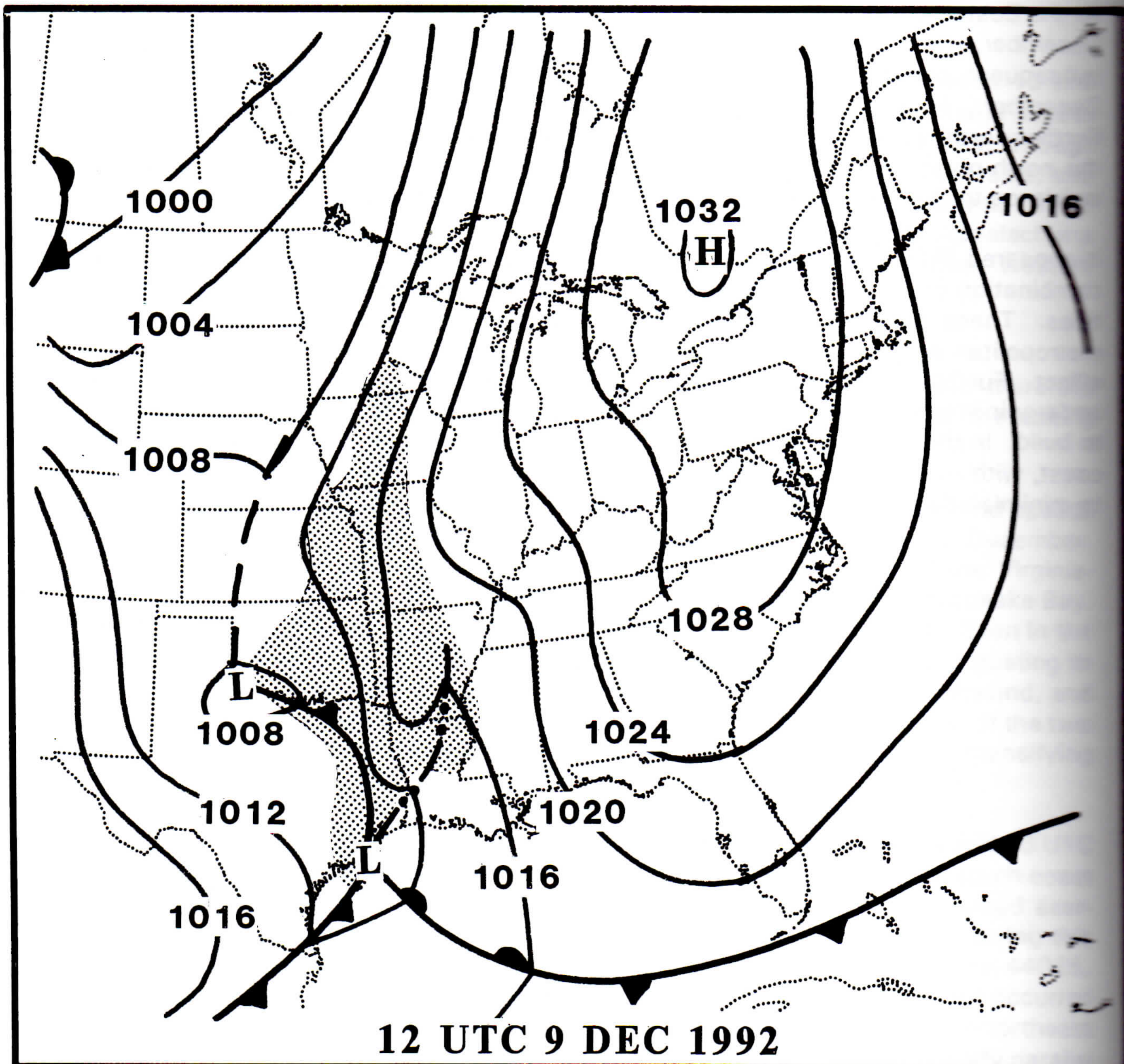
As the low moved through North Carolina into Virginia and deepened, wind speeds reached a maximum in the Middle Atlantic States around 00 UTC 11 December. During this period of time, the winds at buoy 44014, located east of the Virginia-North Carolina border, and at Chesapeake Light, near the mouth of Chesapeake Bay, were from the southeast in excess of 39 kt with gusts to around 49 kt. Even in the more protected waters of the upper Chesapeake Bay, east winds of 33 kt gusting to near 43 kt were recorded around this time. Tides along the Virginia, Maryland, and Delaware Coasts were approaching high tide. However, this was the lower of the two high tides during the semidiurnal cycle, and the storm was in the midst of intensifying rapidly.

The most intense winds measured during the storm occurred between 14 and 16 UTC 11 December. The area of strongest winds had shifted northward to the south coast of New England, including the New York City metropolitan area. Sustained east-northeast winds from 43 to 50 kt with gusts near 58 kt were recorded during this period as far east as Buzzards Bay Light, just south of Cape Cod, to buoy 44025, south of Long Island. The strongest winds recorded during the entire event occurred at Ambrose Light (ALSN6; Fig. 18), just south of New York Harbor, as east-northeast winds of 68 kt gusting to 79 kt were observed at 16 UTC. Winds were nearly parallel to much of the south coast of New England; however, Long Island Sound, as it narrows from east to west, produces a funnelling effect for both wind and water coming from an easterly direction. Further west, these winds came directly onshore for northern New Jersey. High tide occurred for much of this region, including Long

Island Sound, during or near this period of very strong winds. This was not only the higher of the two high tides for the day, but it was also the highest tide during the month.

During this time, the winds were increasing along the eastern New England Coast. At the Boston Large Navigational Buoy, the wind reached a maximum at 09 UTC 12 December, when they were northeast at 45 kt gusting to 56 kt. There were several subsequent peaks observed at 14 and 21 UTC 12 December and 01 UTC 13 December. However, none of these peaks occurred near the time of high tide. Further north, at Isle of Shoals off the New Hampshire Coast, the winds were from the north-northeast when they reached a maximum, resulting in a smaller angle of incidence to the coastline in addition to occurring near low tide.

It appeared likely that much of the initial damage to the coastline was due to the combination of large wind-generated waves created by the onshore fetch and high tides. These two factors came together most dramatically in the New York City metropolitan area, possibly enhanced in the Long Island Sound due to a funnelling effect. Further south, winds reached a peak during high tide just as the storm was undergoing rapid intensification. Large wave action may not have had the opportunity to build. In the New York/New Jersey area, winds were more parallel to much of the coast, with the strongest winds occurring near low tide. Both of these factors helped to minimize damage relative to other areas.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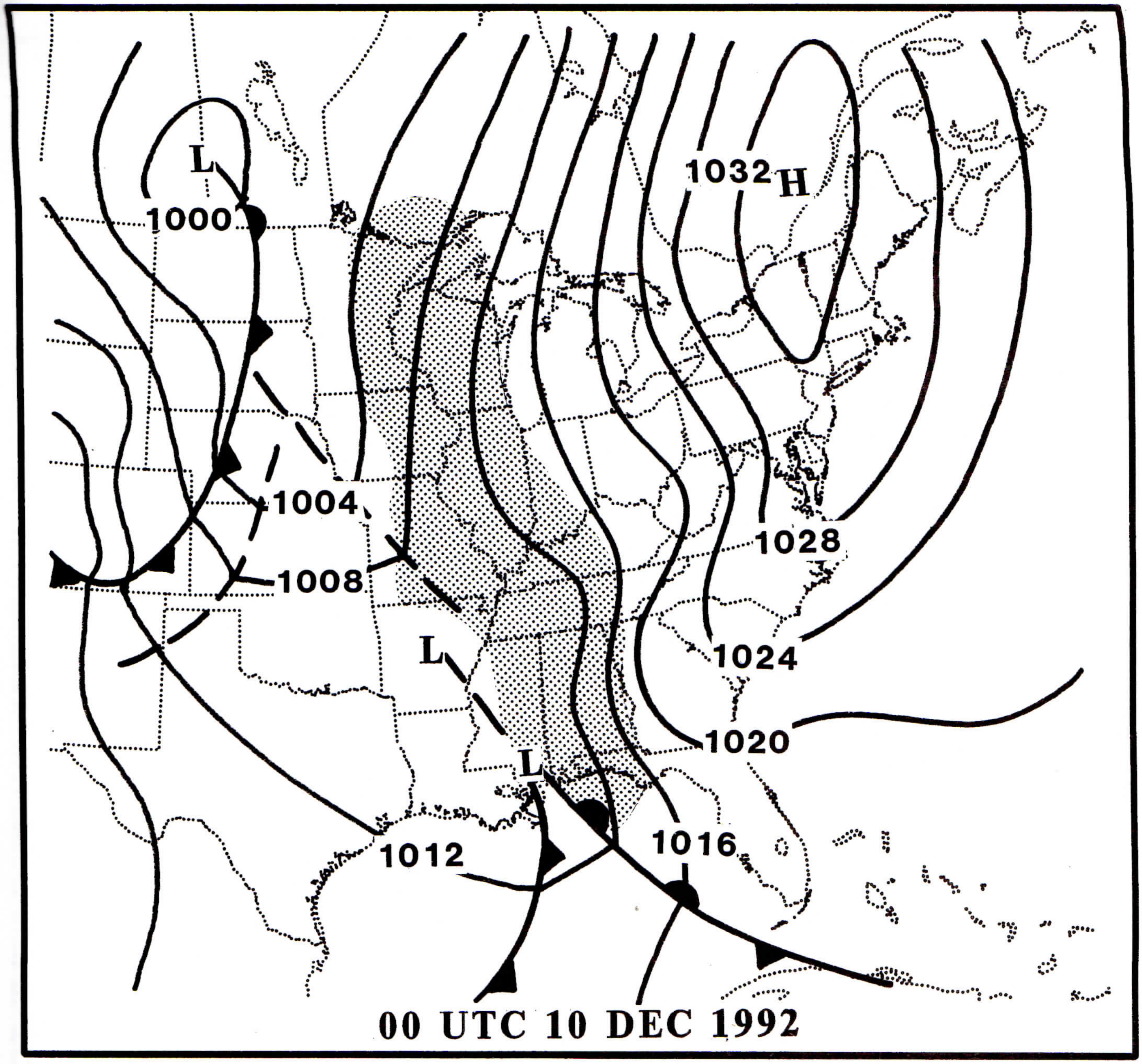
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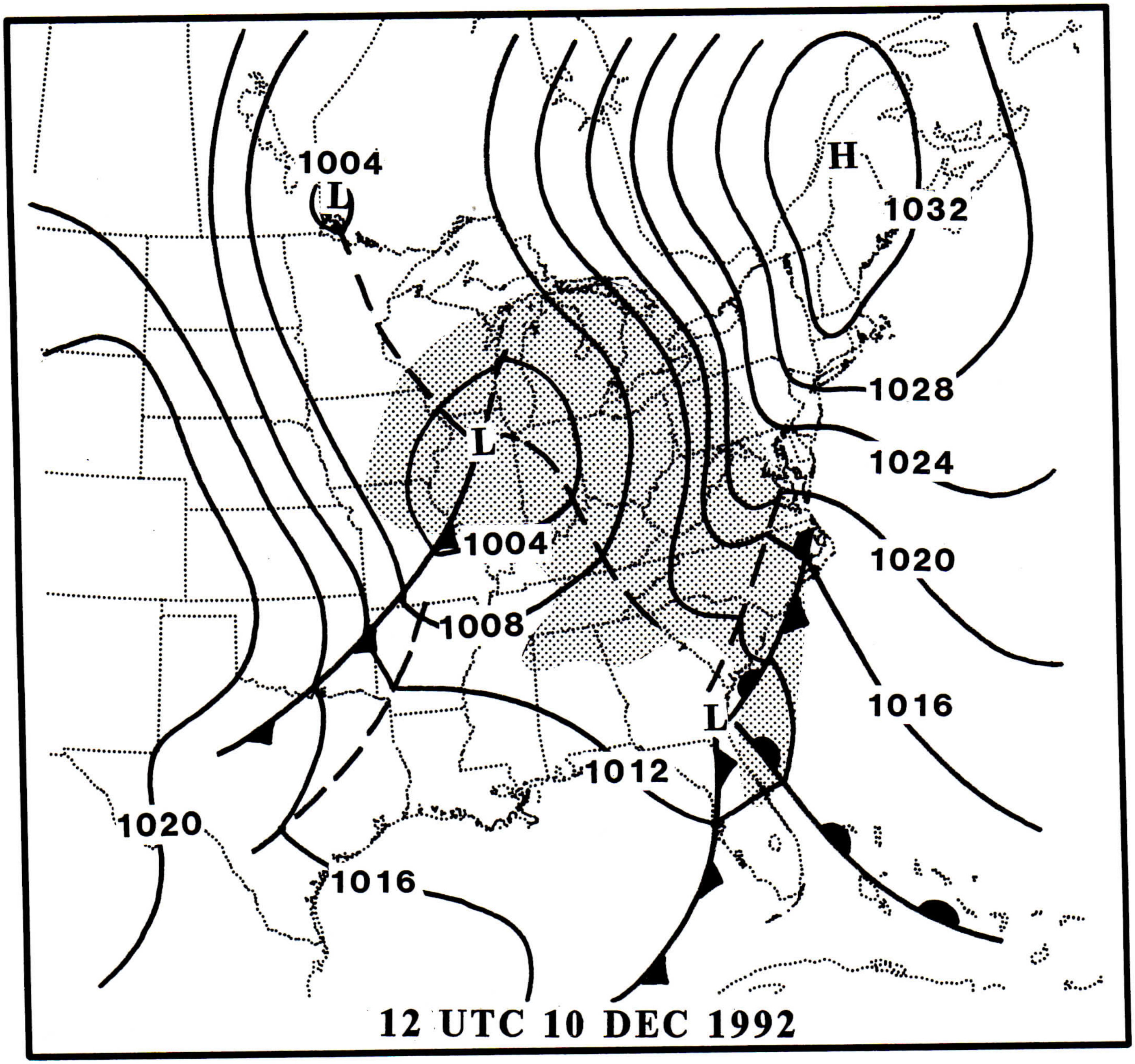
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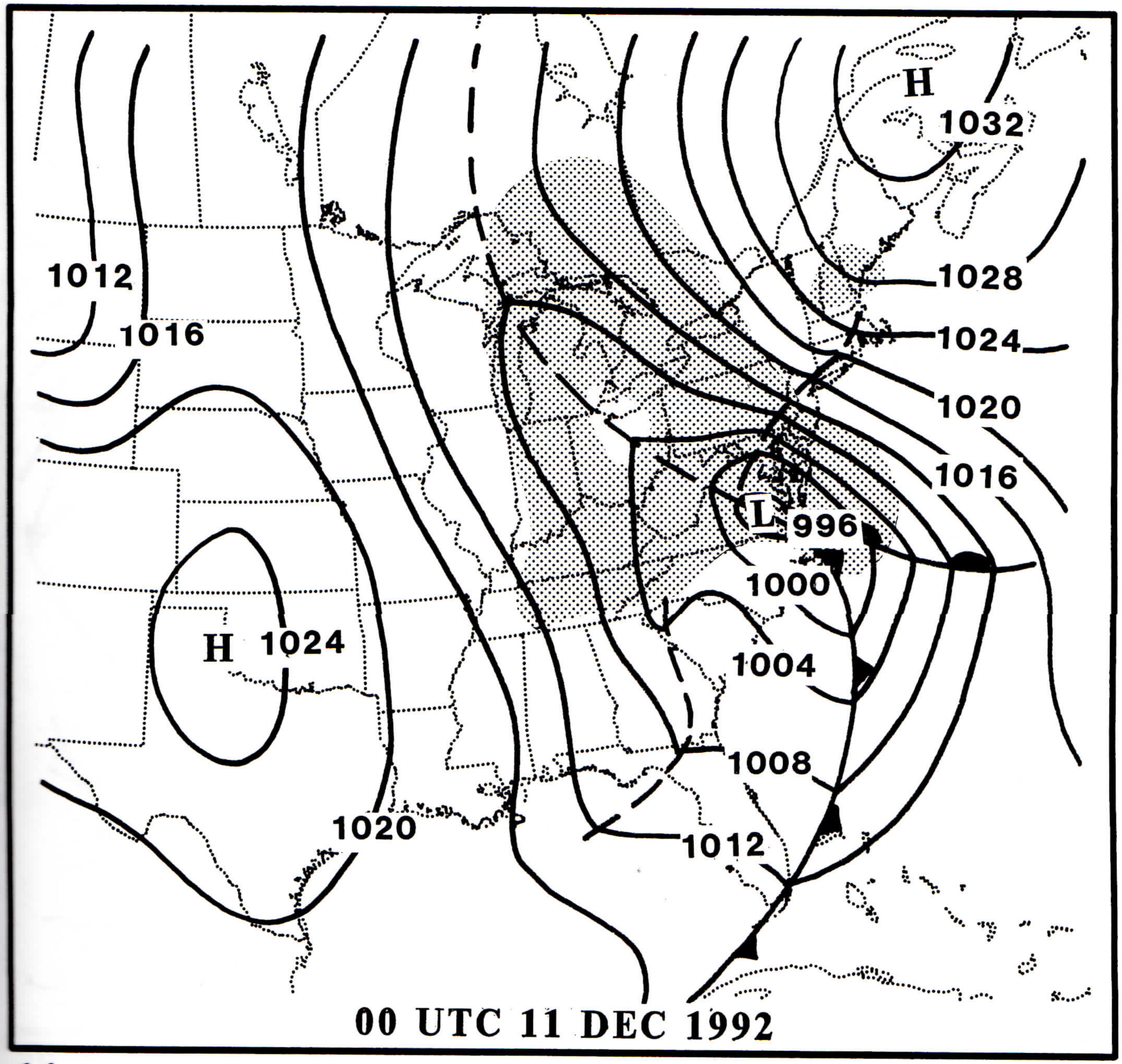
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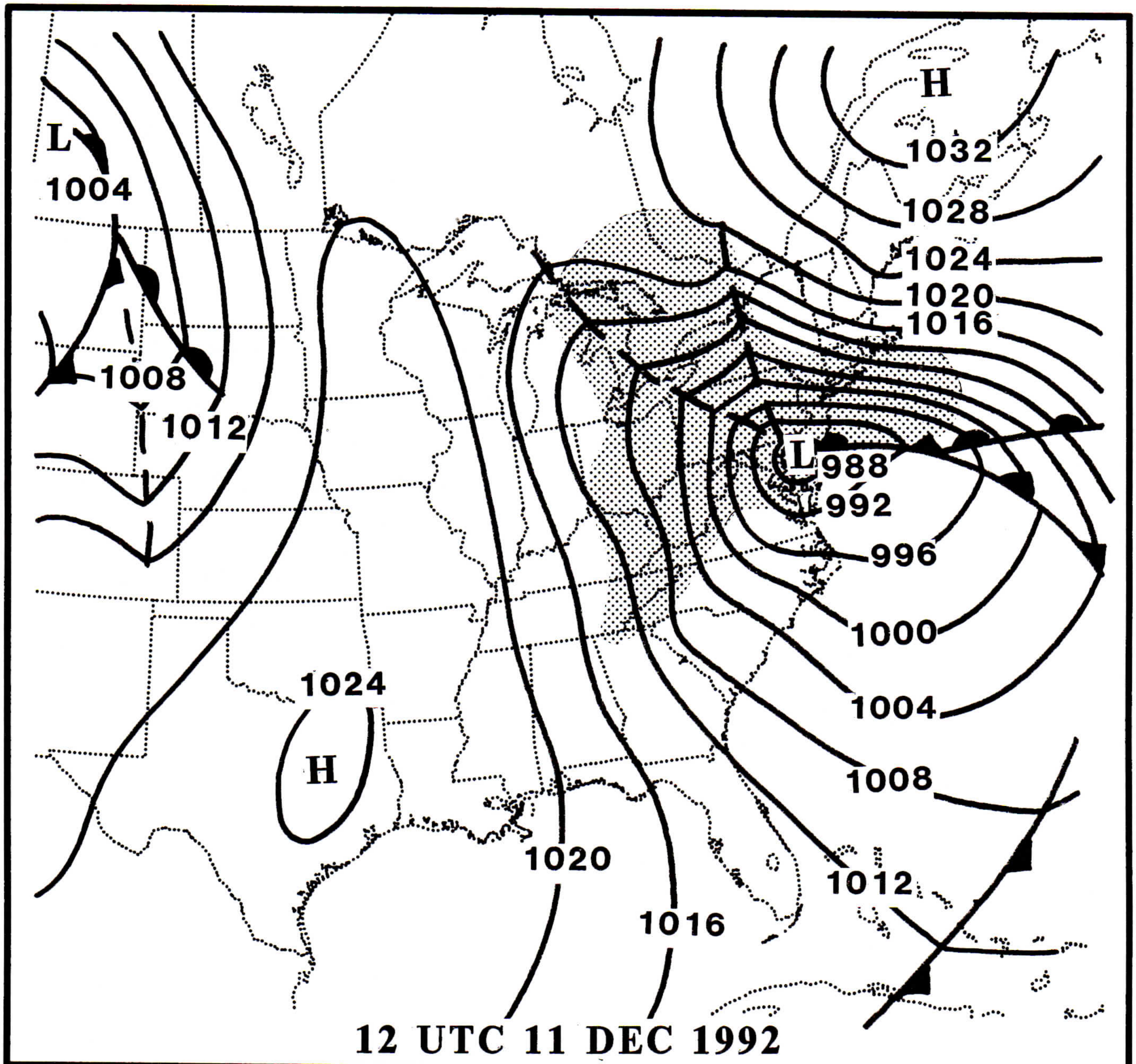

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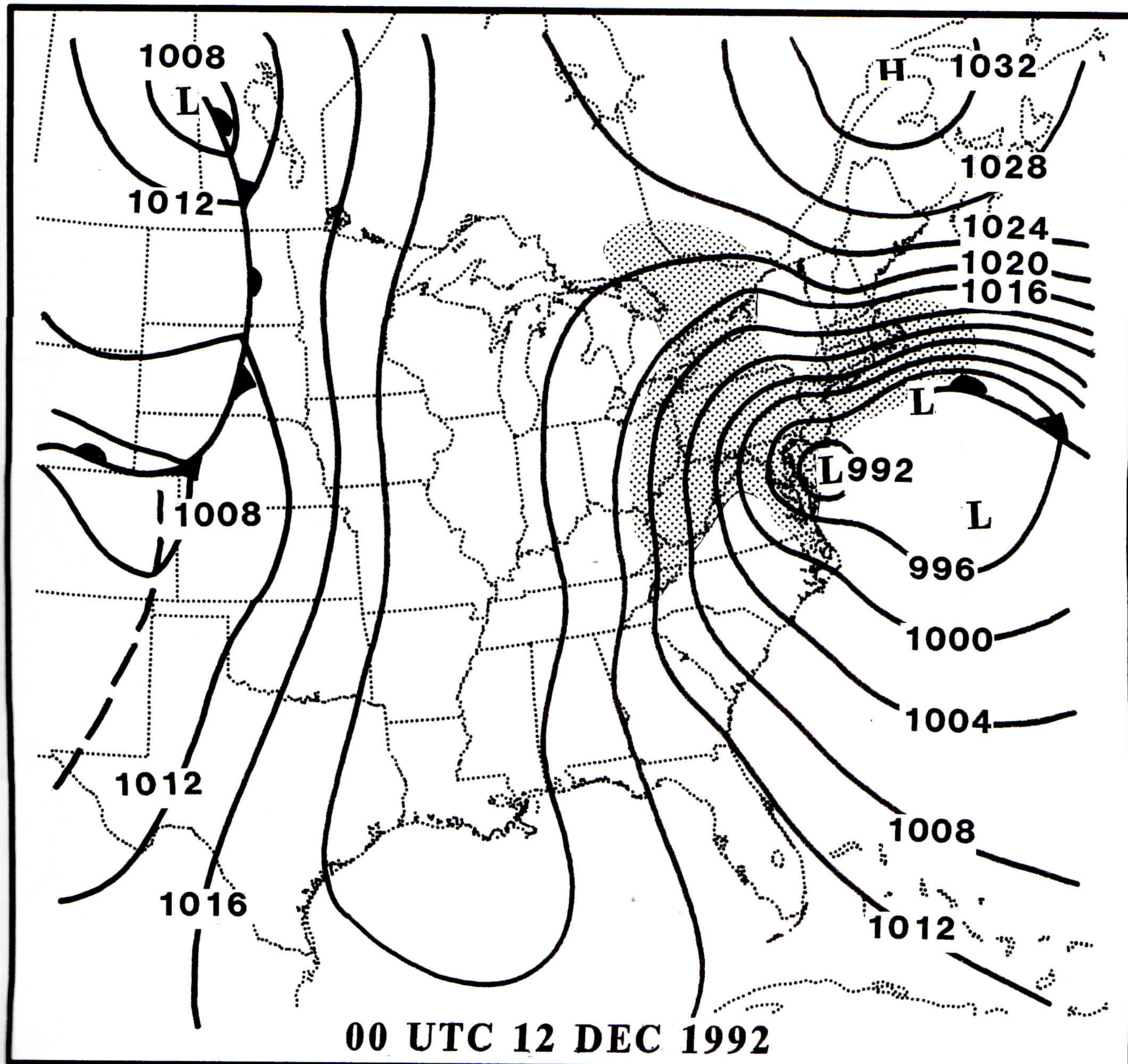

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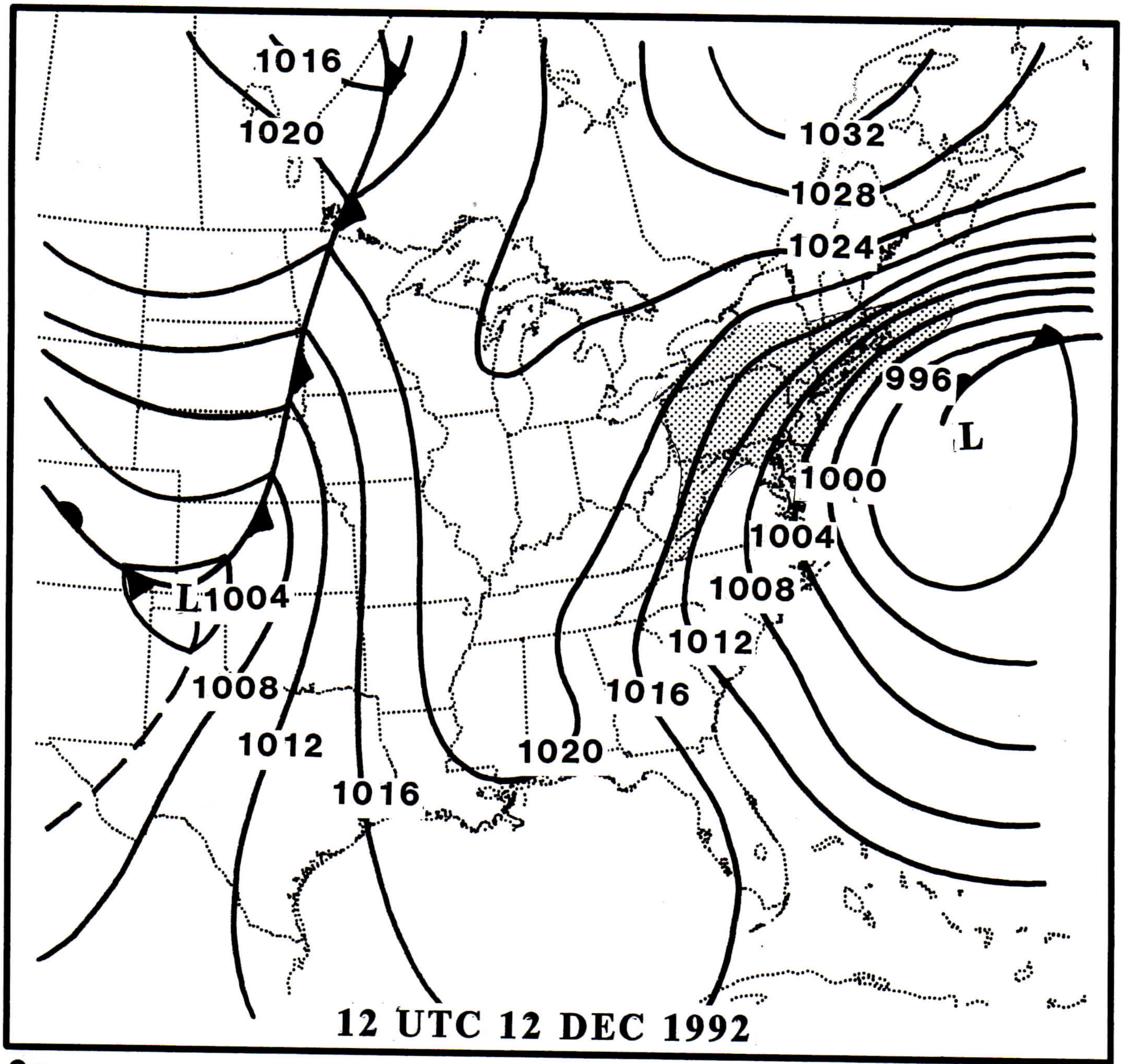

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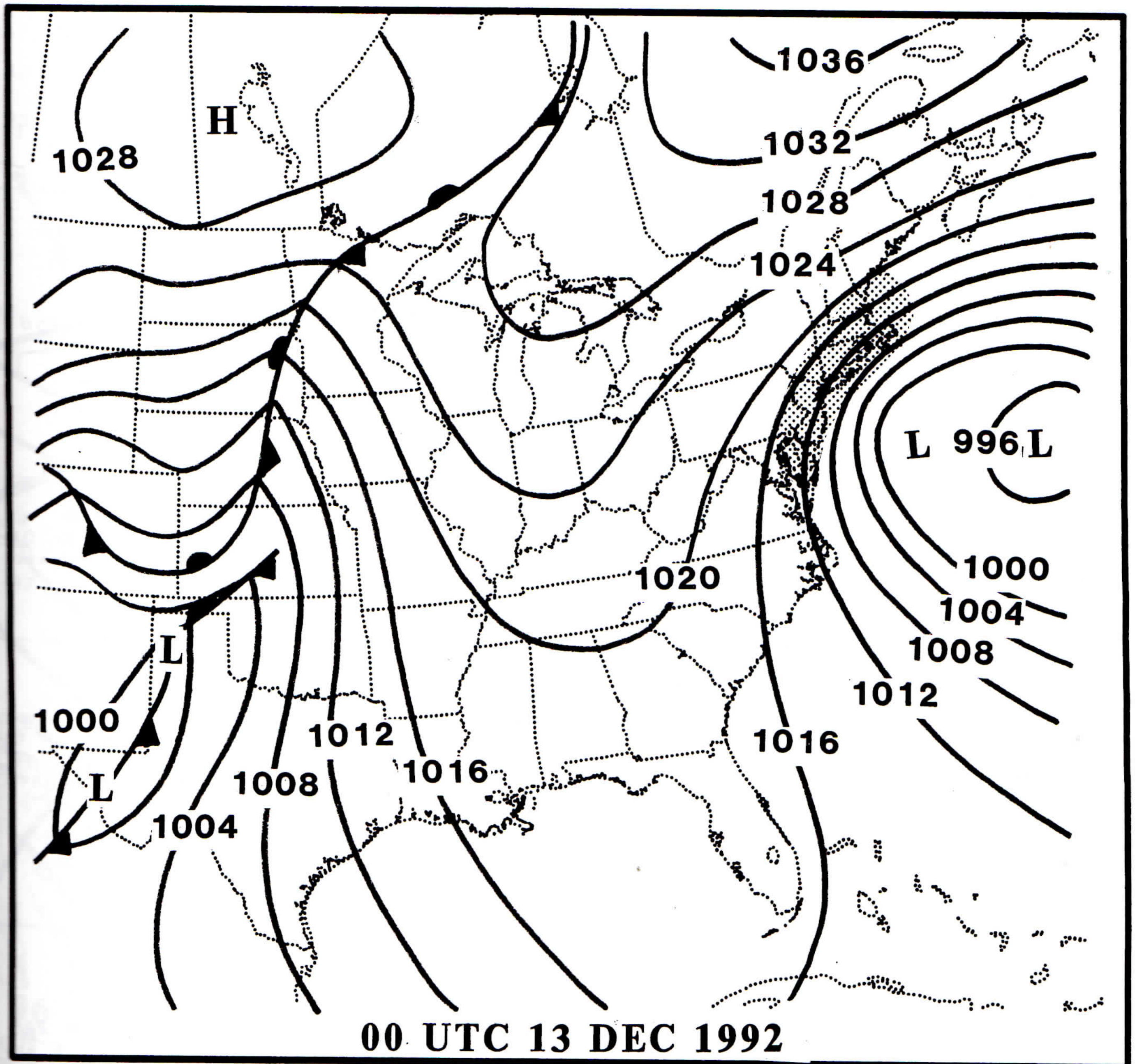
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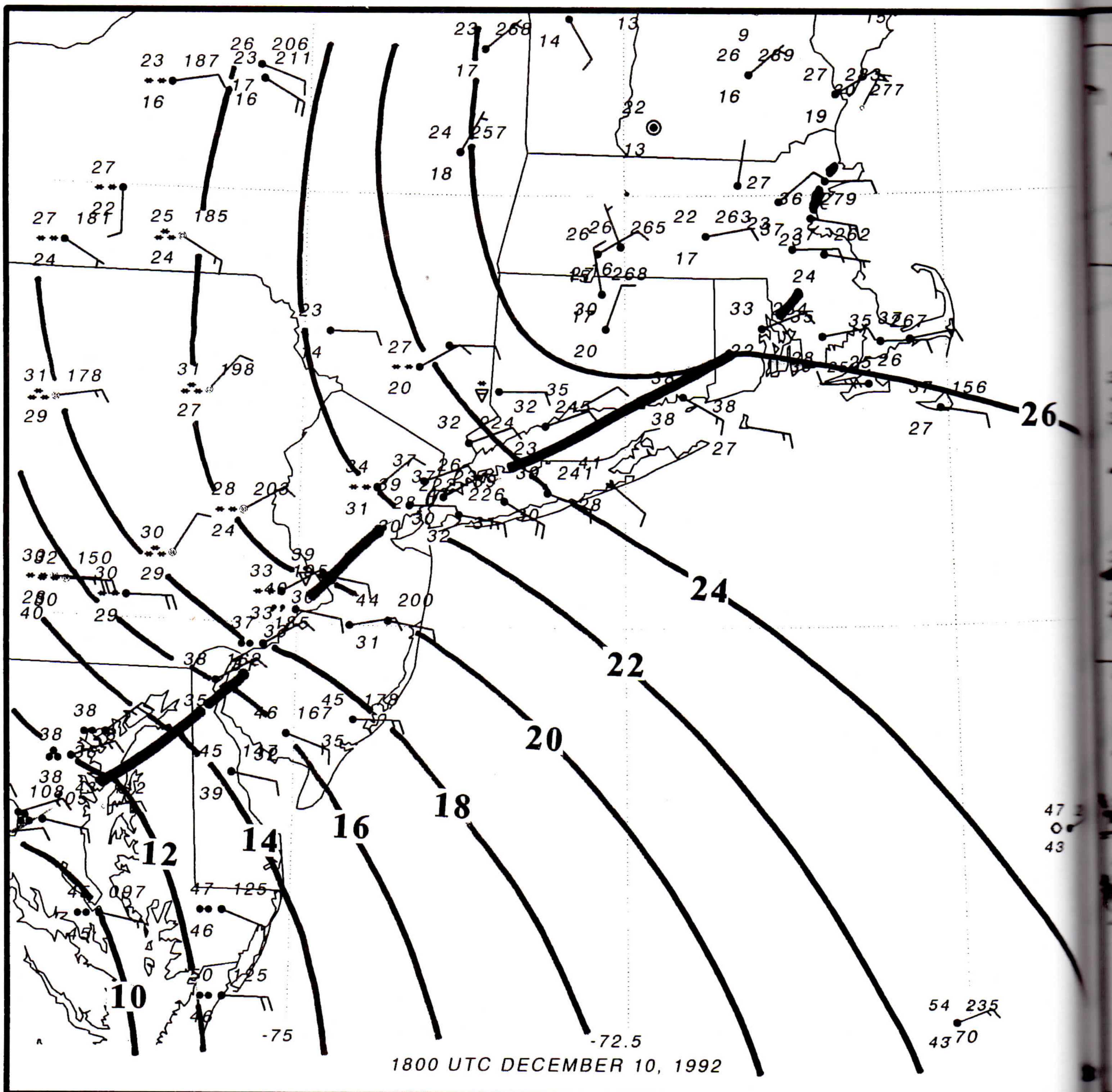

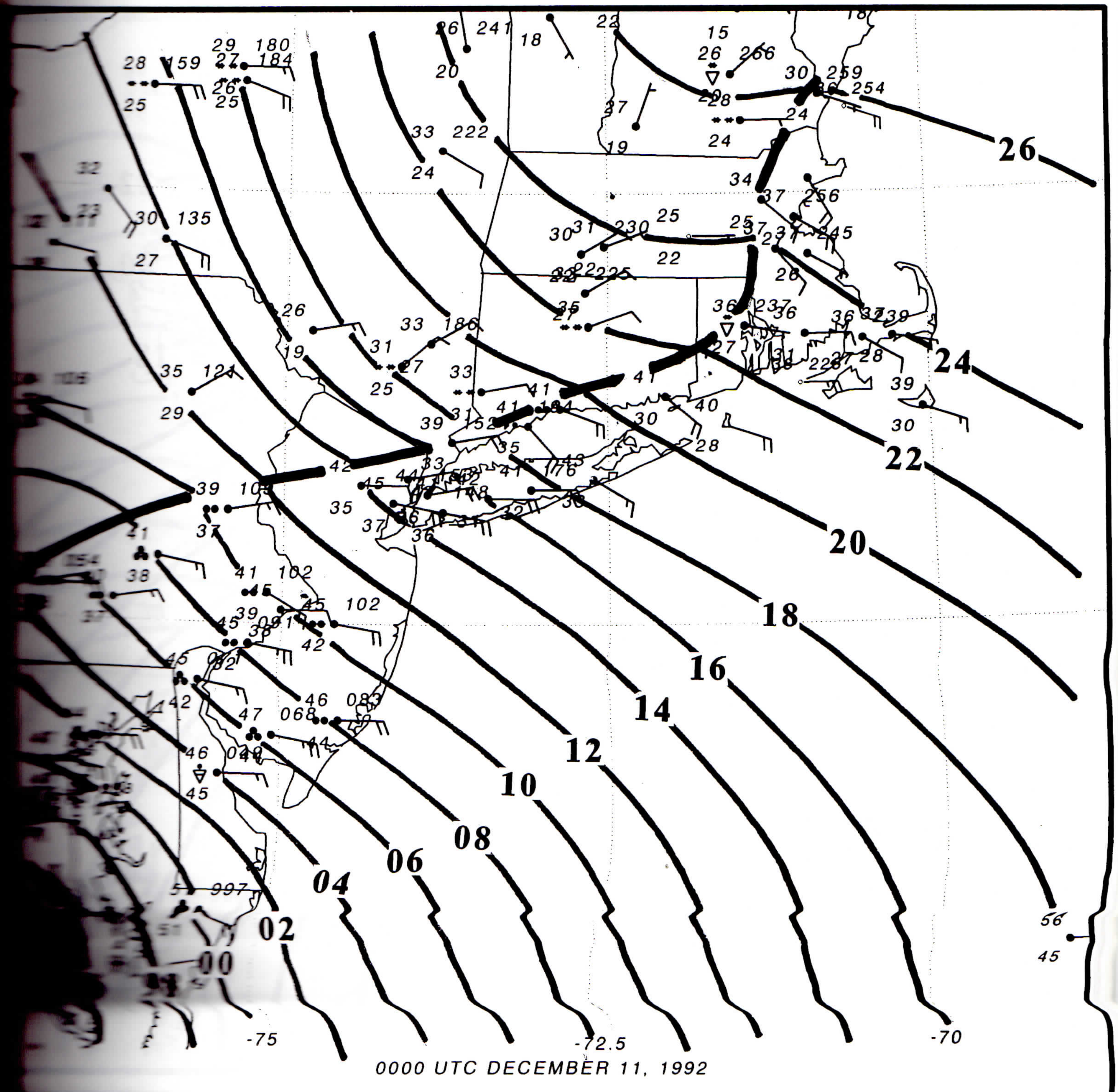

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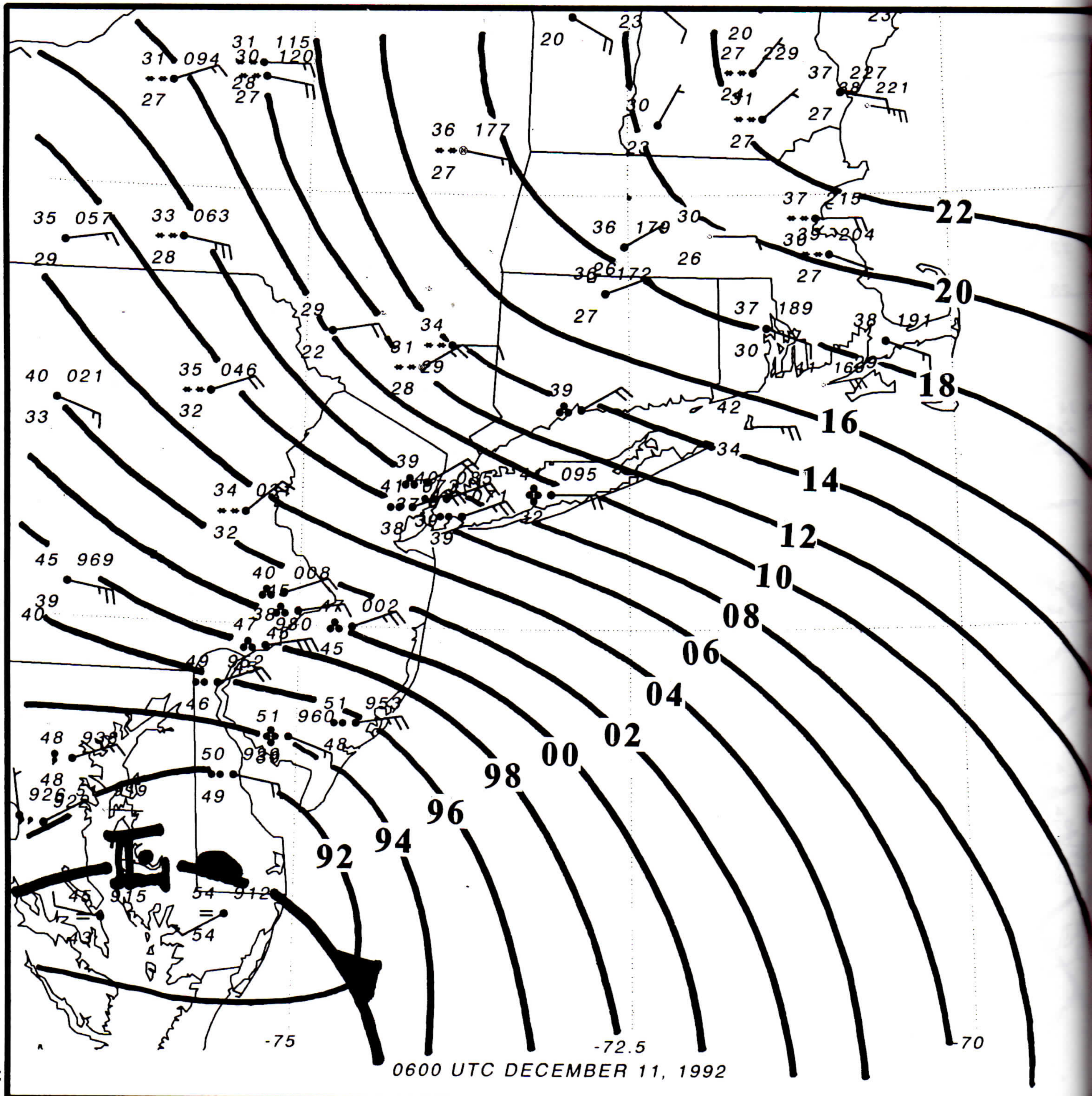
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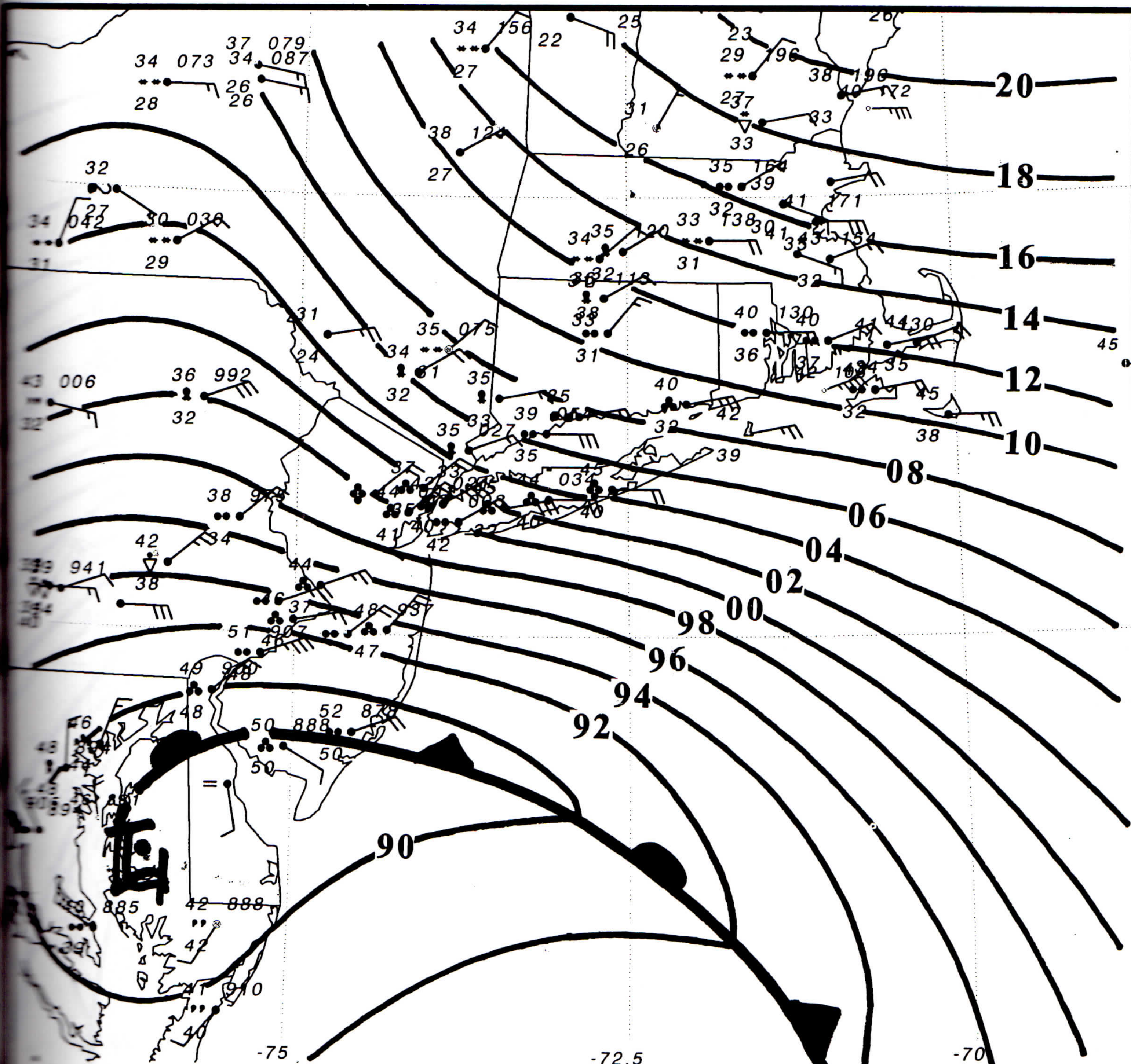

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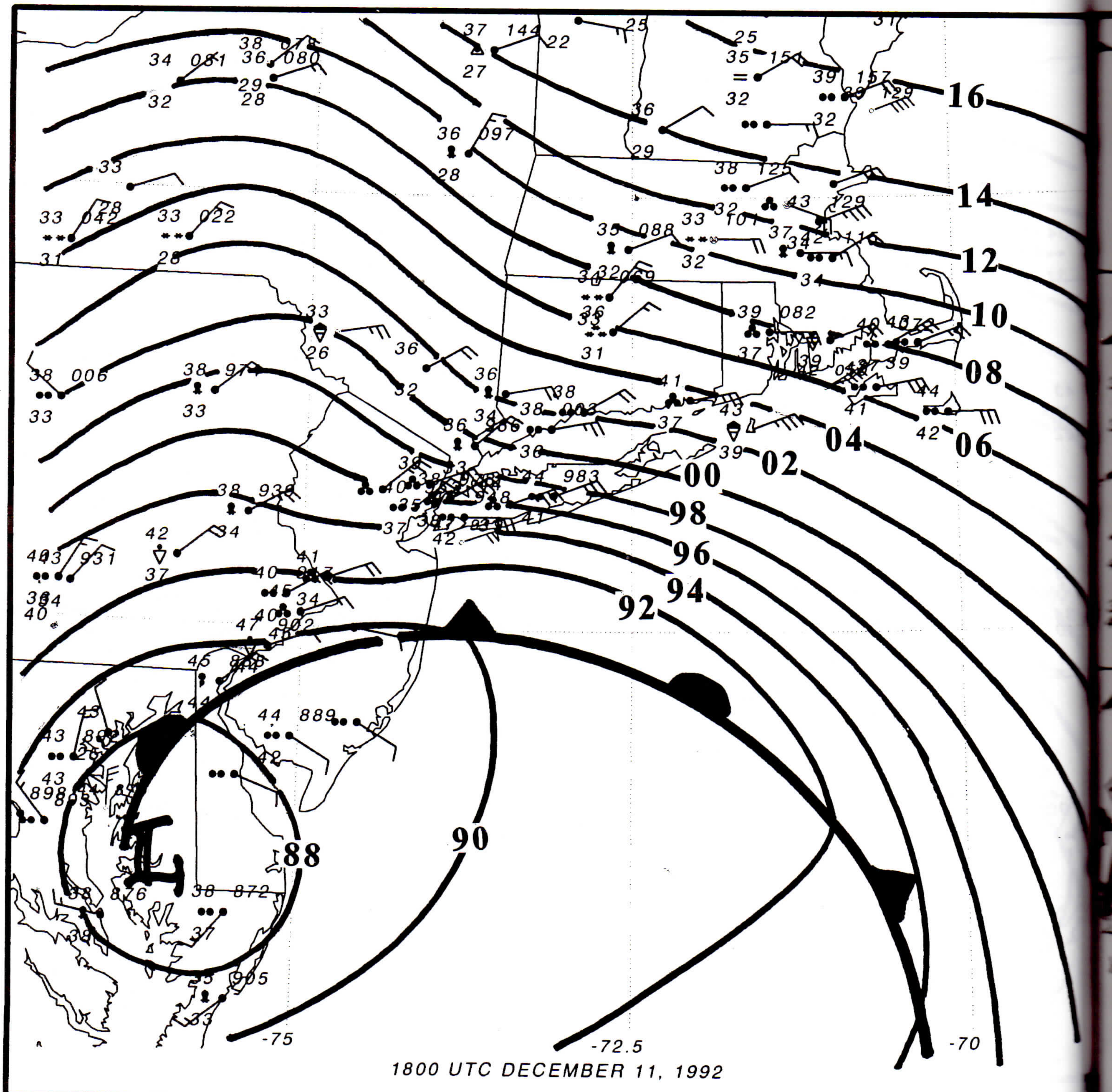

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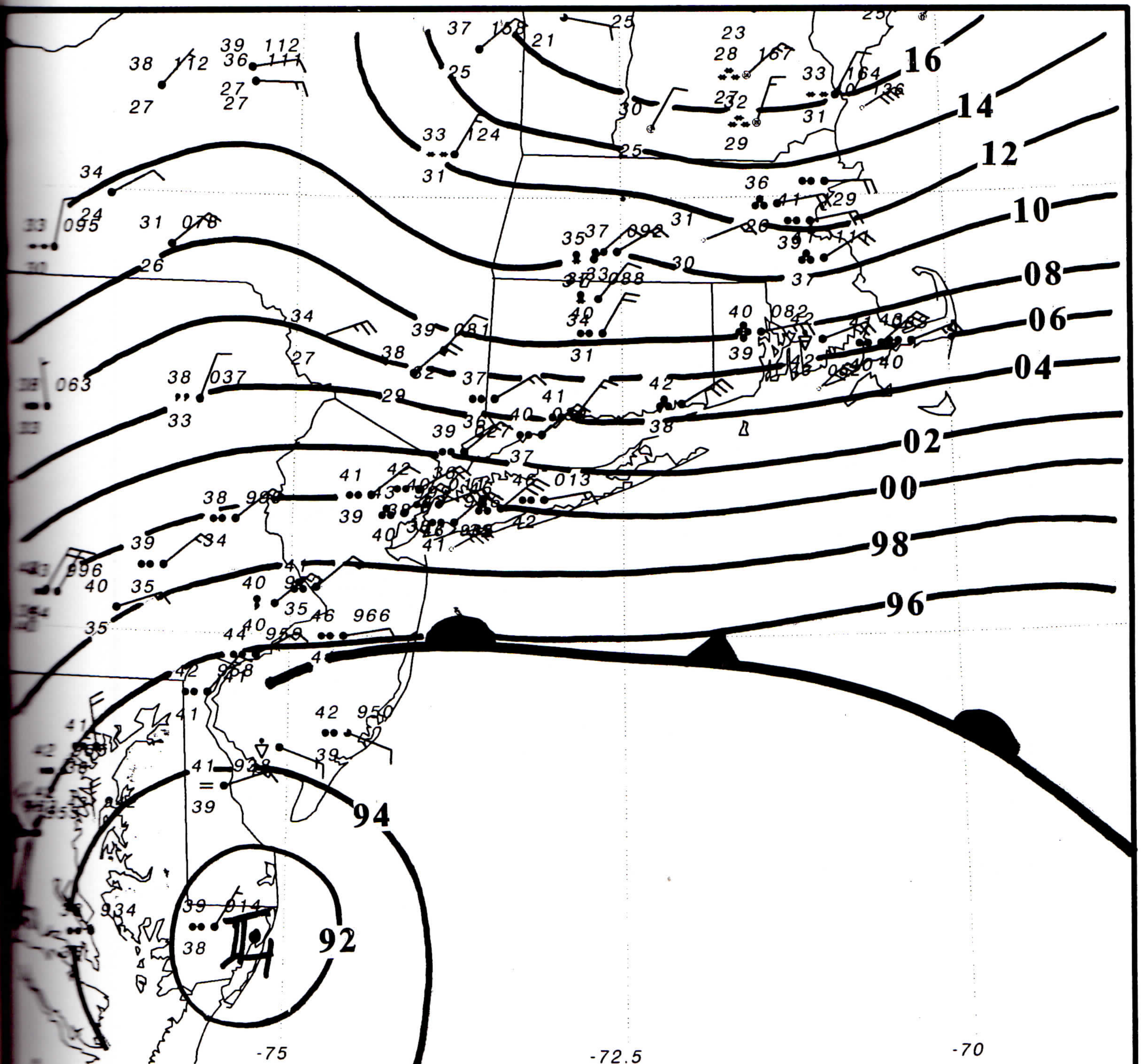

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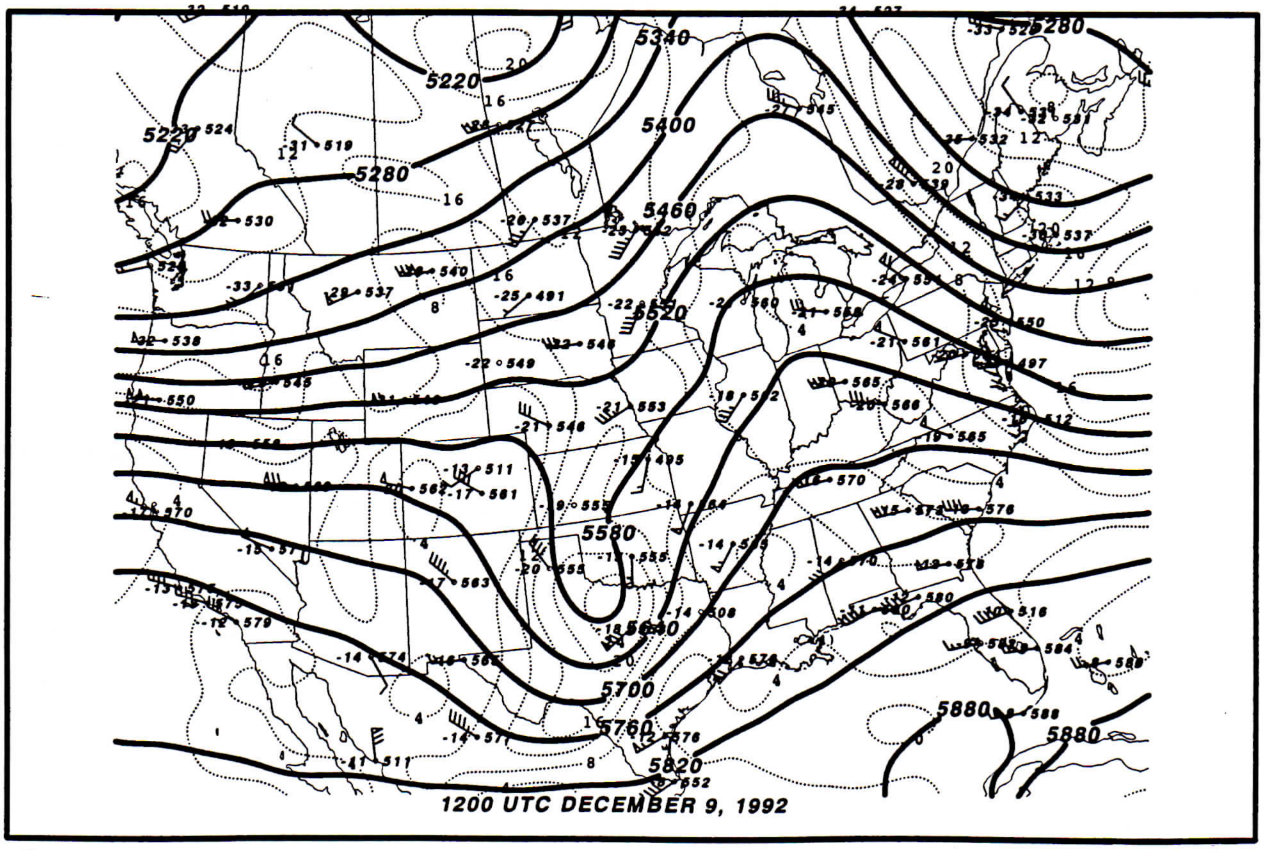

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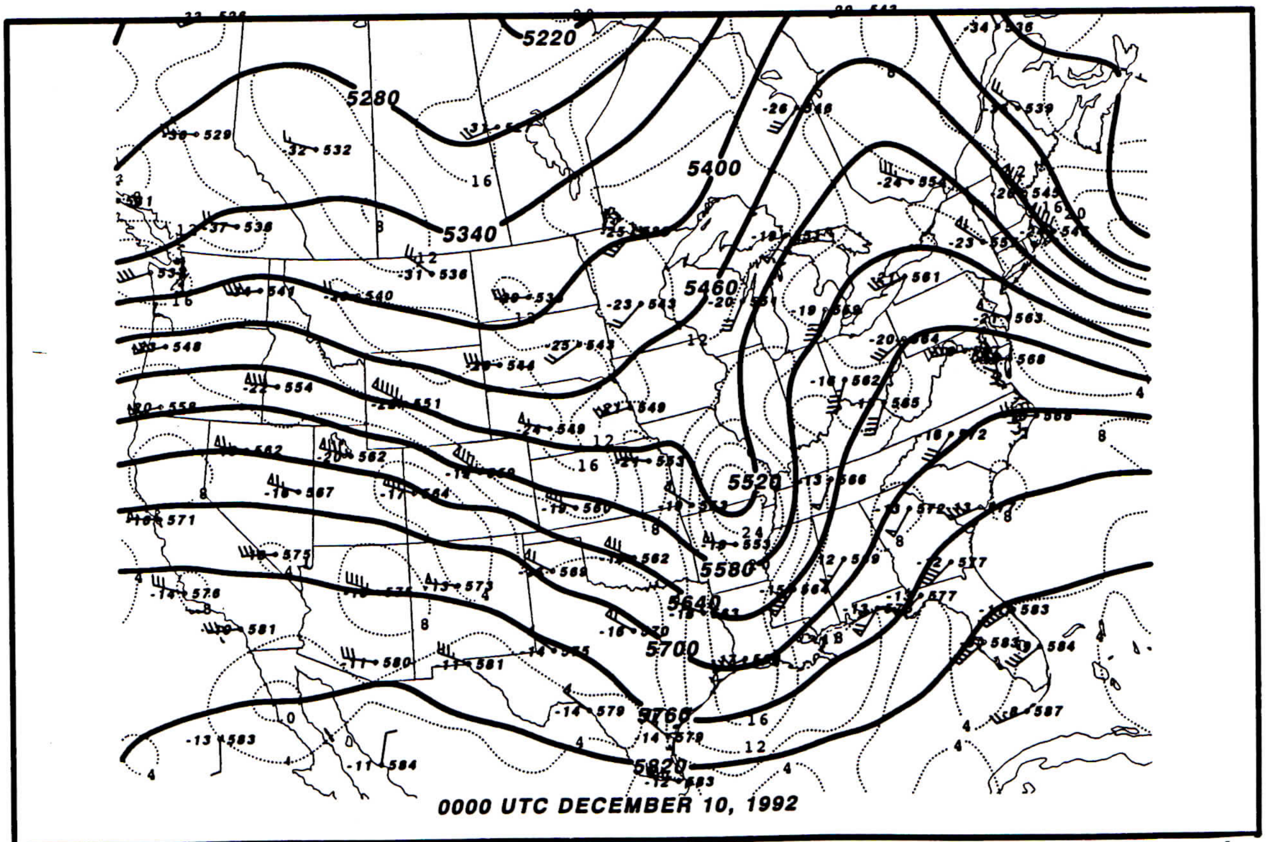
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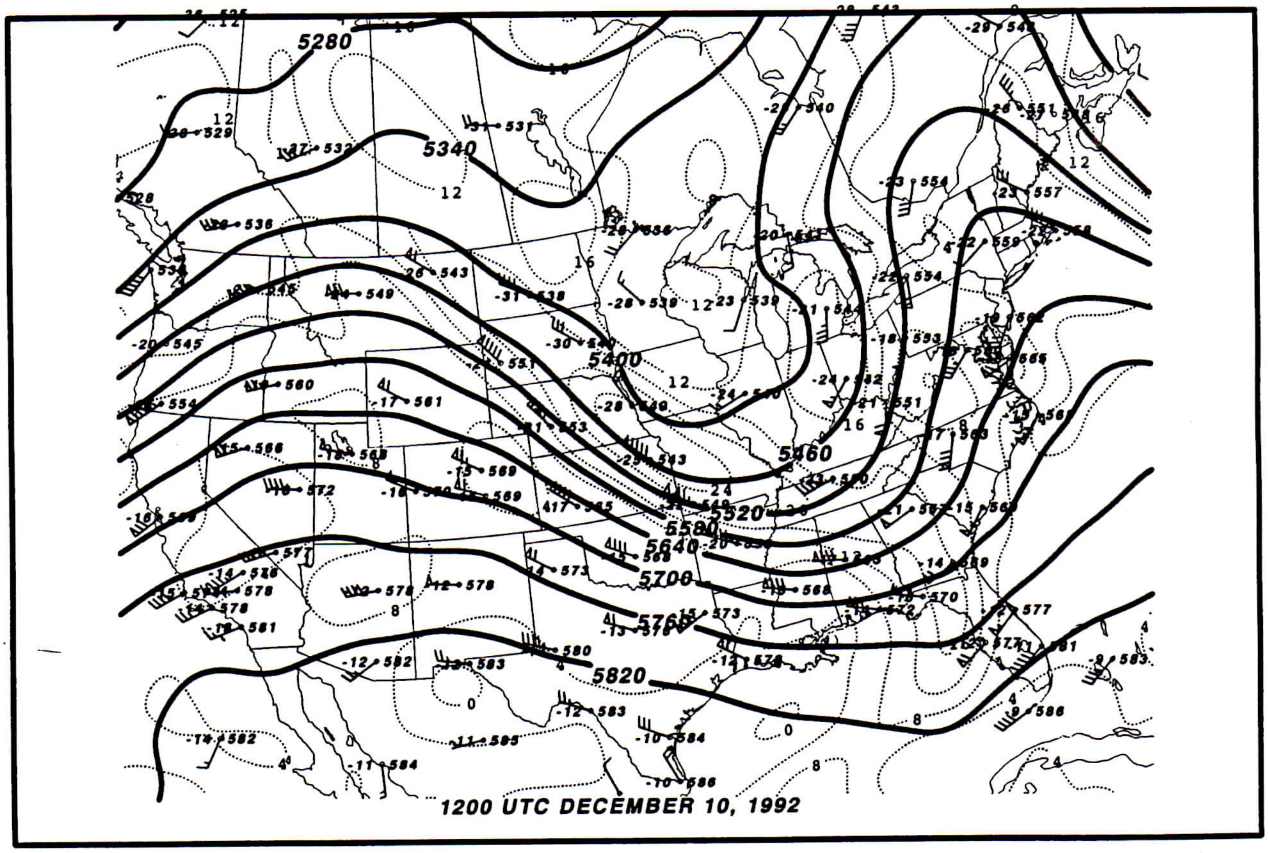
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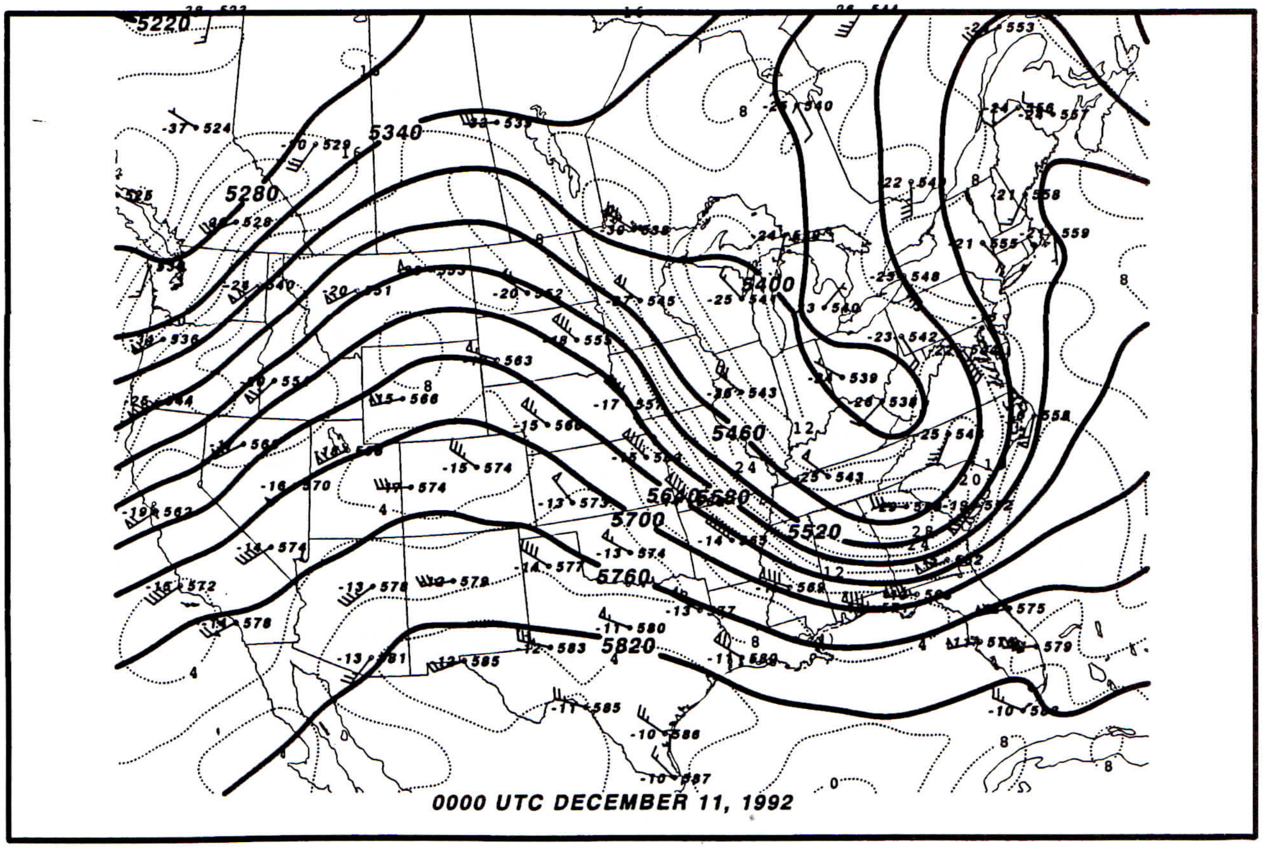
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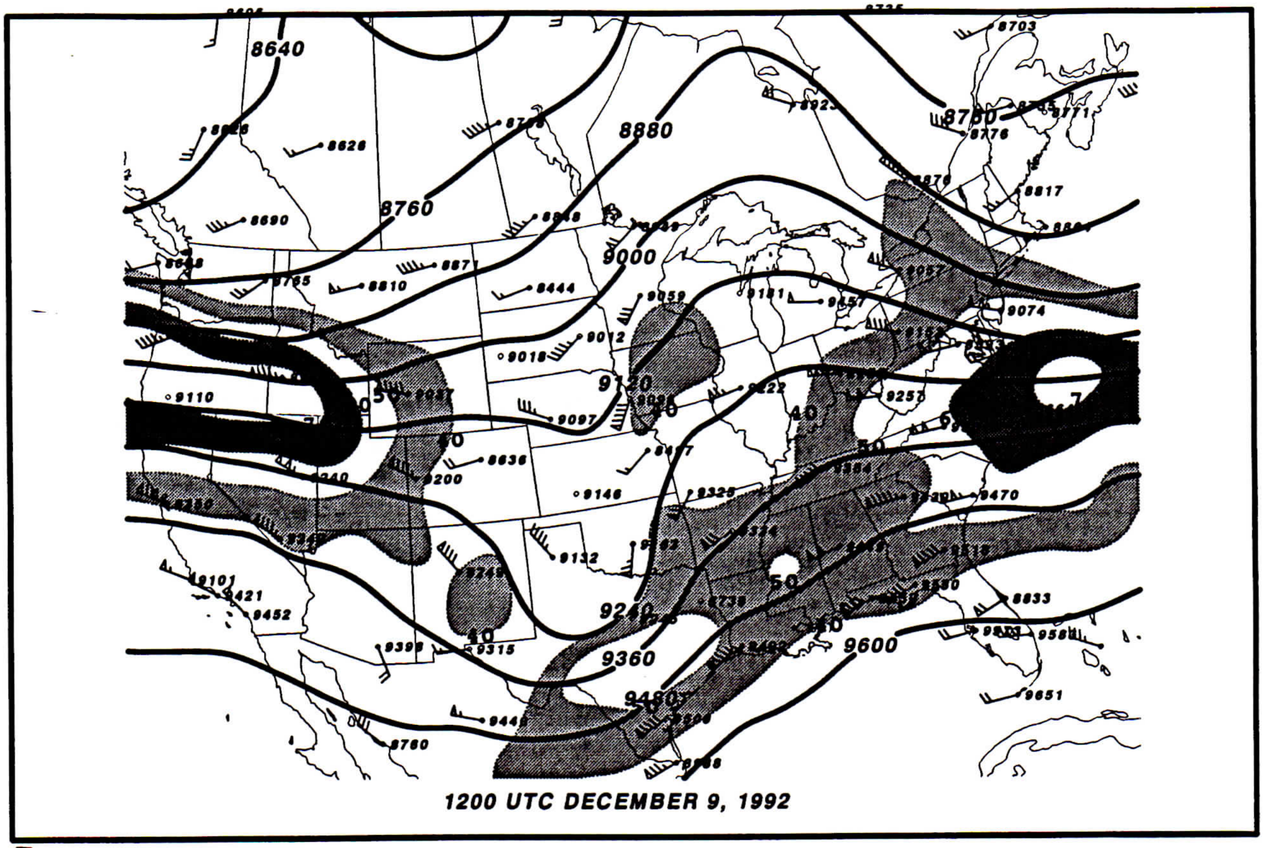
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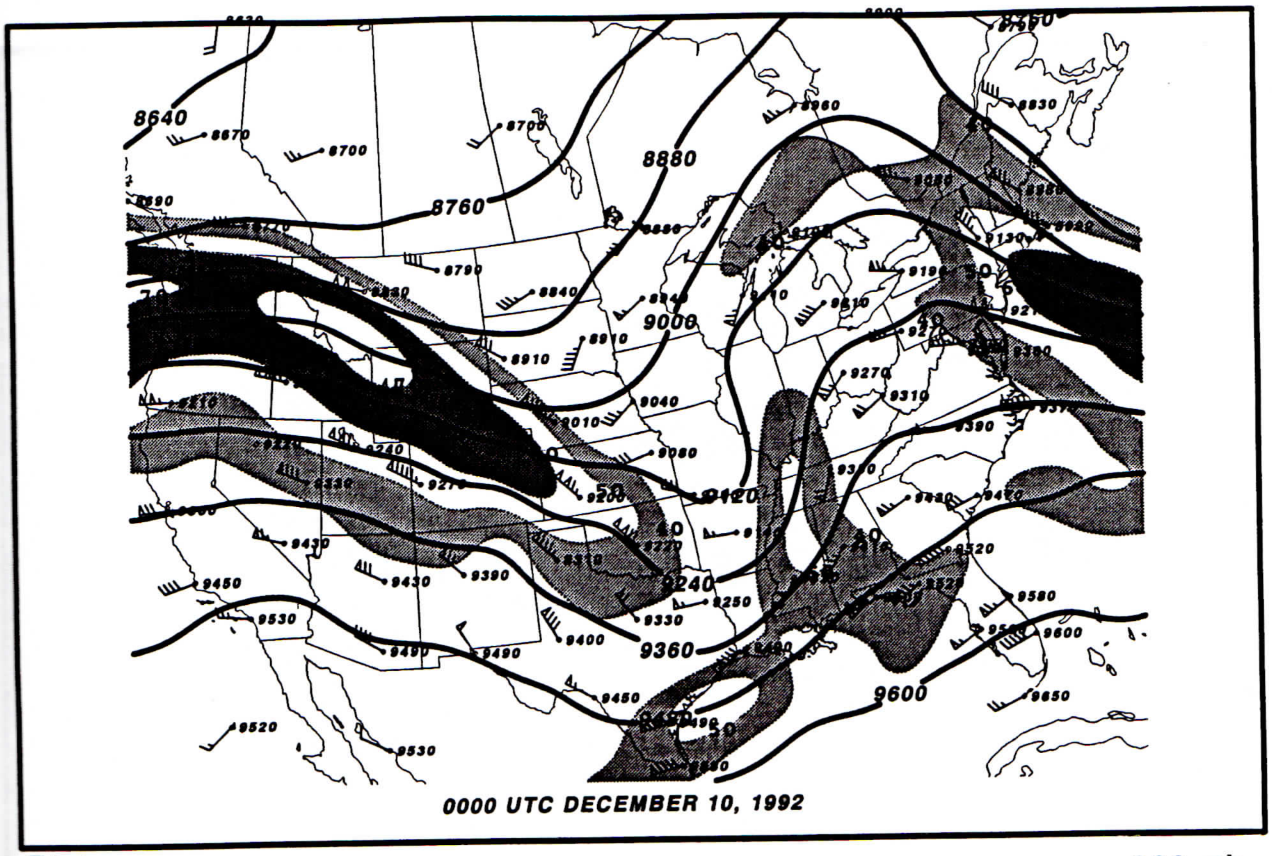
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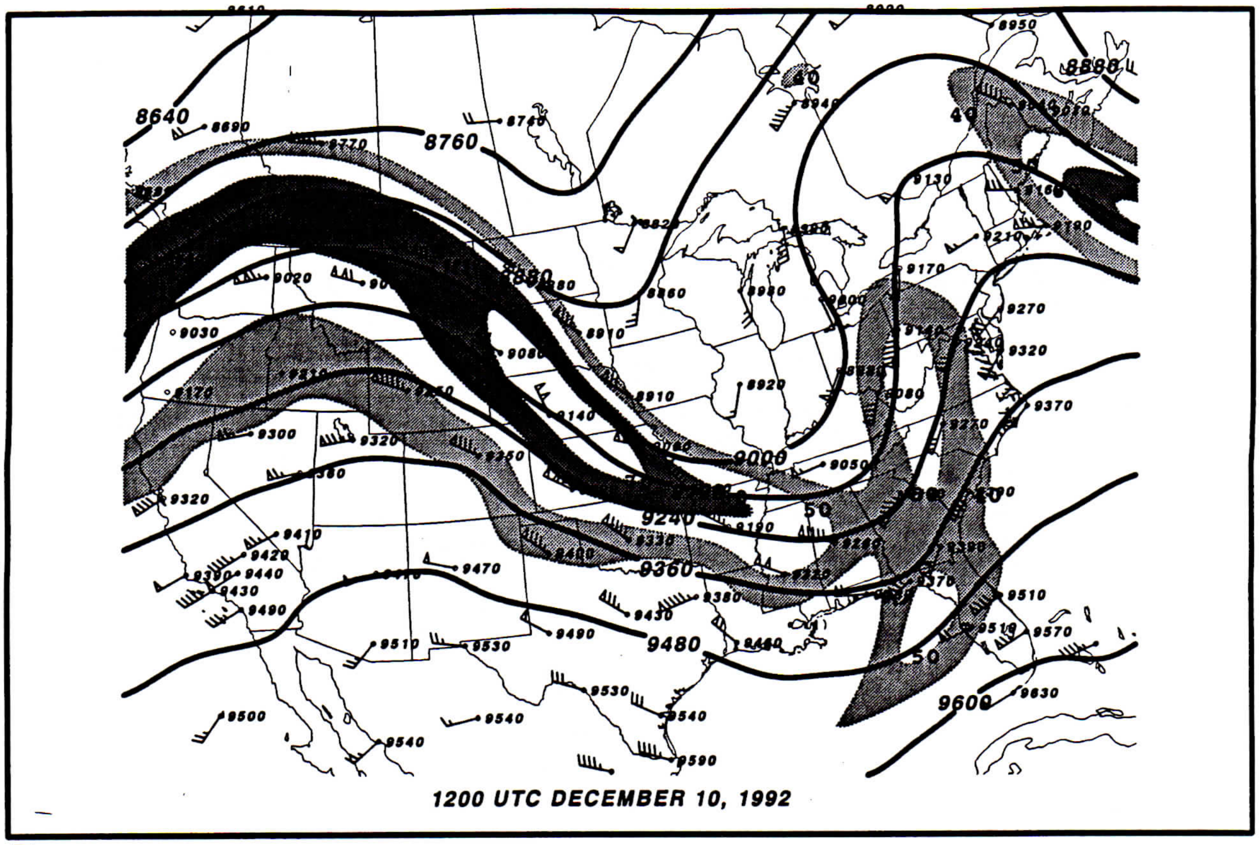

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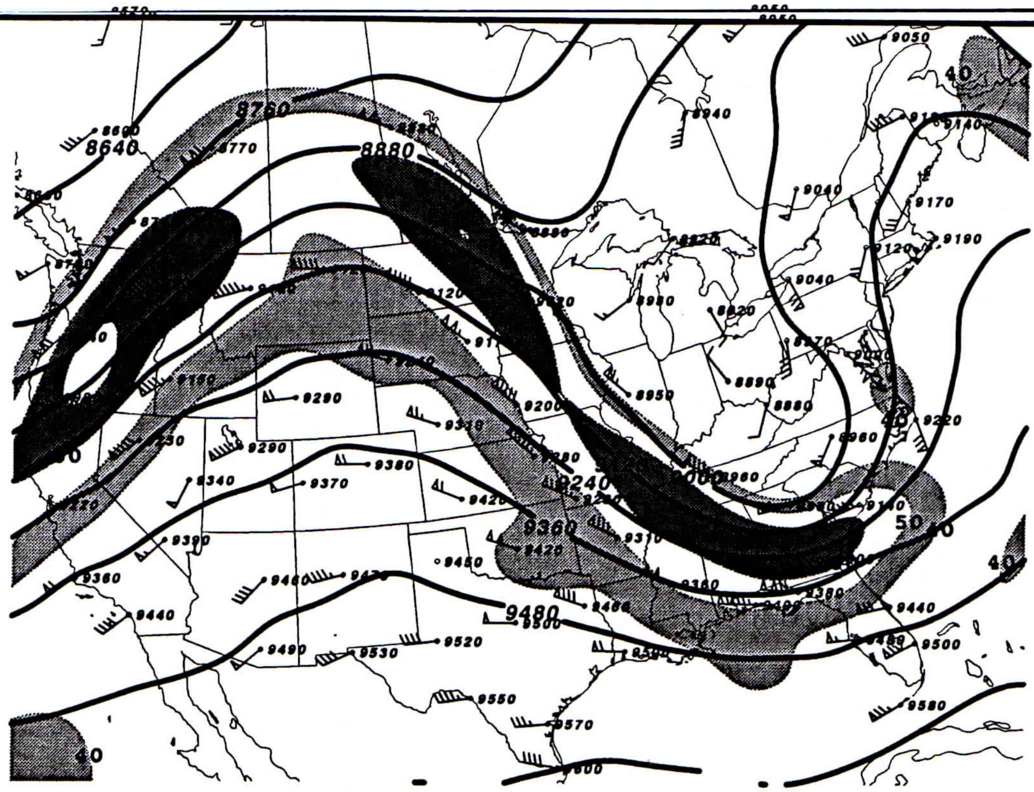

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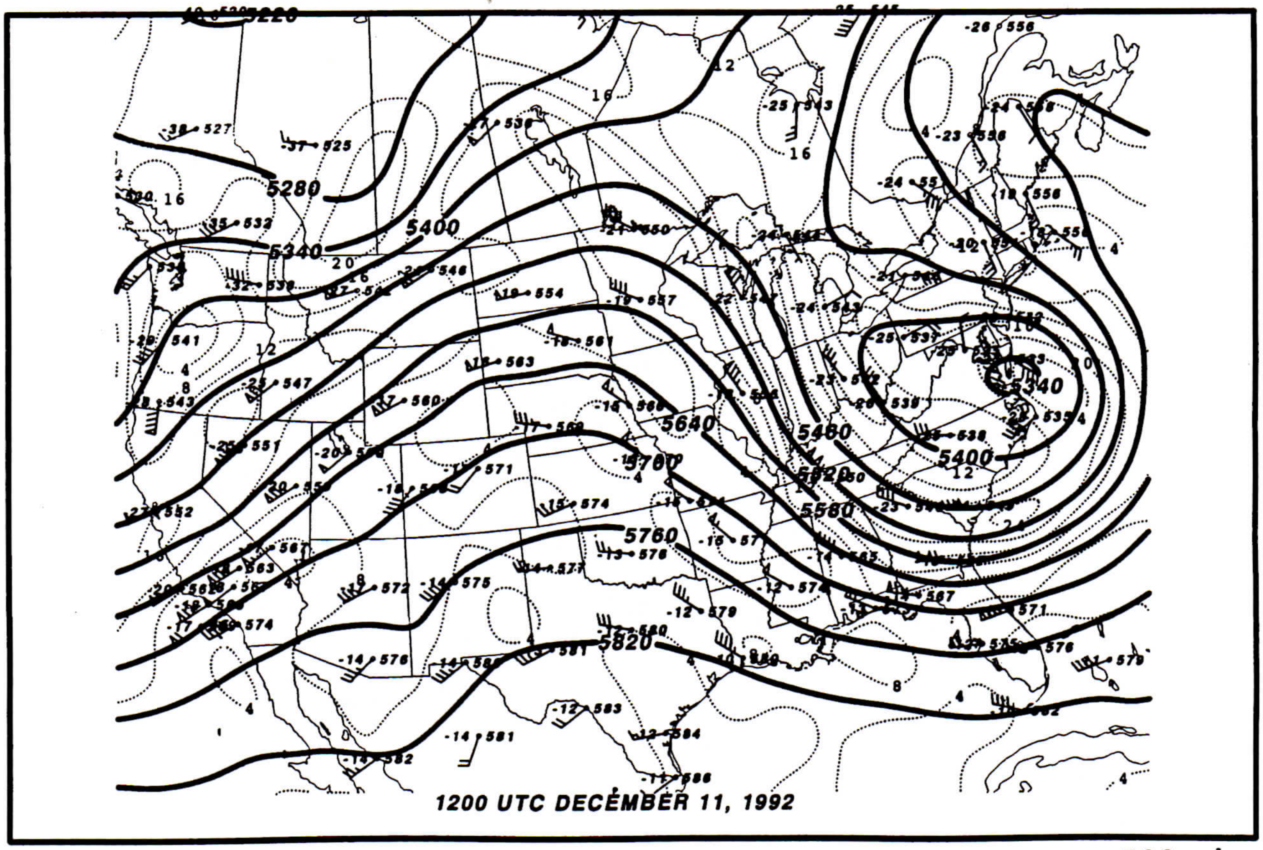
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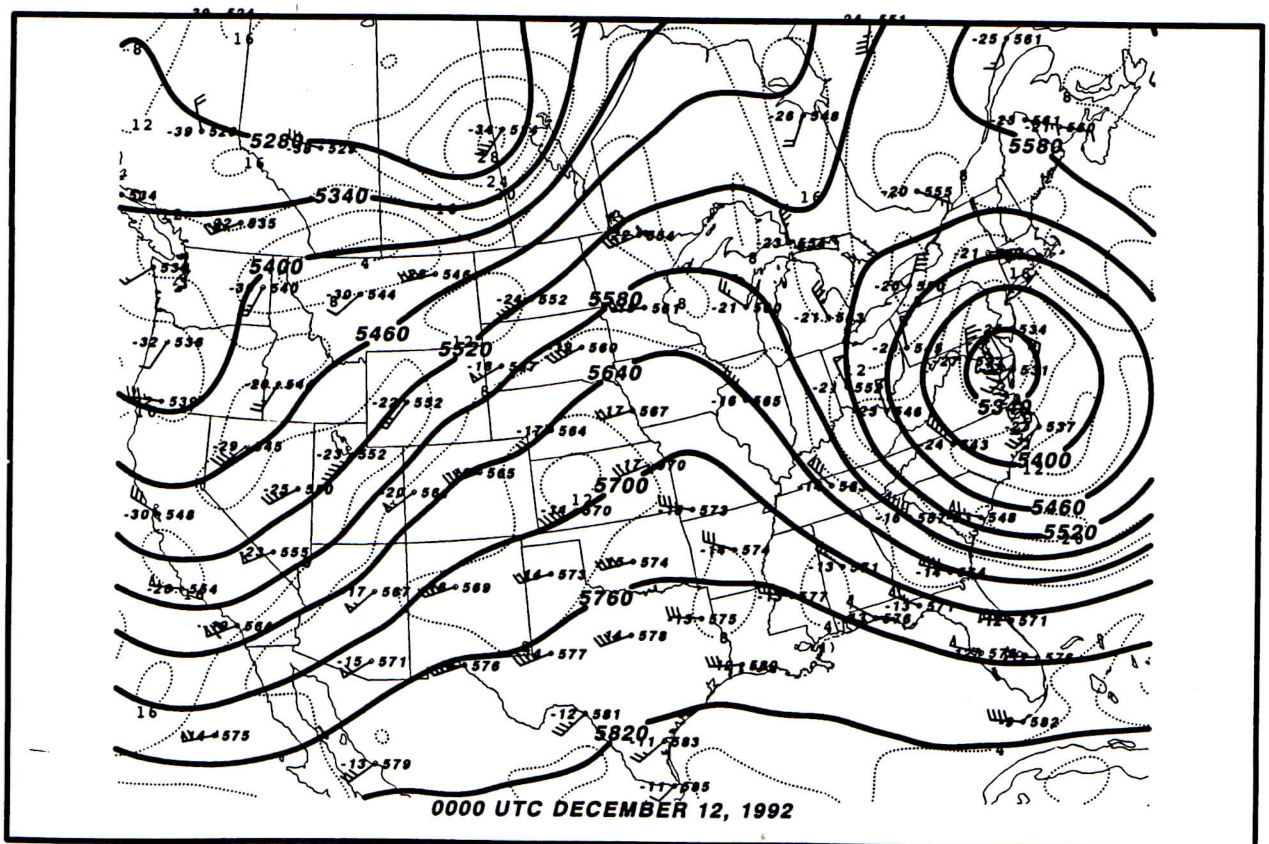

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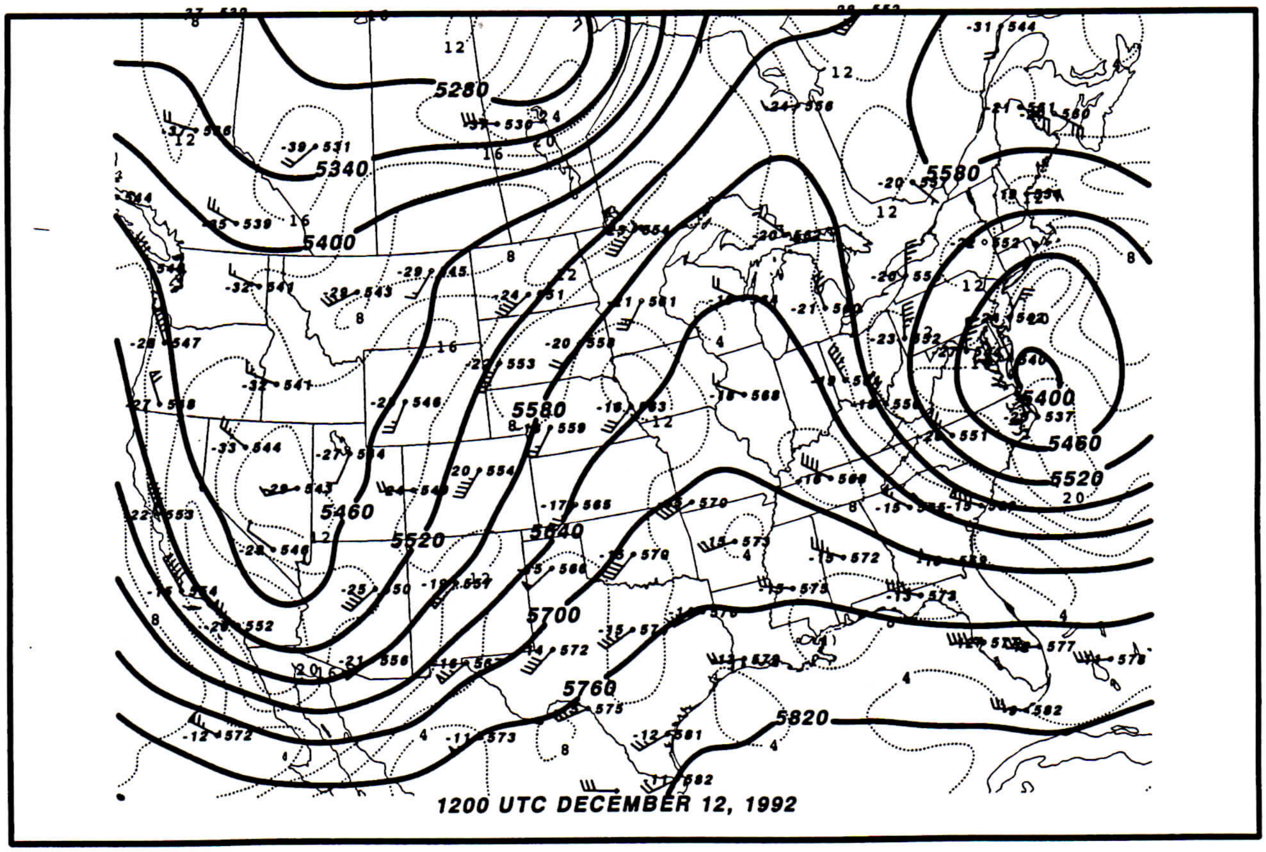
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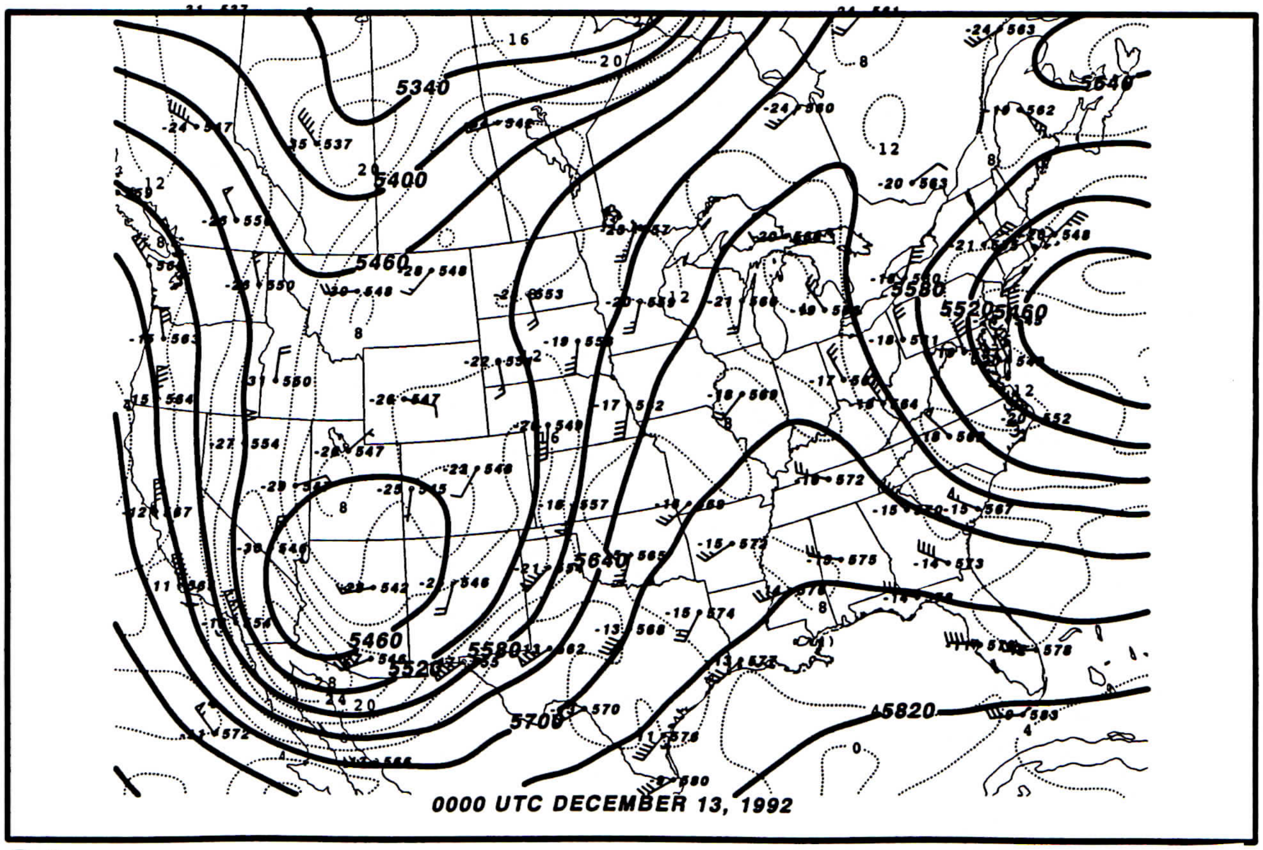
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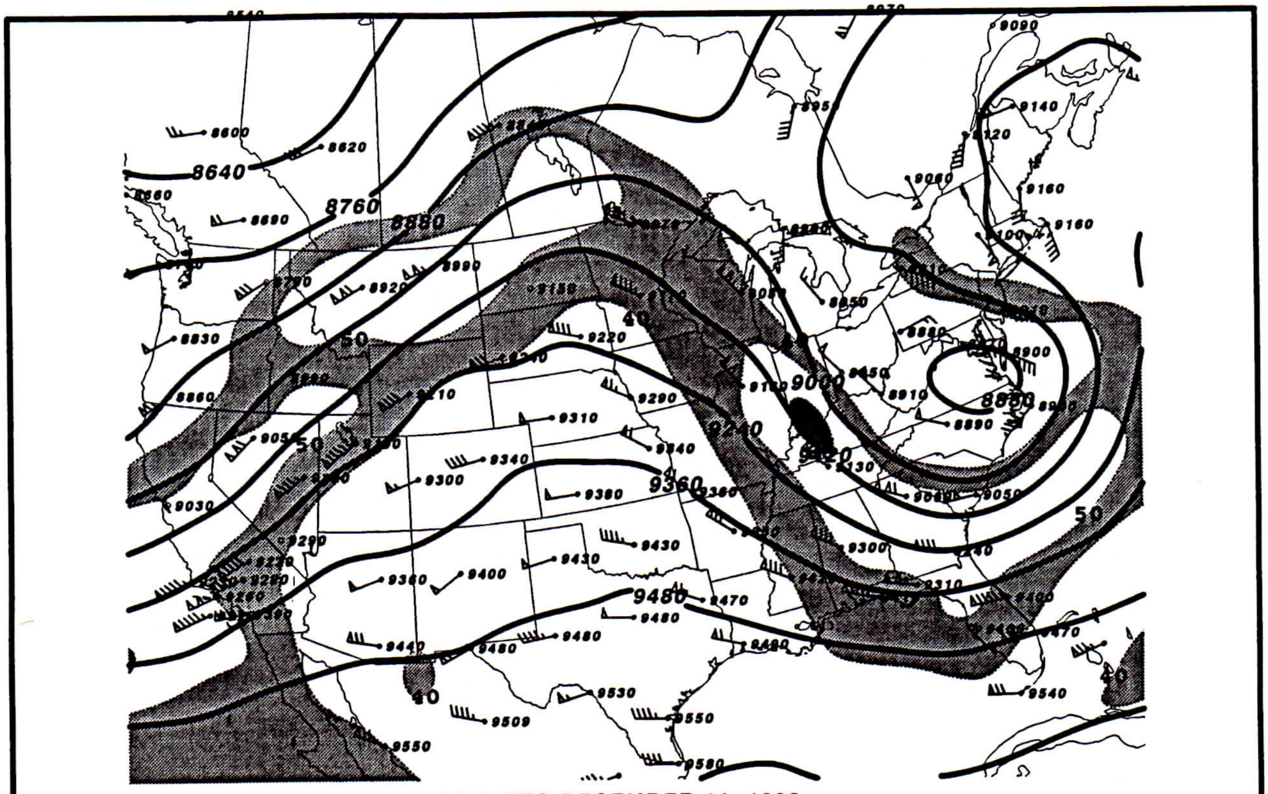

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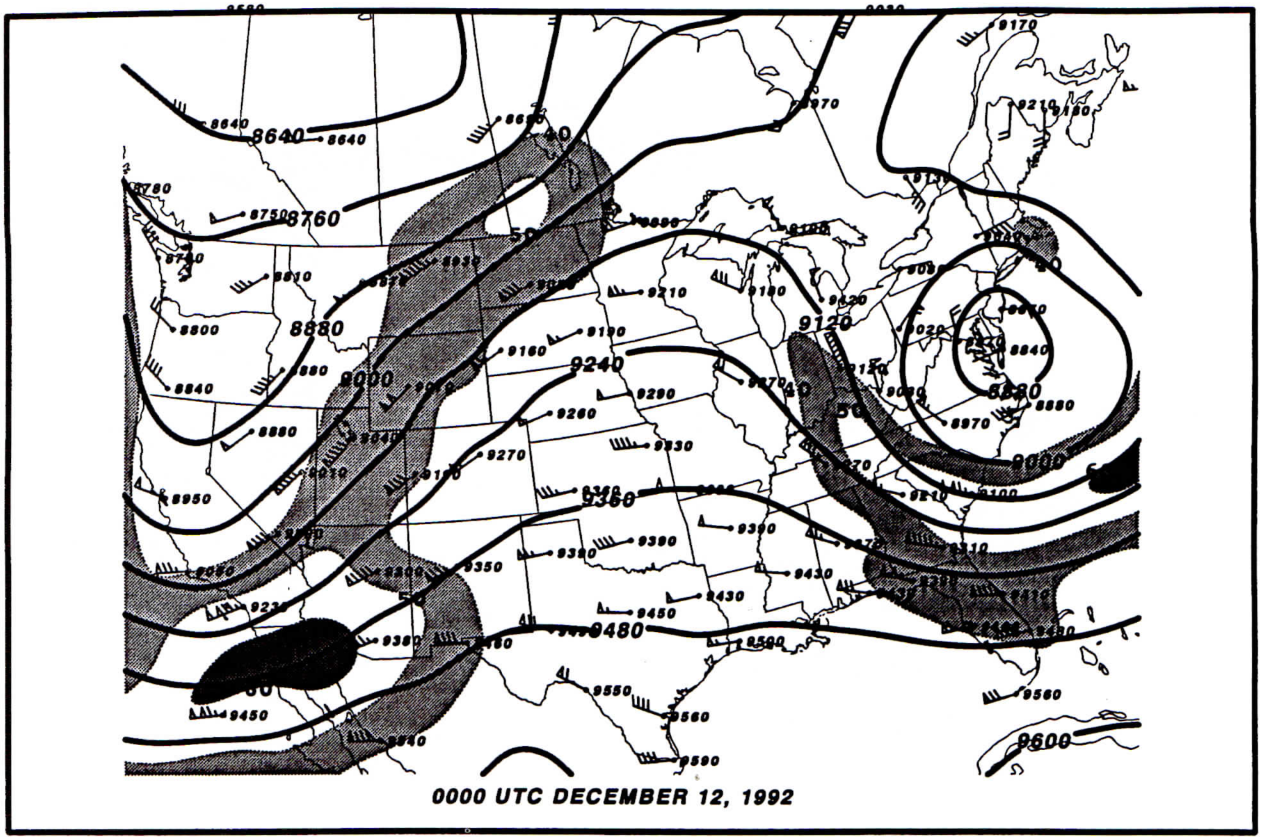
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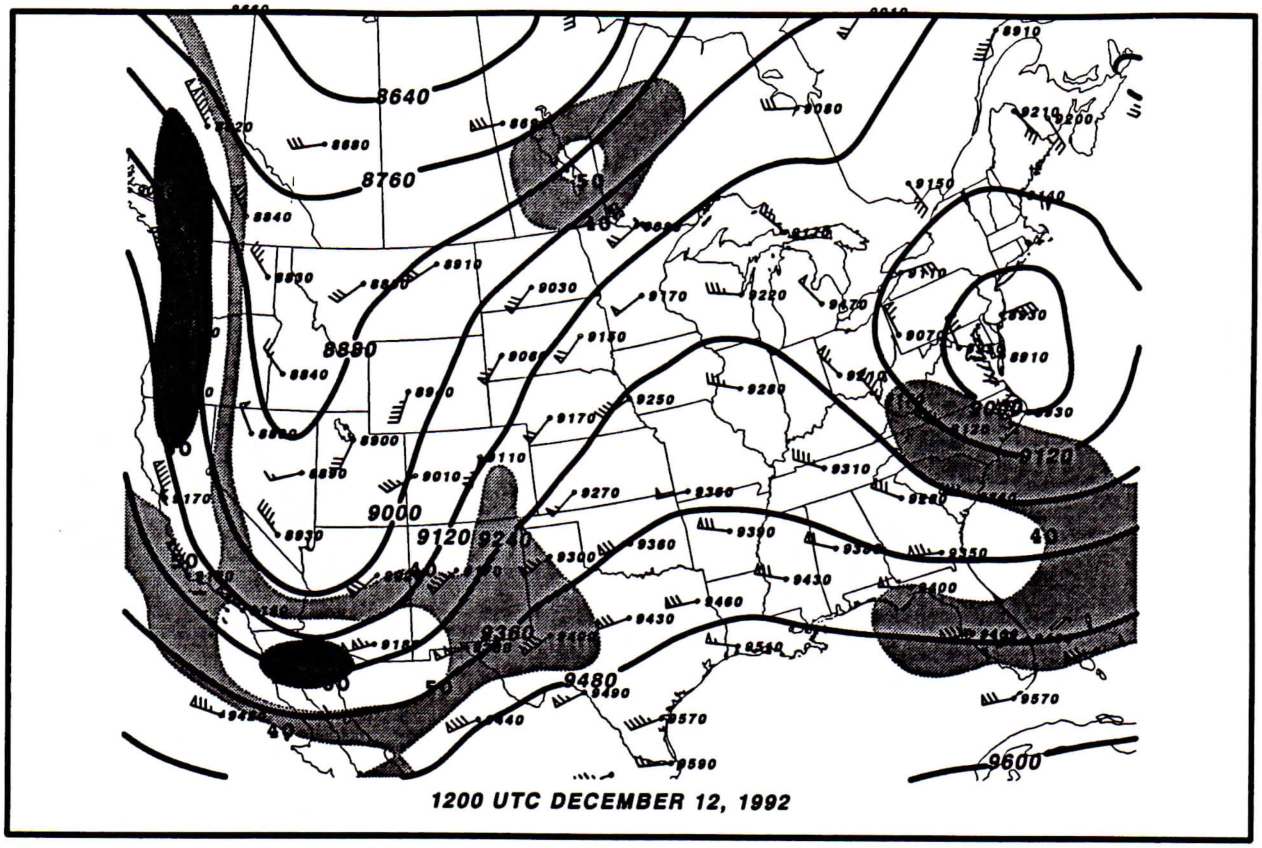

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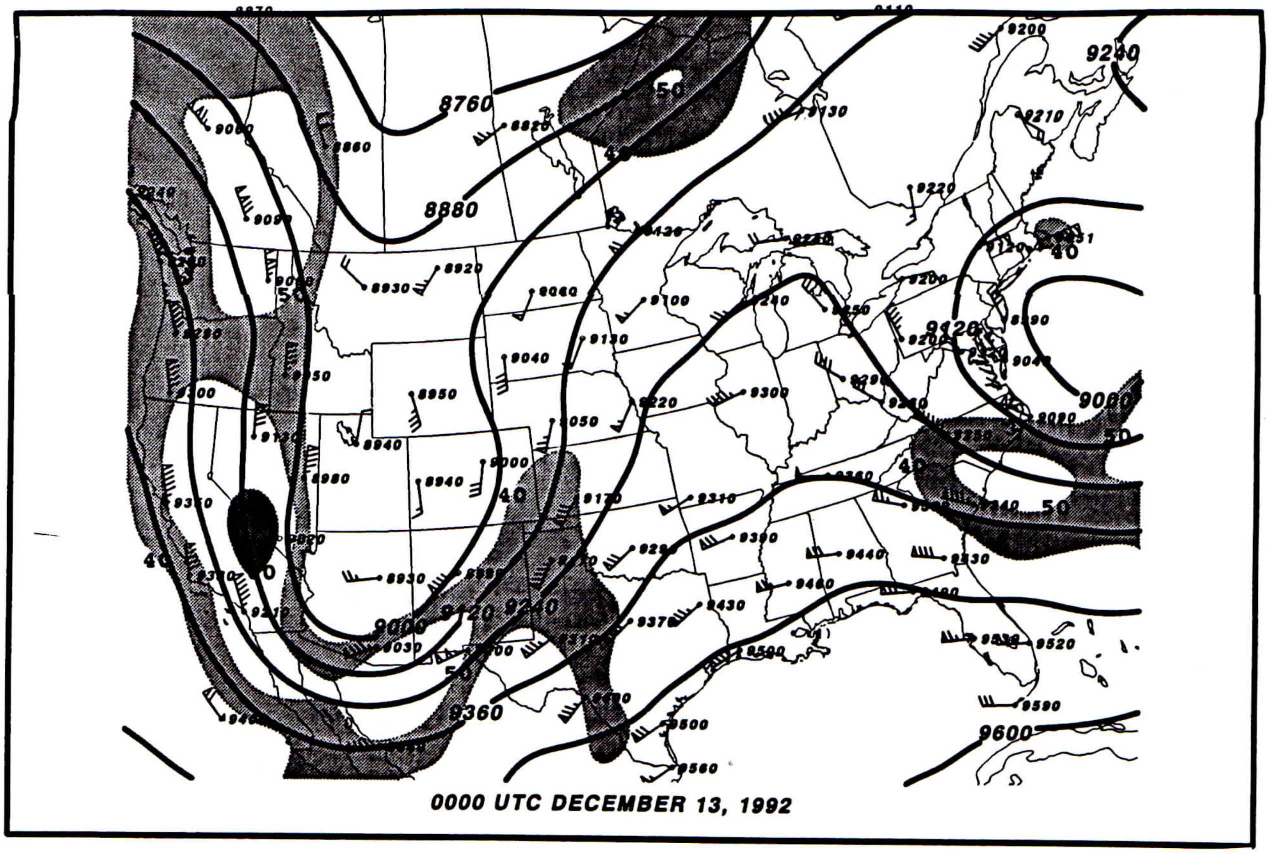
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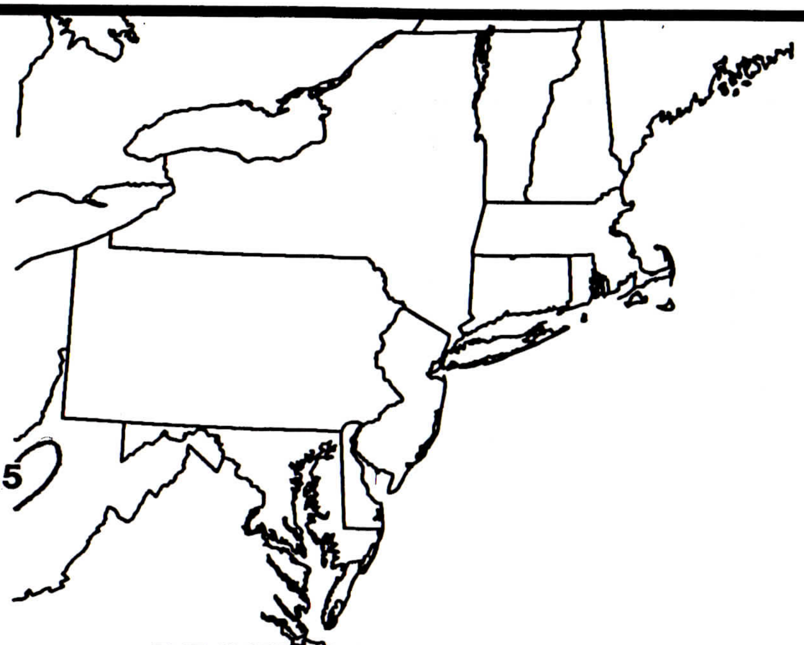

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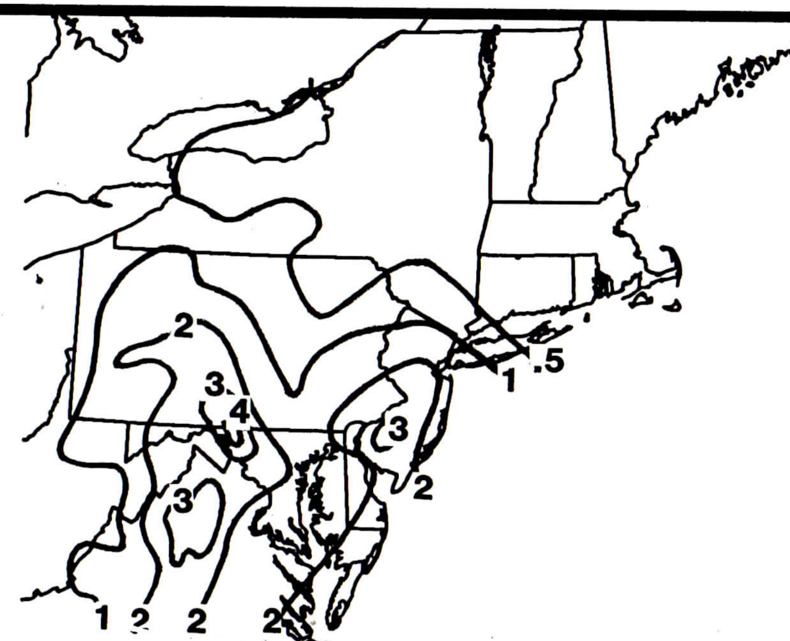

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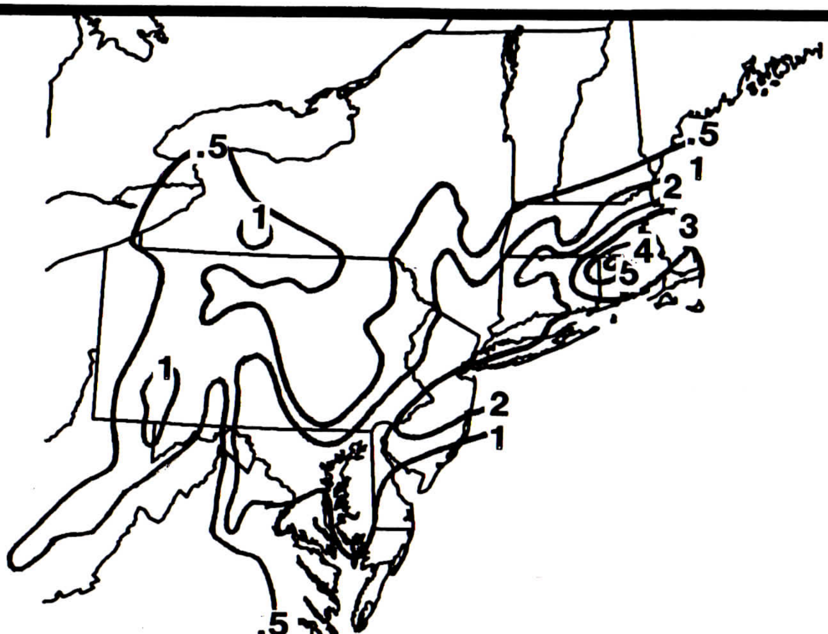
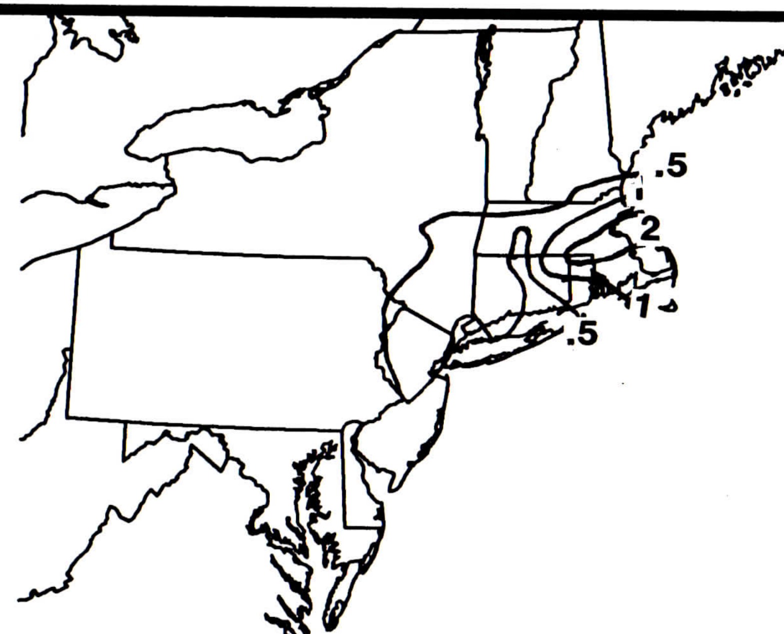


DECEMBER 12, 1992



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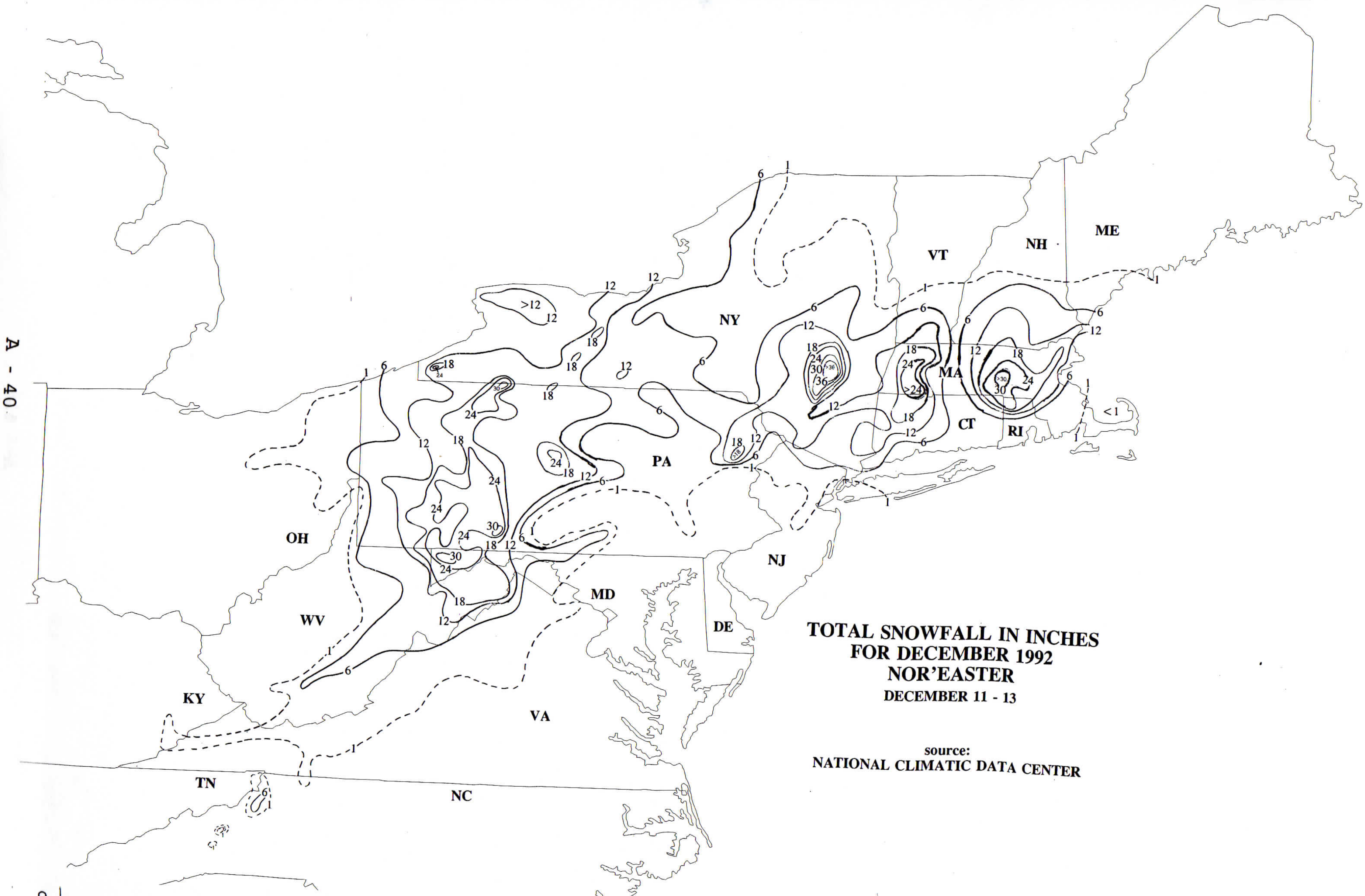
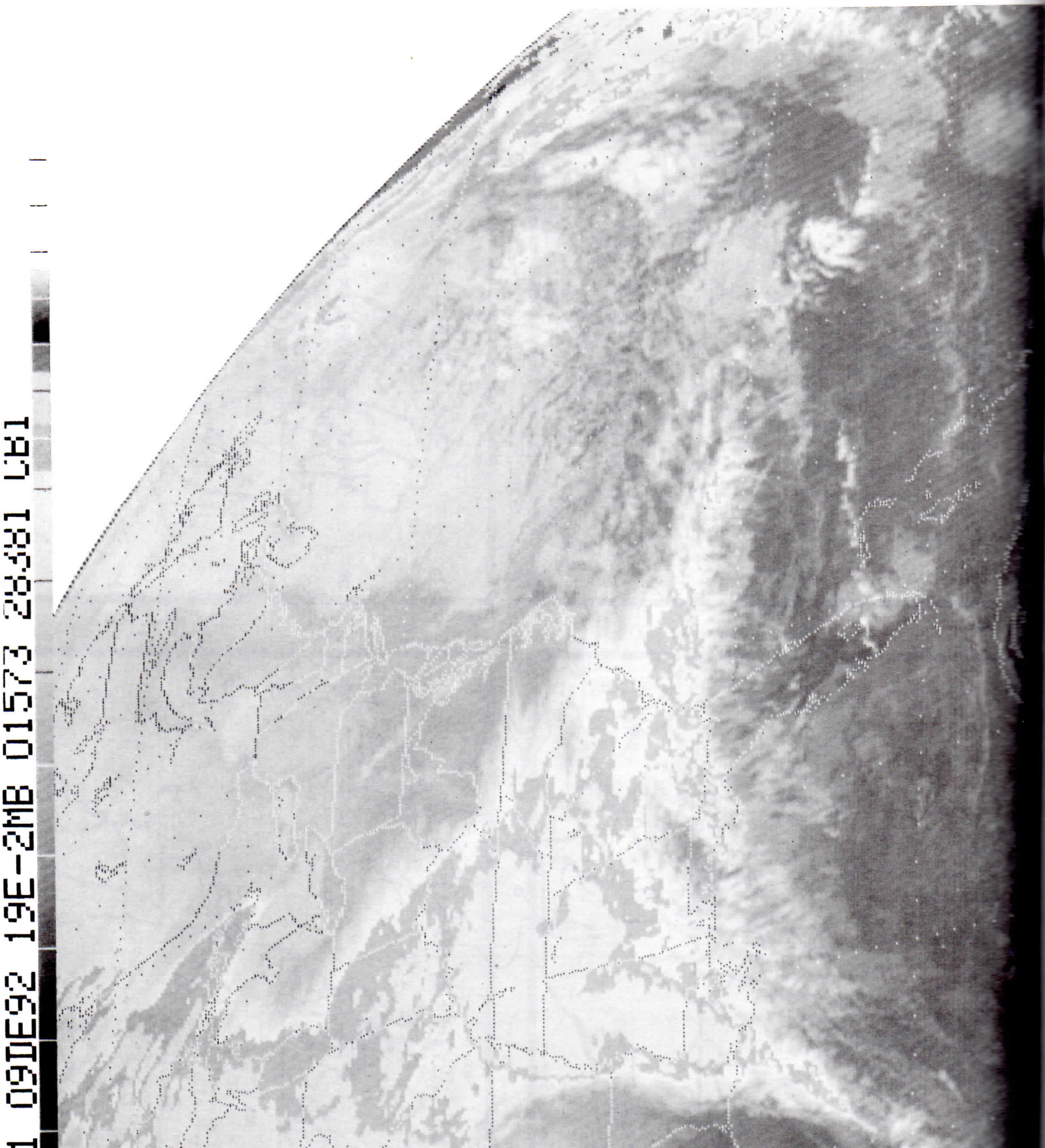


TOTAL SNOWFALL IN INCHES
FOR DECEMBER 1992
NOR'EASTER
DECEMBER 11 - 13

source:
NATIONAL CLIMATIC DATA CENTER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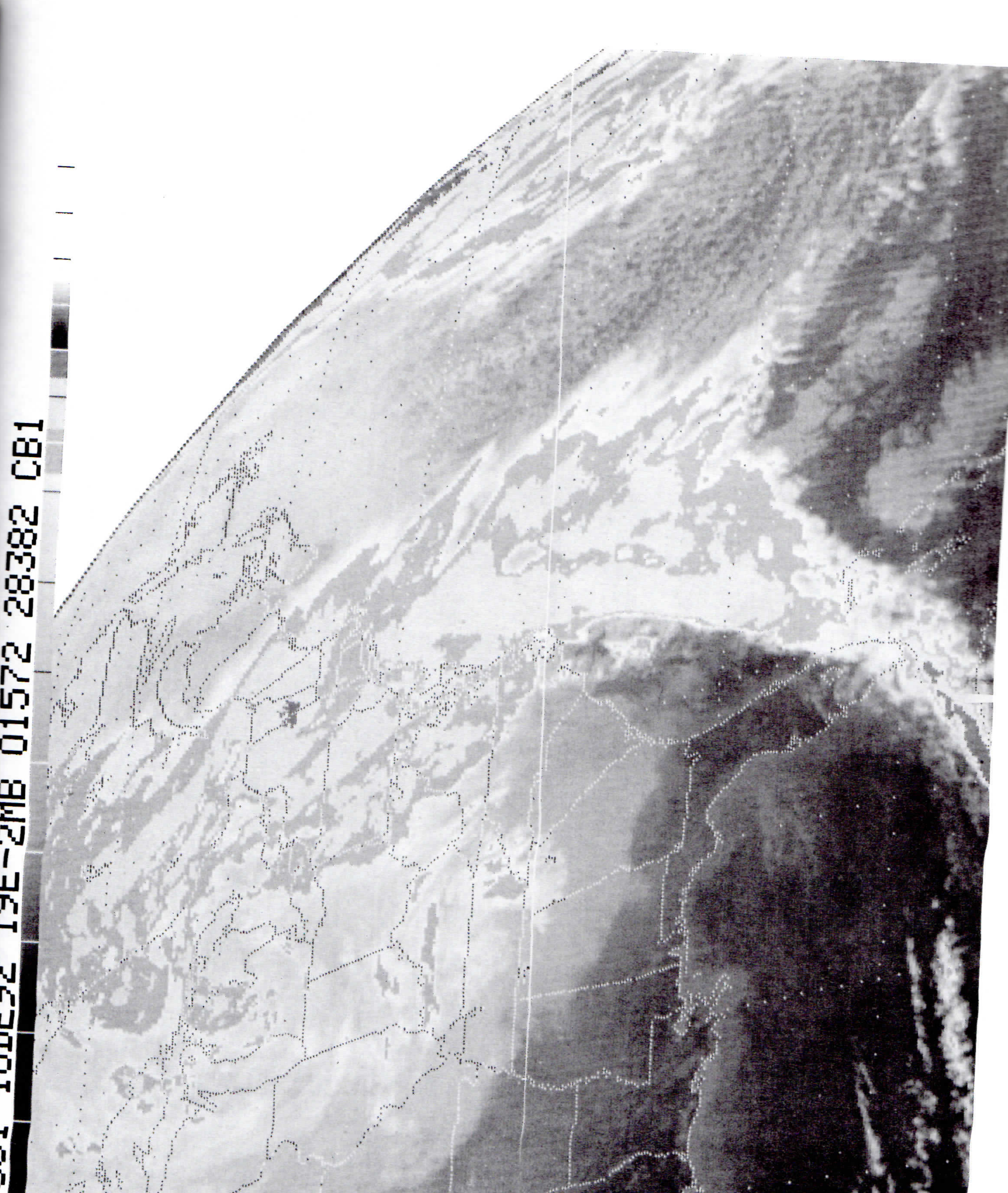
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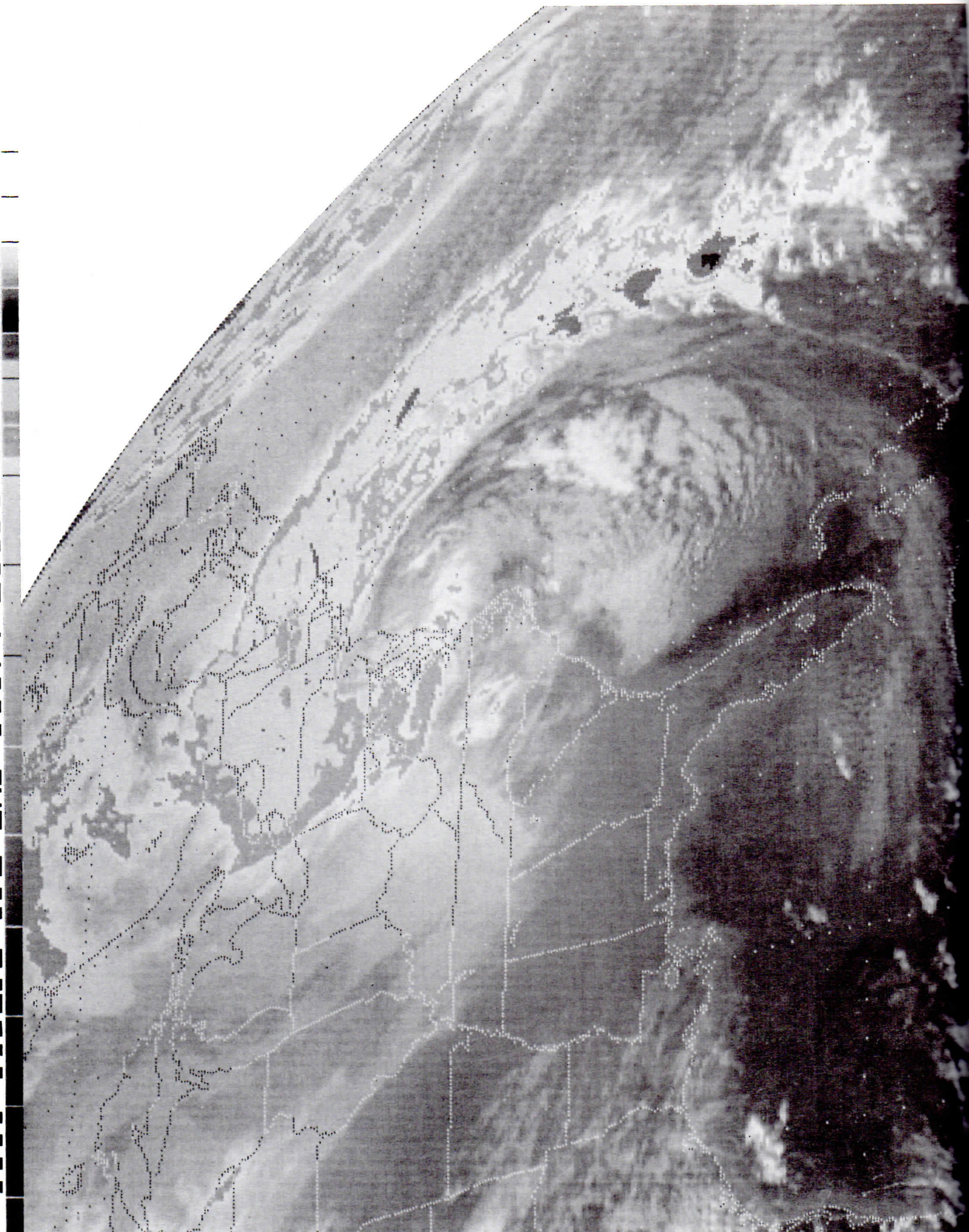
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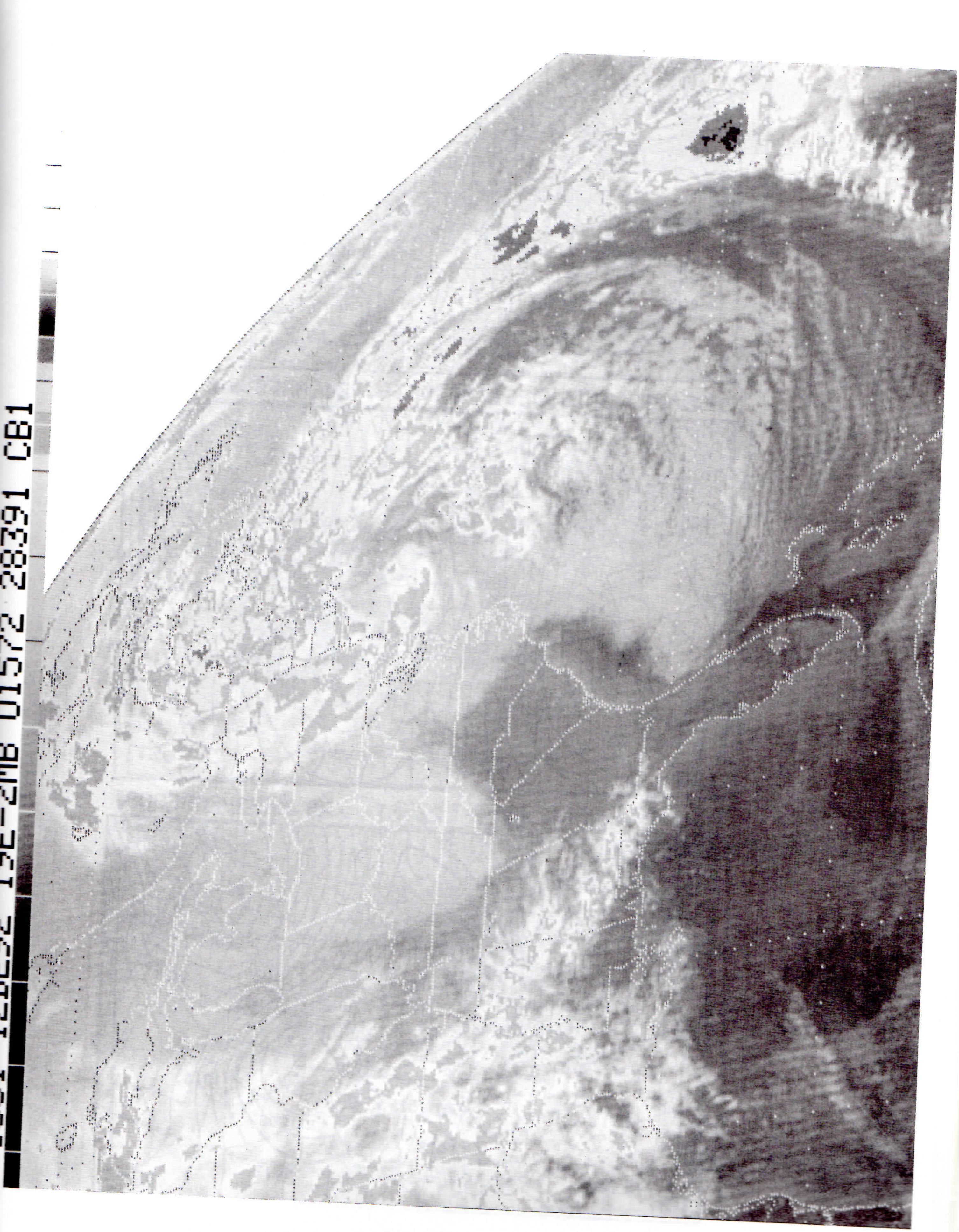
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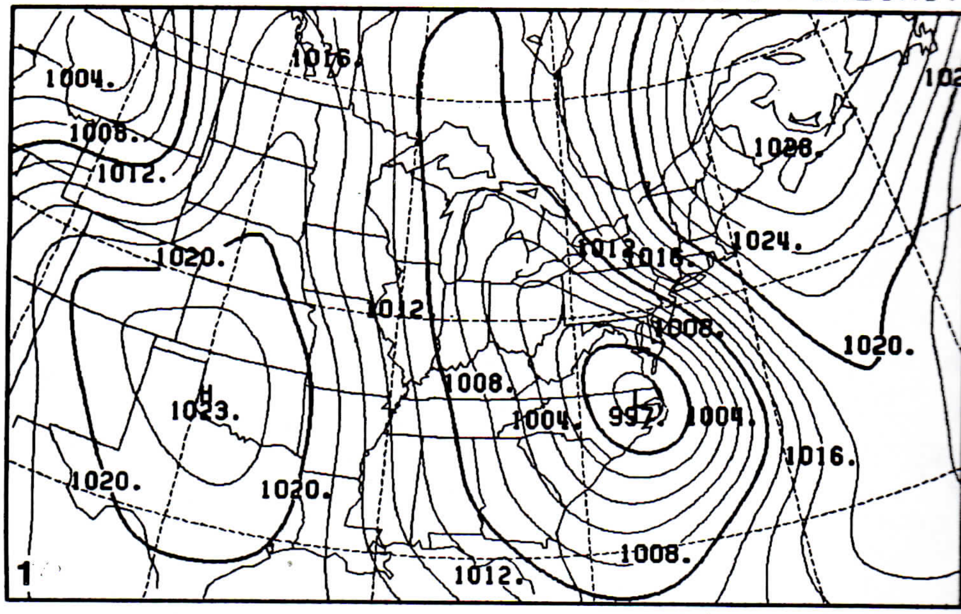

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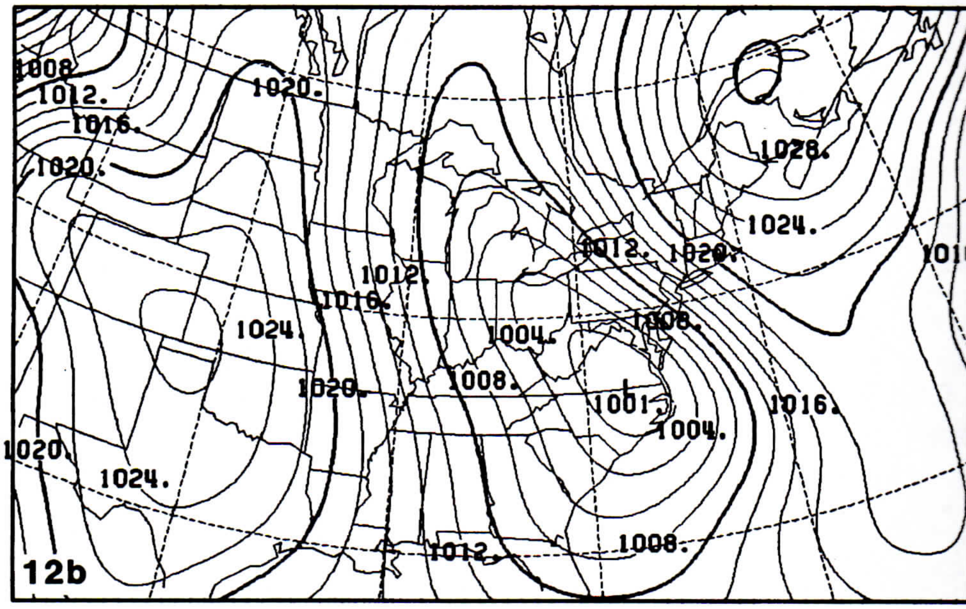

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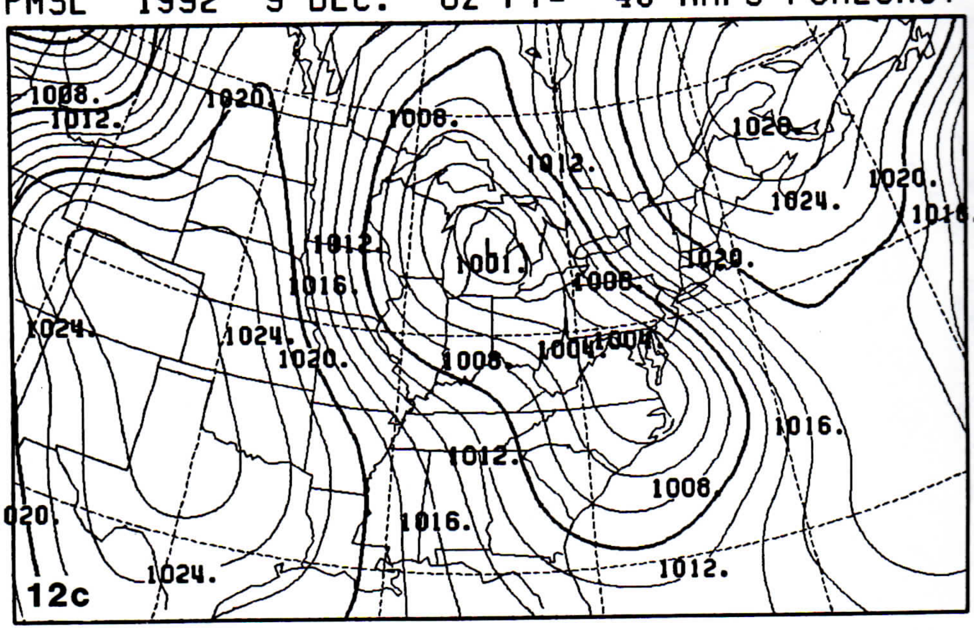

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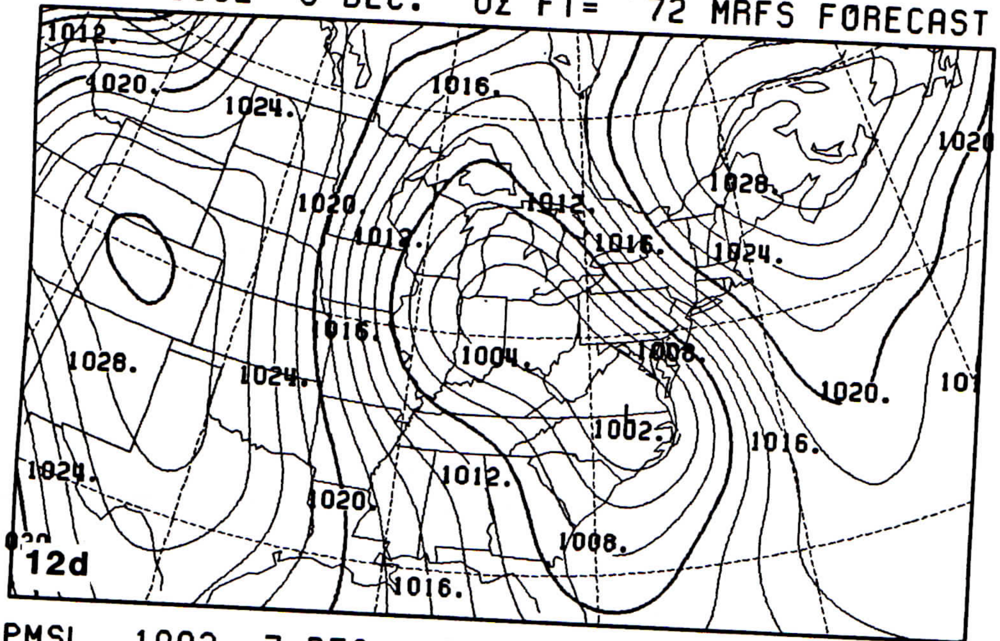

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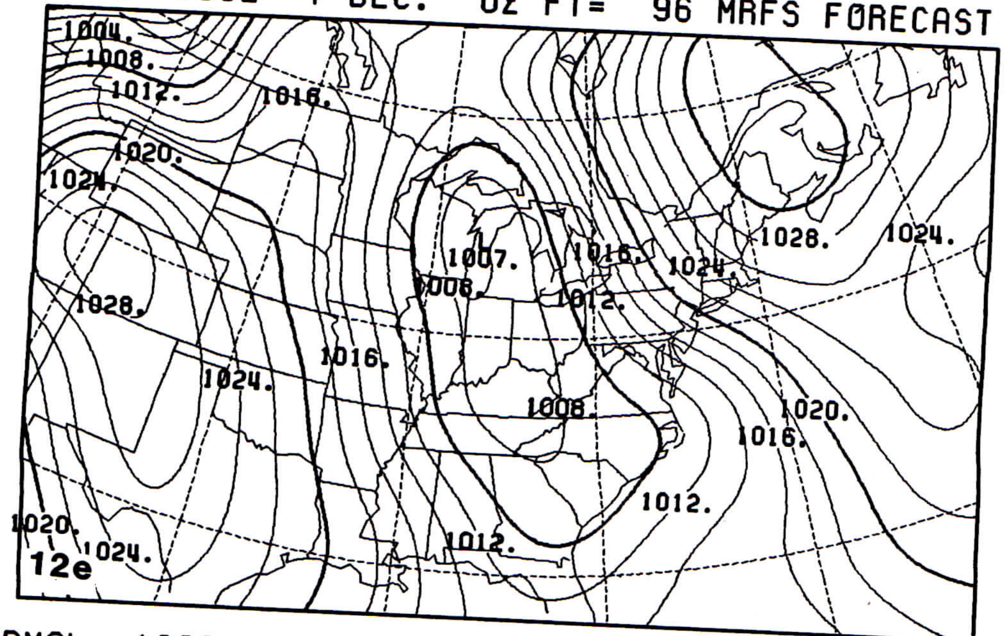

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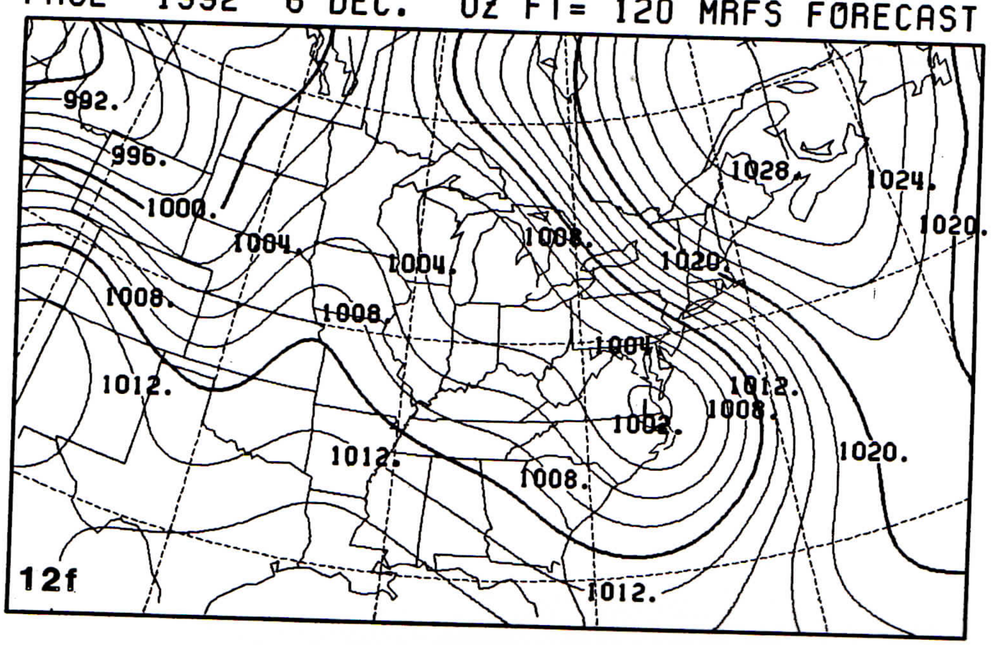

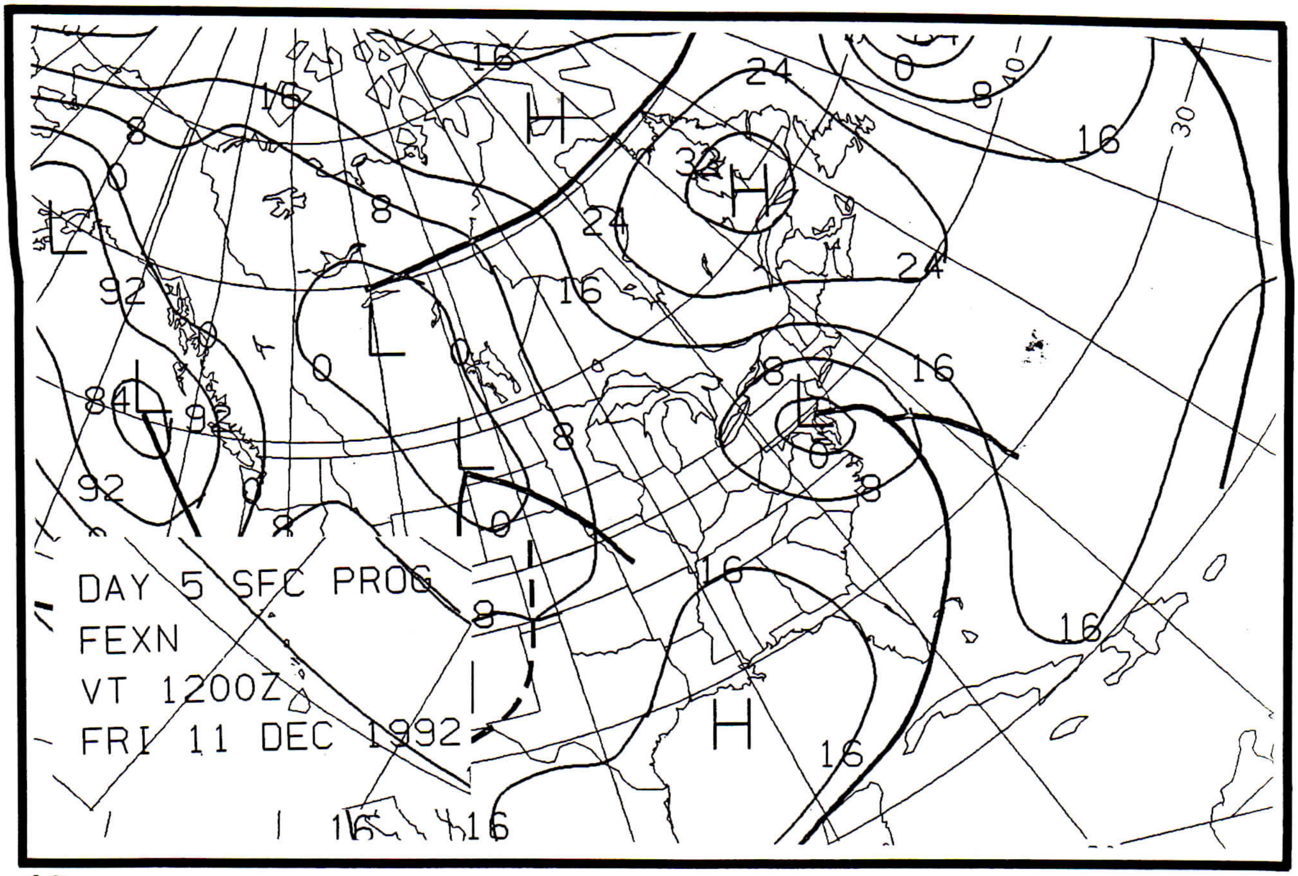

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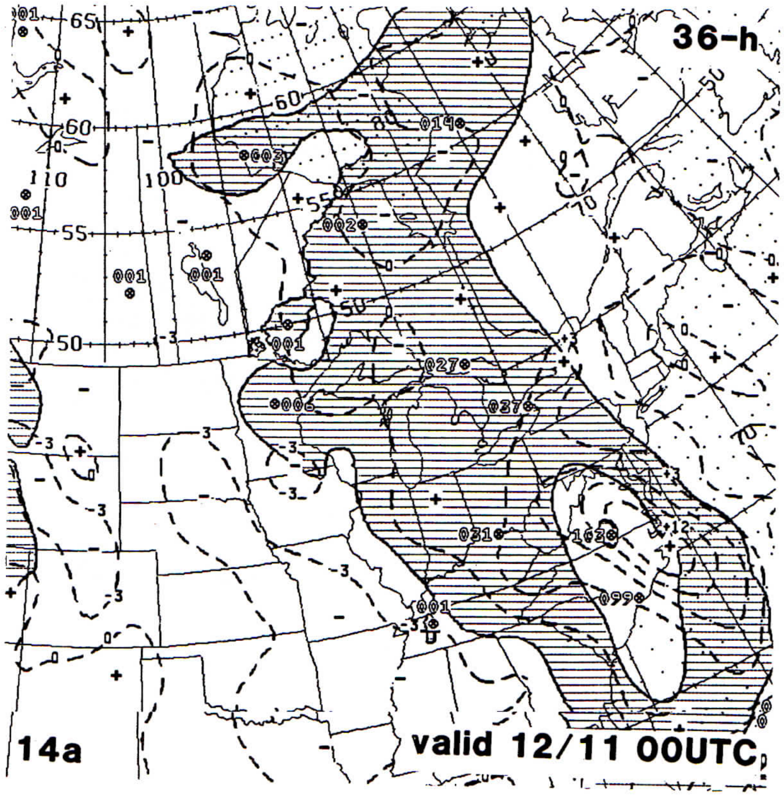
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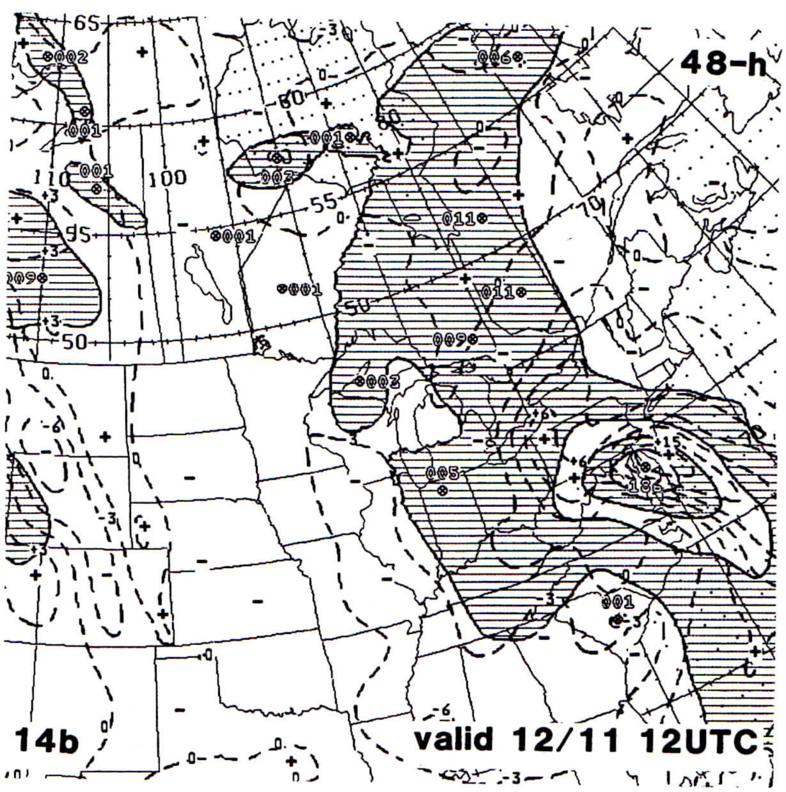
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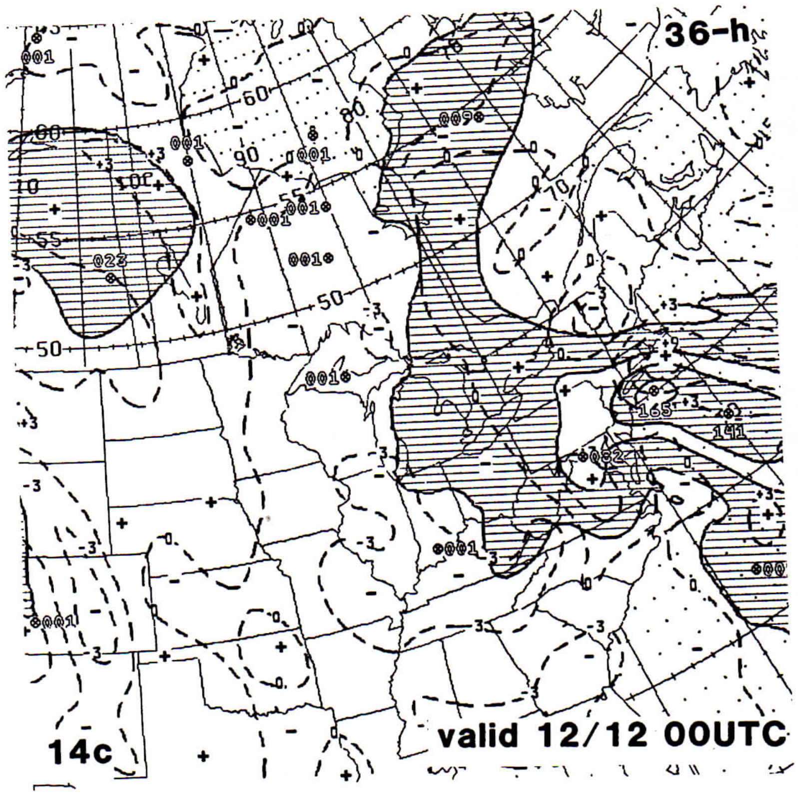
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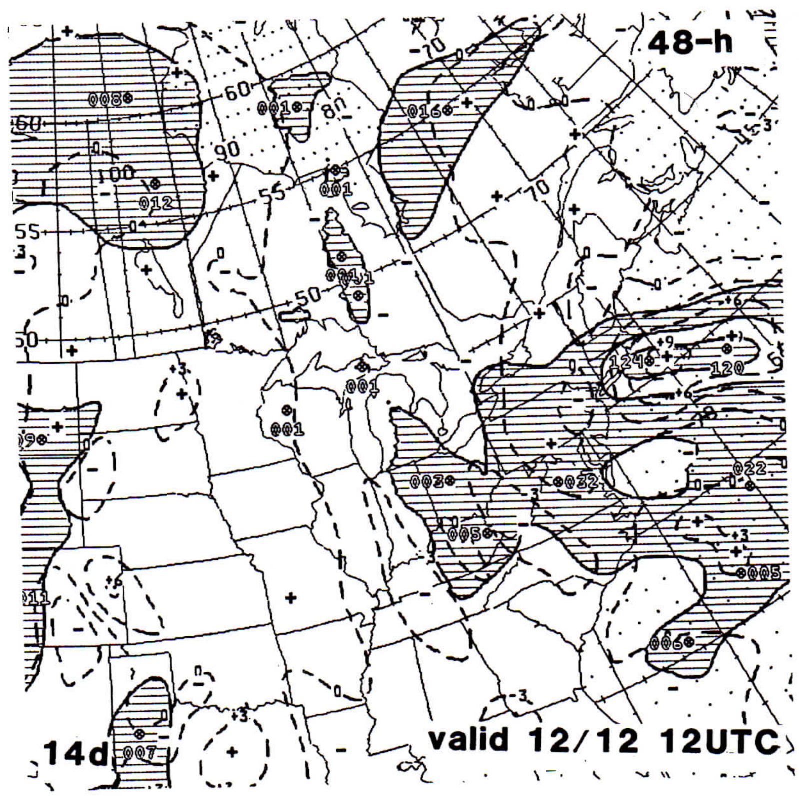
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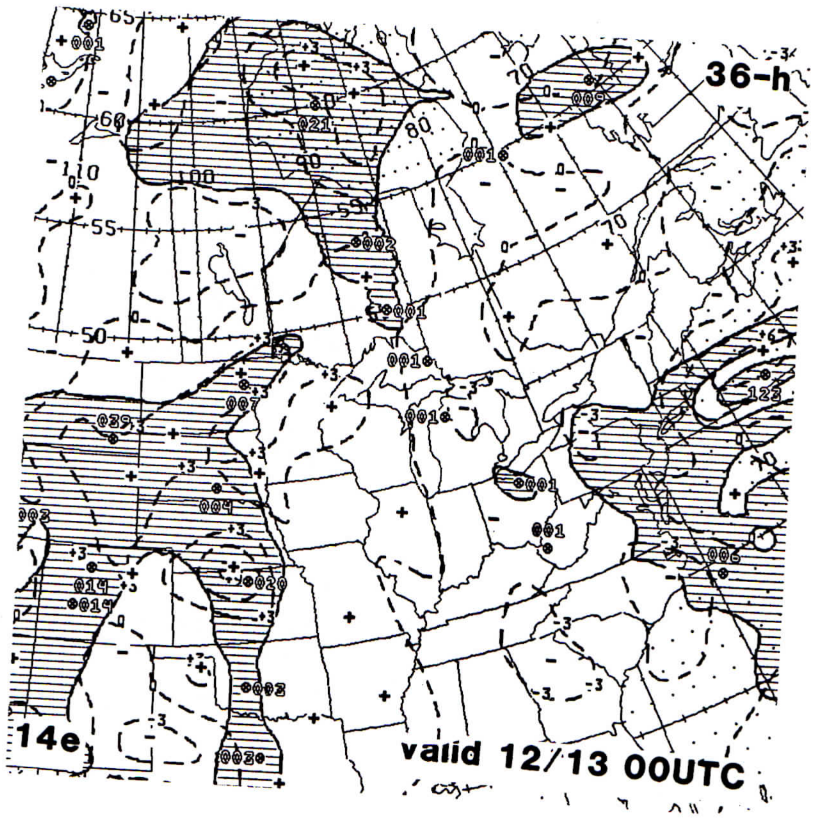
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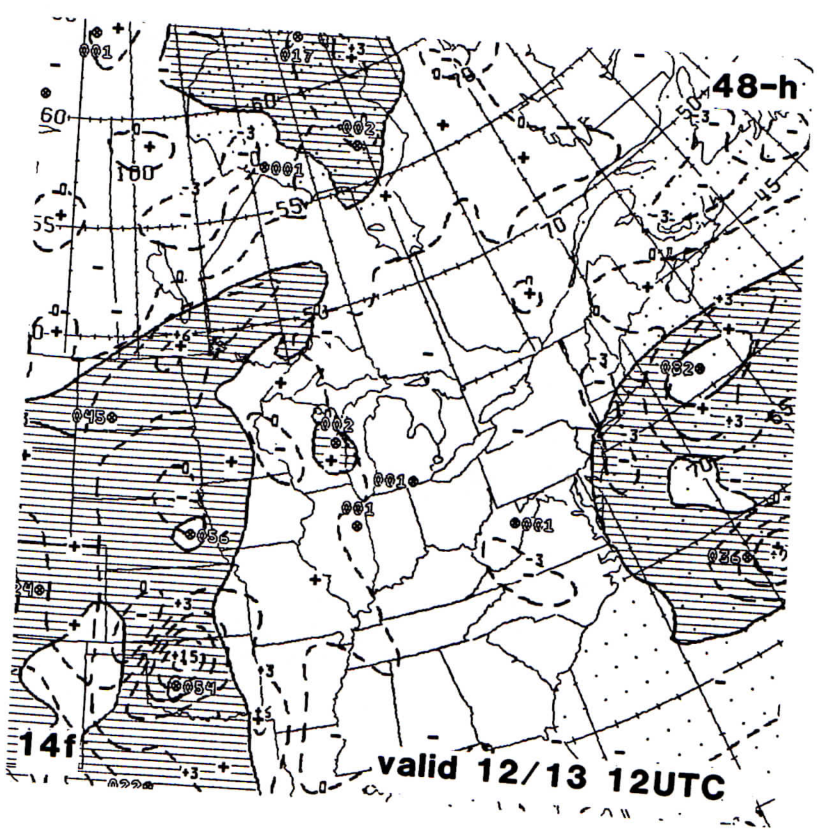
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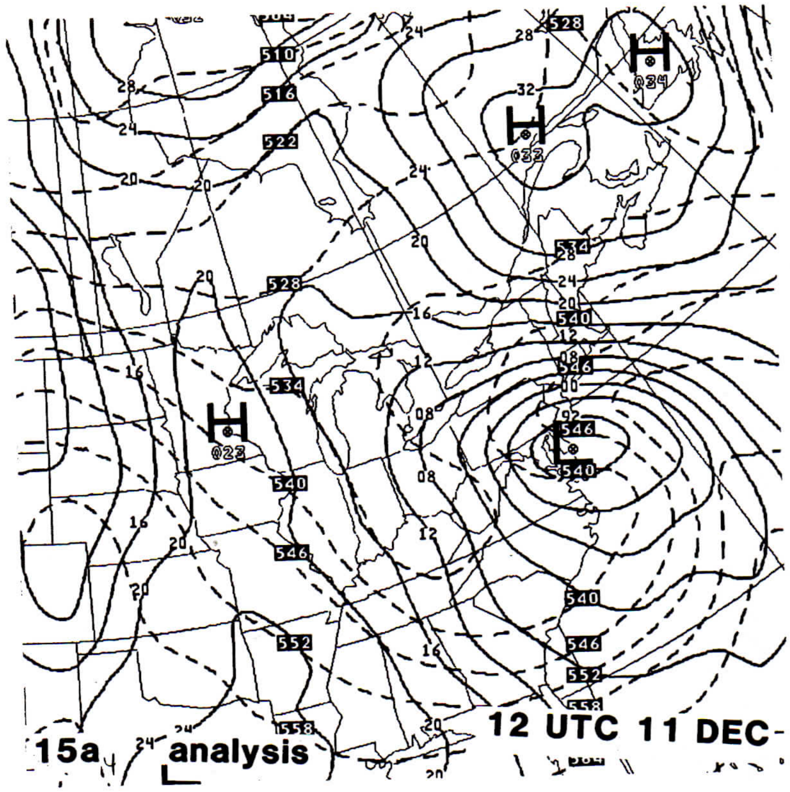
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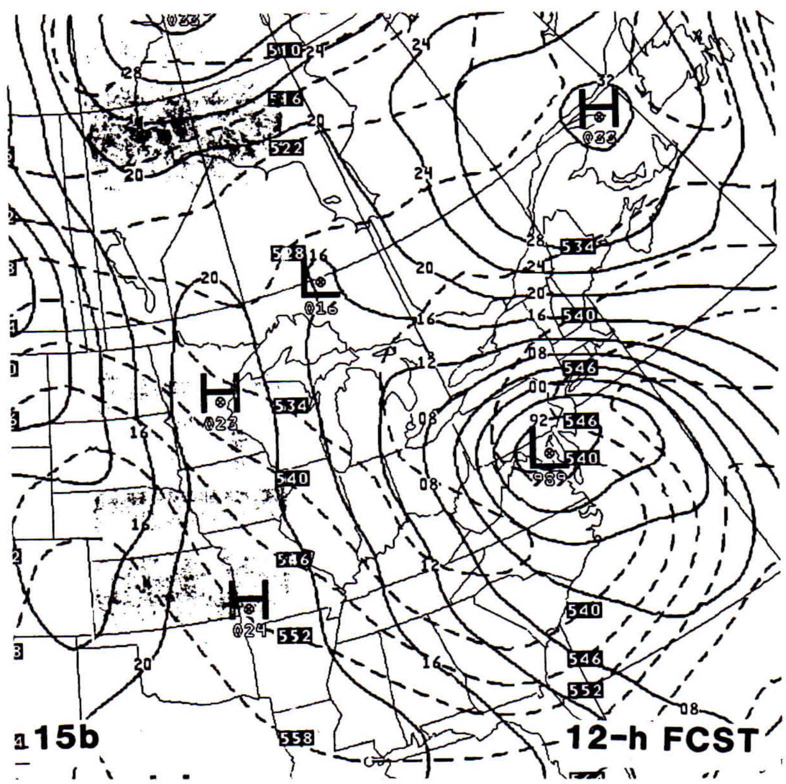
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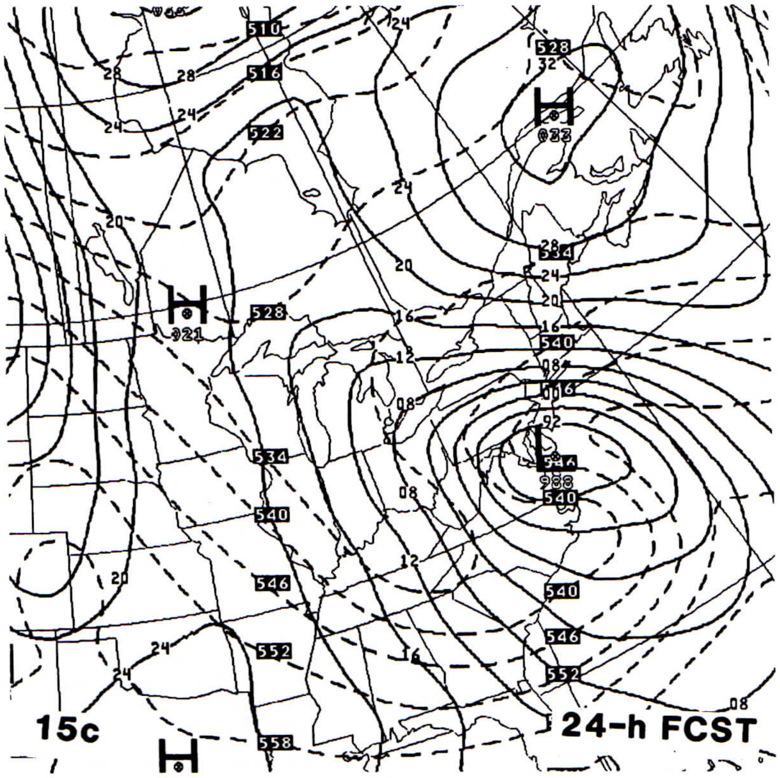
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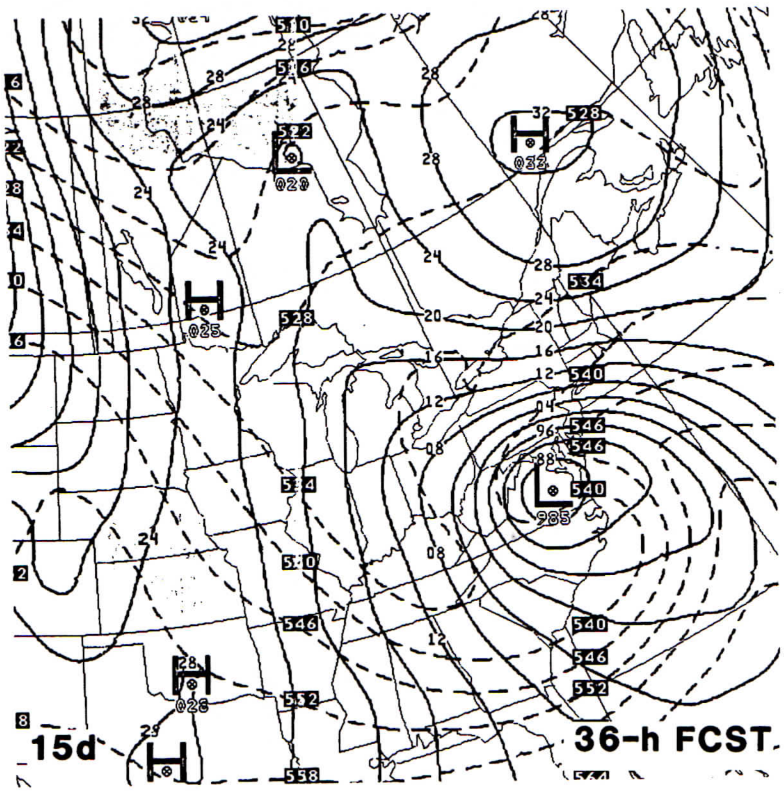
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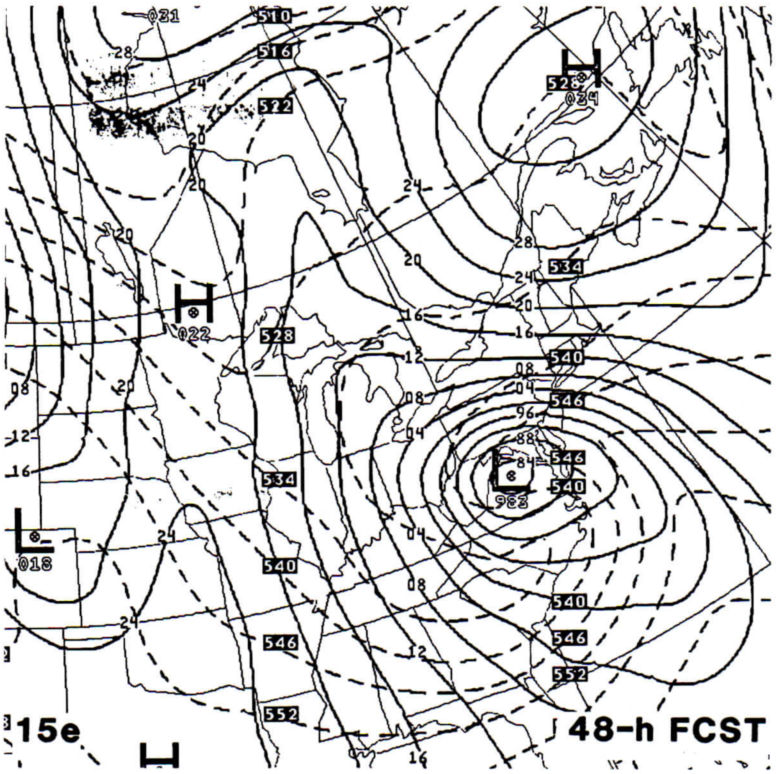
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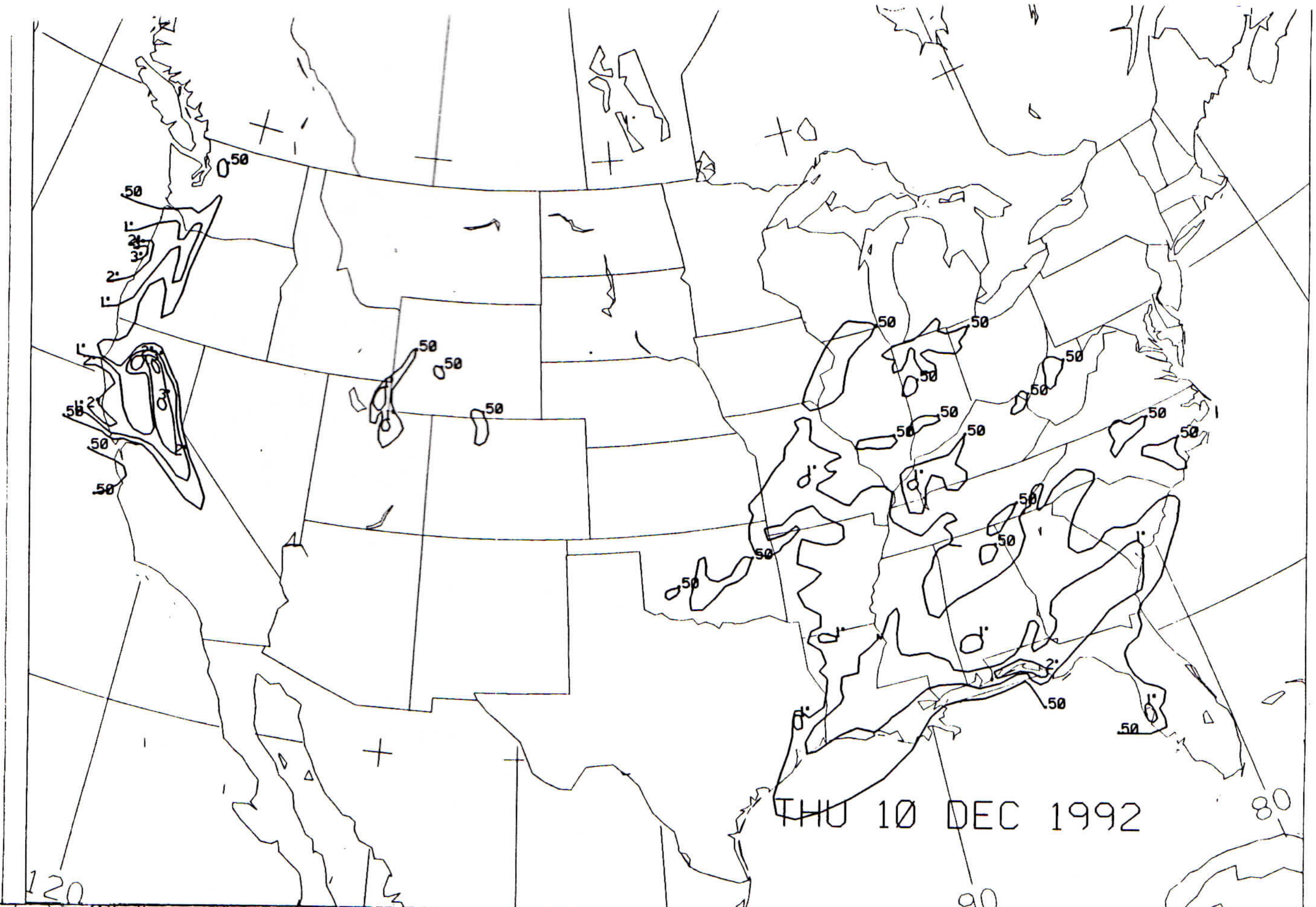
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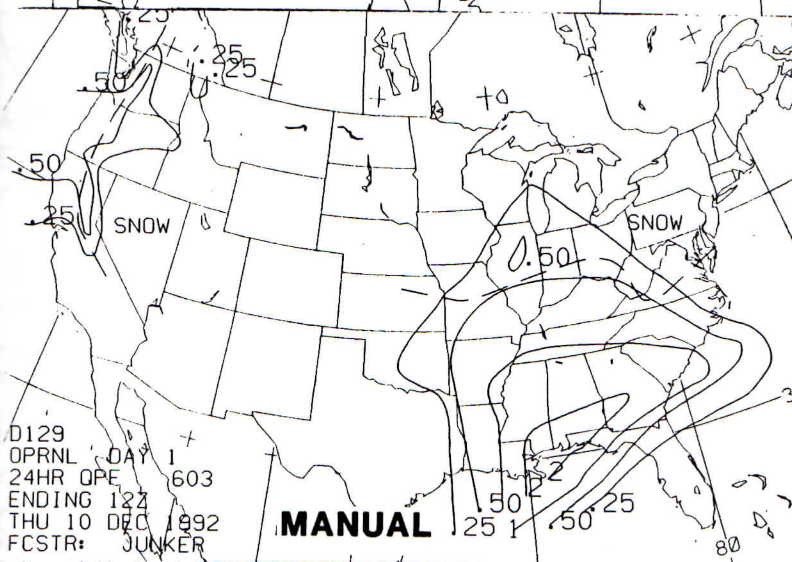
2"
3"
80
90
120


SNOW
SNOW
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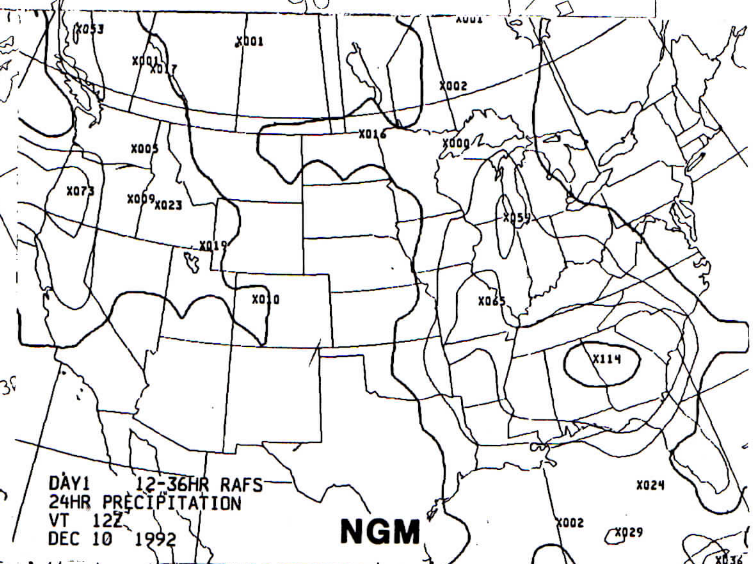
D129
OPRNL DAY 1
24HR QPF 603
ENDING 12Z
THU 10 DEC 1992
FCSTR: JUNKER
MANUAL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VT 12Z
DEC 10 1992
NGM
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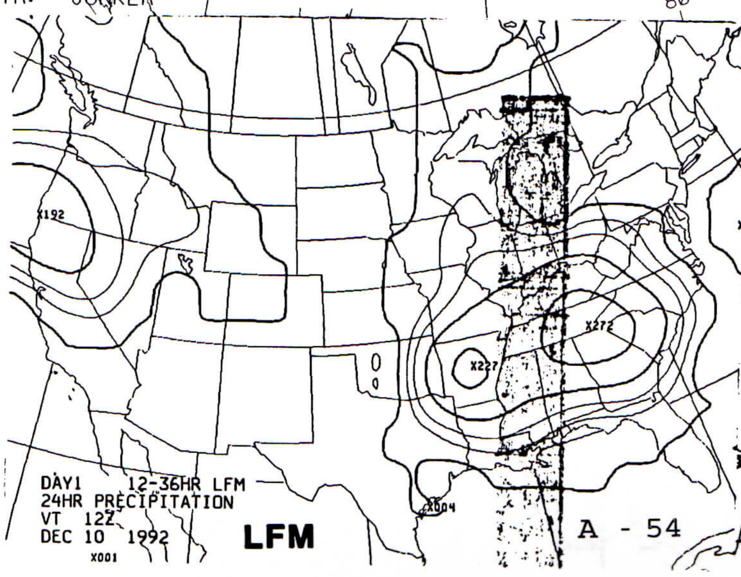
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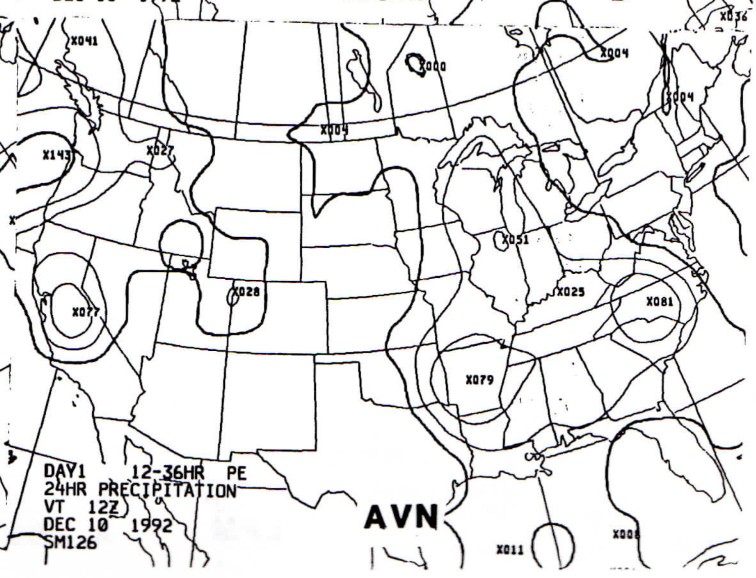
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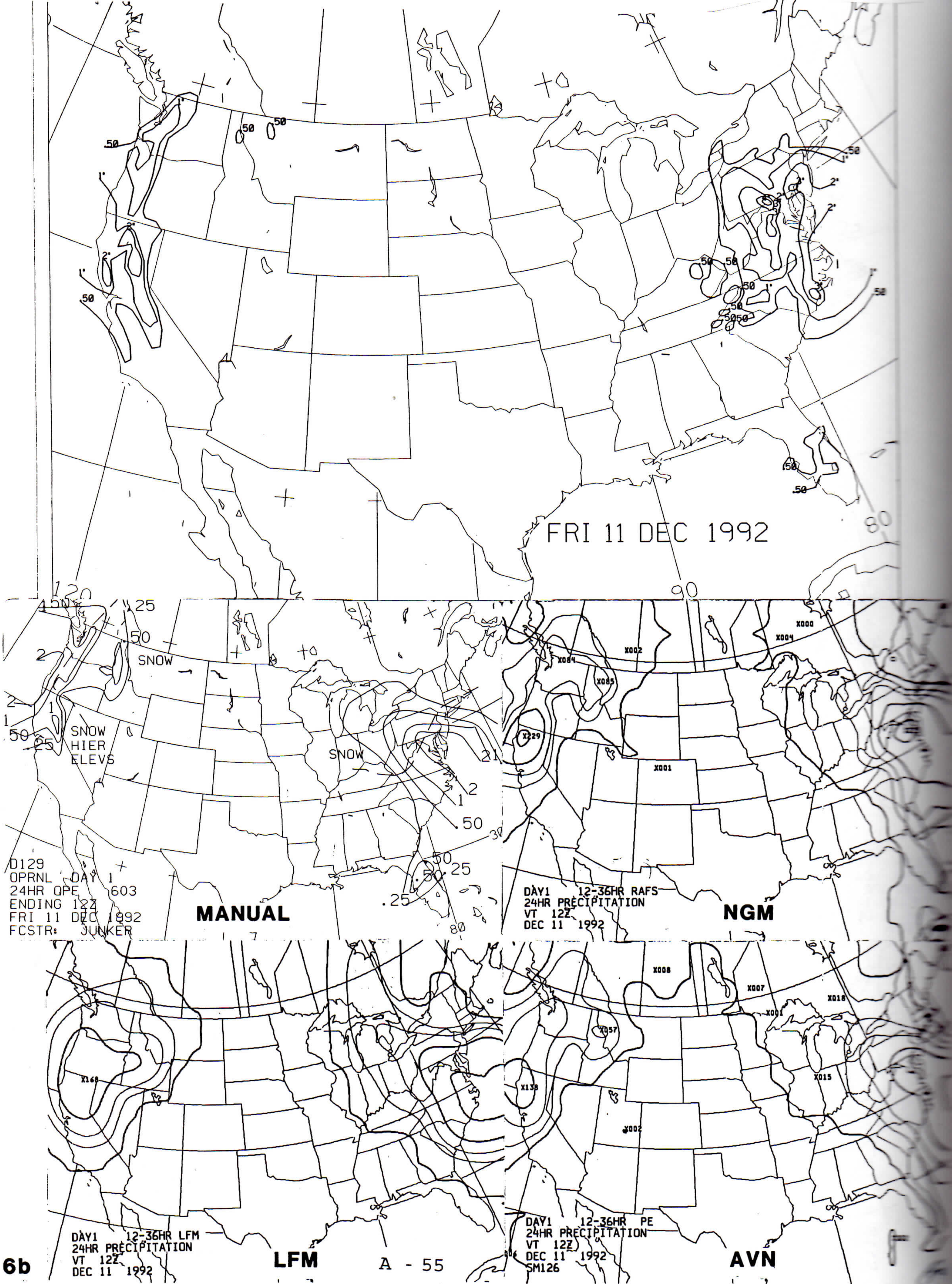
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D129
OPRNL DAY 1
24HR QPF 603
ENDING 12Z
FRI 11 DEC 1992
FCSTR: JUNKER
MANUAL
SNOW
SNOW HIER ELEVS
DAY1 12-36HR RAFS
24HR PRECIPITATION
VT 12Z
DEC 11 1992
NGM
DAY1 12-36HR LFM
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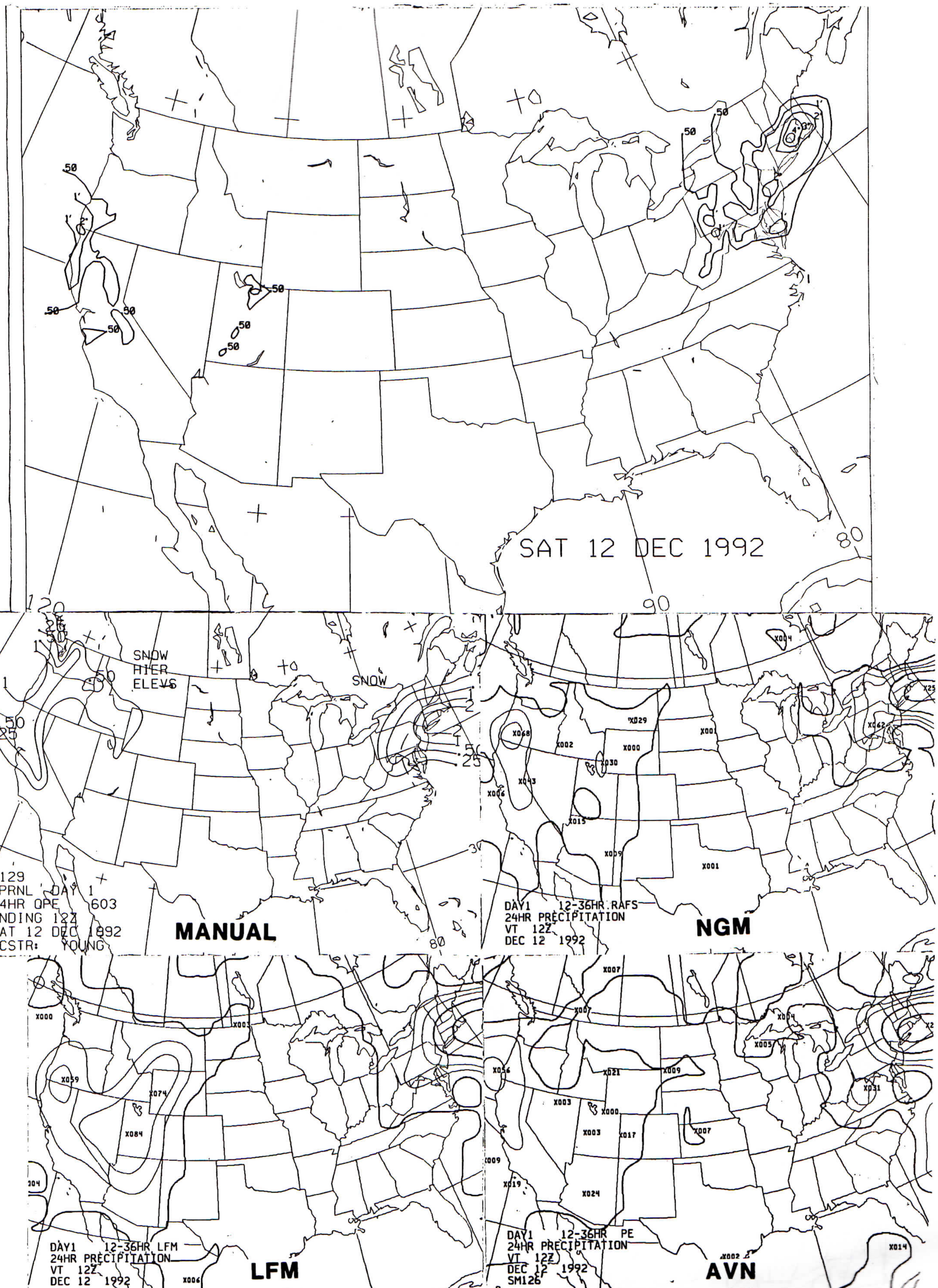
16b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SNOW HIER ELEVS
SNOW
D129
OPRNL DAY 1
24HR QPF 603
ENDING 12Z
SAT 12 DEC 1992
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MANUAL
DAY1 12-36HR RAFS
24HR PRECIPITATION
VT 12Z
DEC 12 1992
NGM
DAY1 12-36HR LFM
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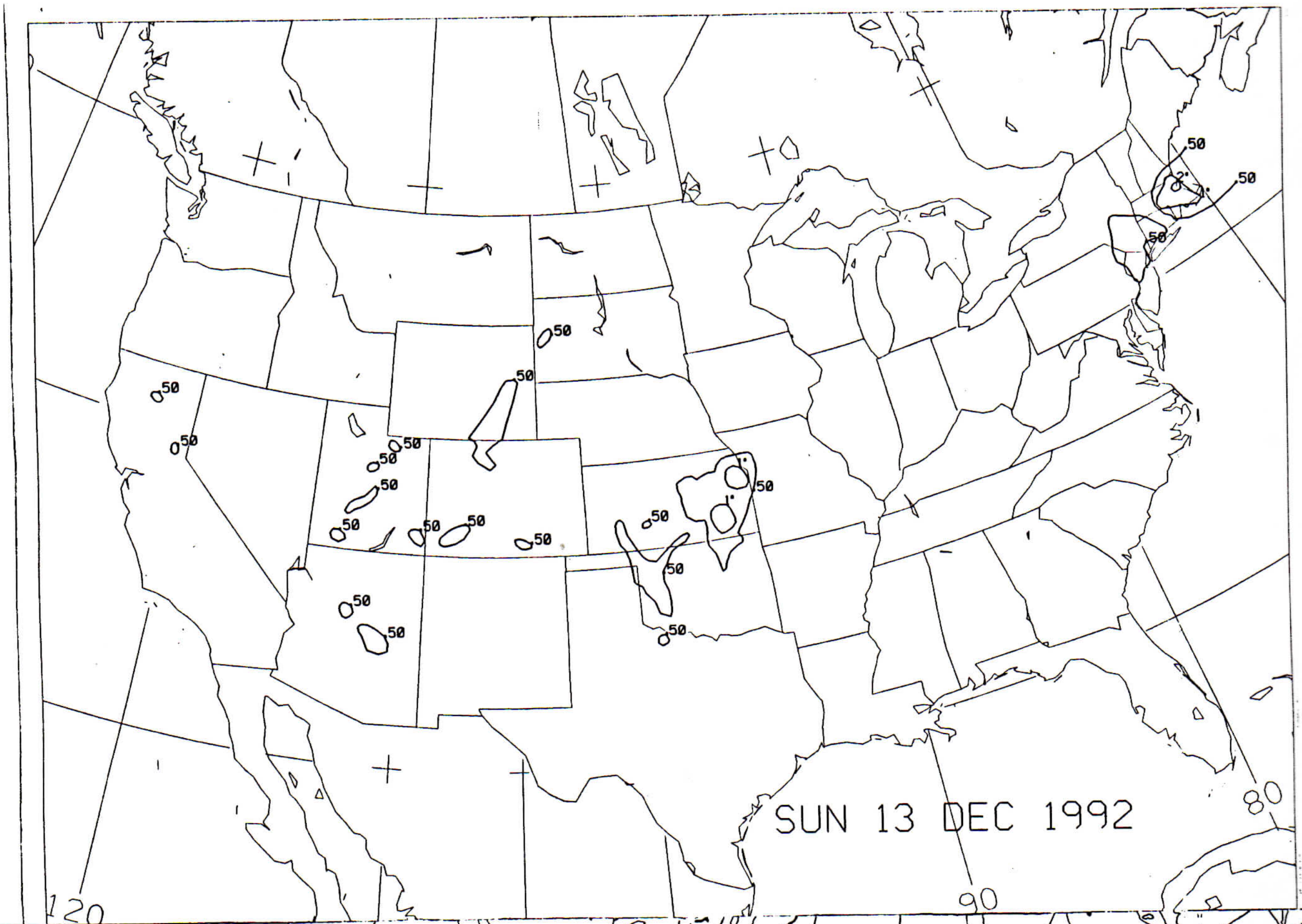
AVN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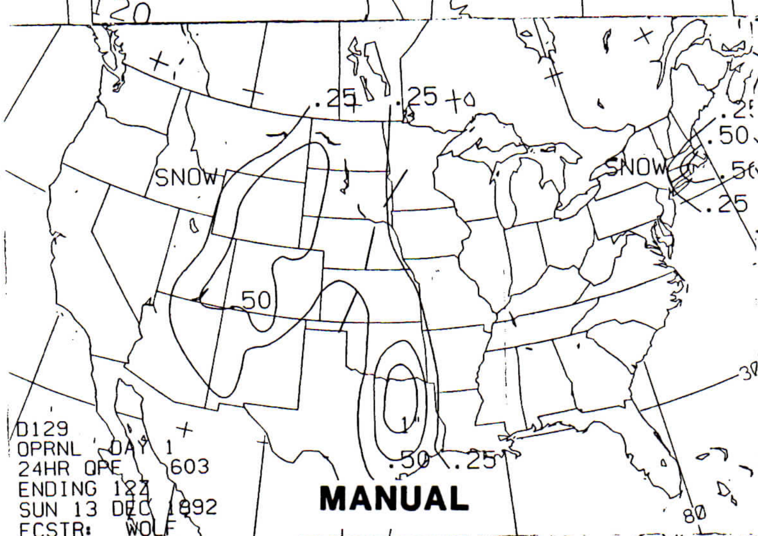
.25
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SNOW
SNOW
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ENDING 12Z
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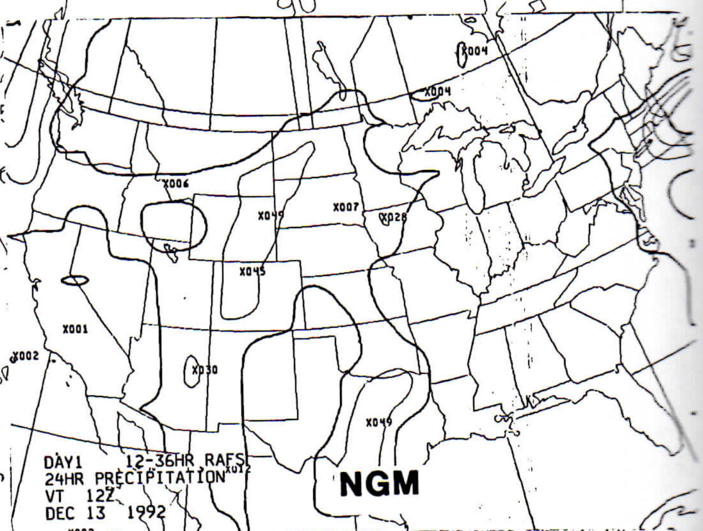
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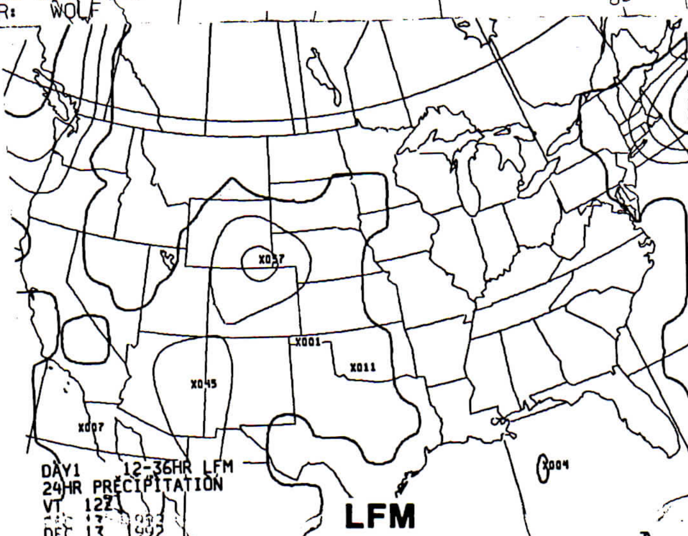
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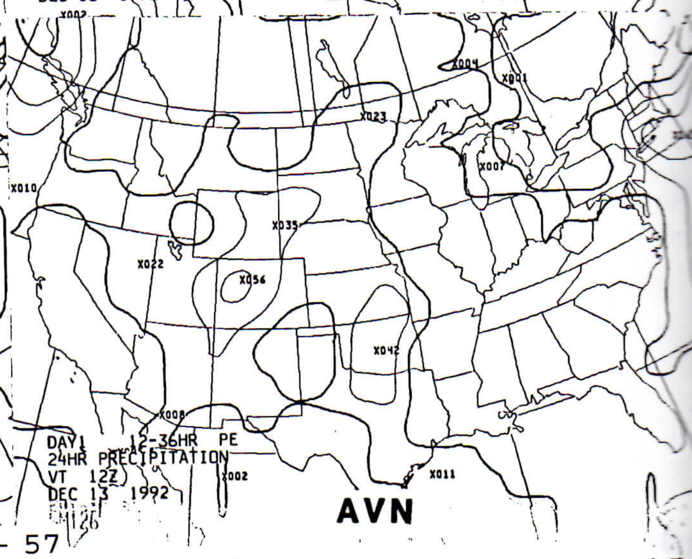
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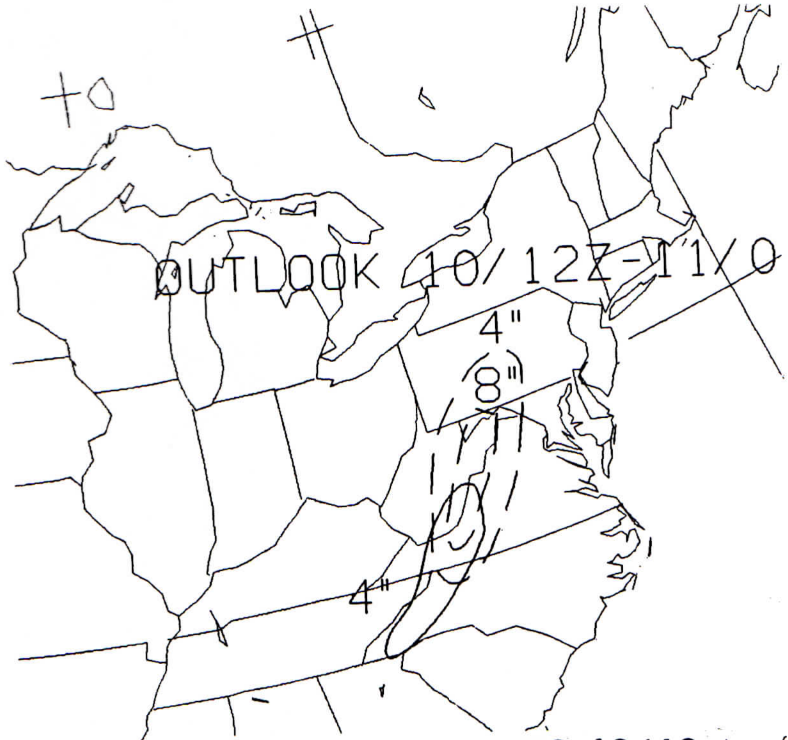

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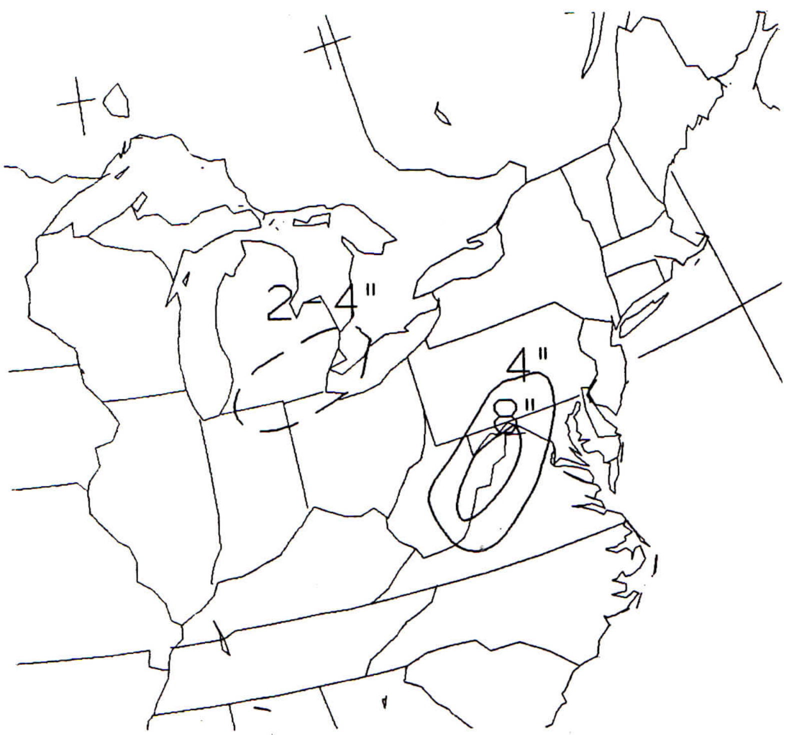

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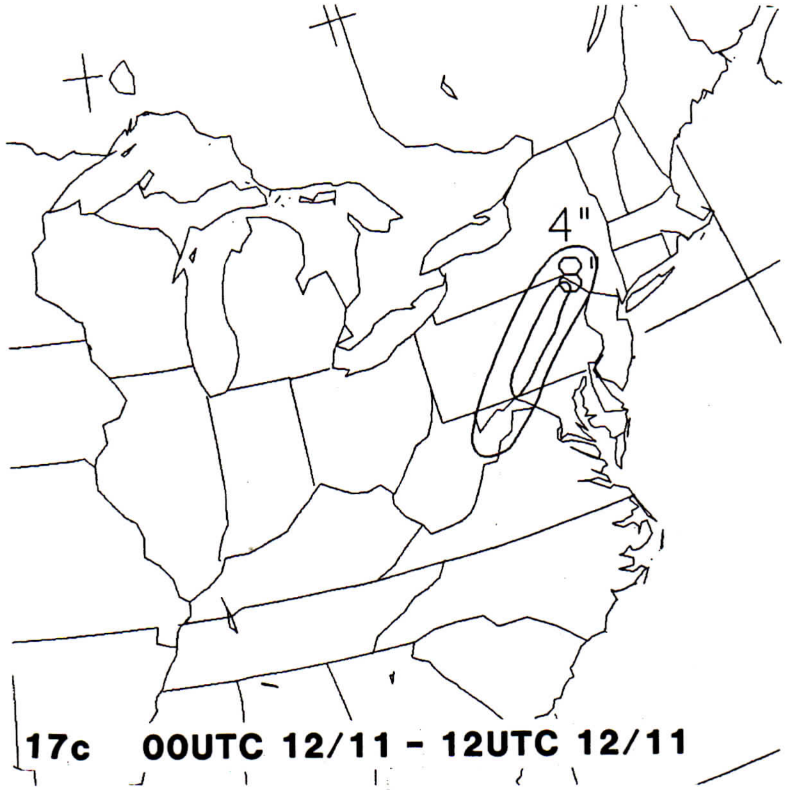

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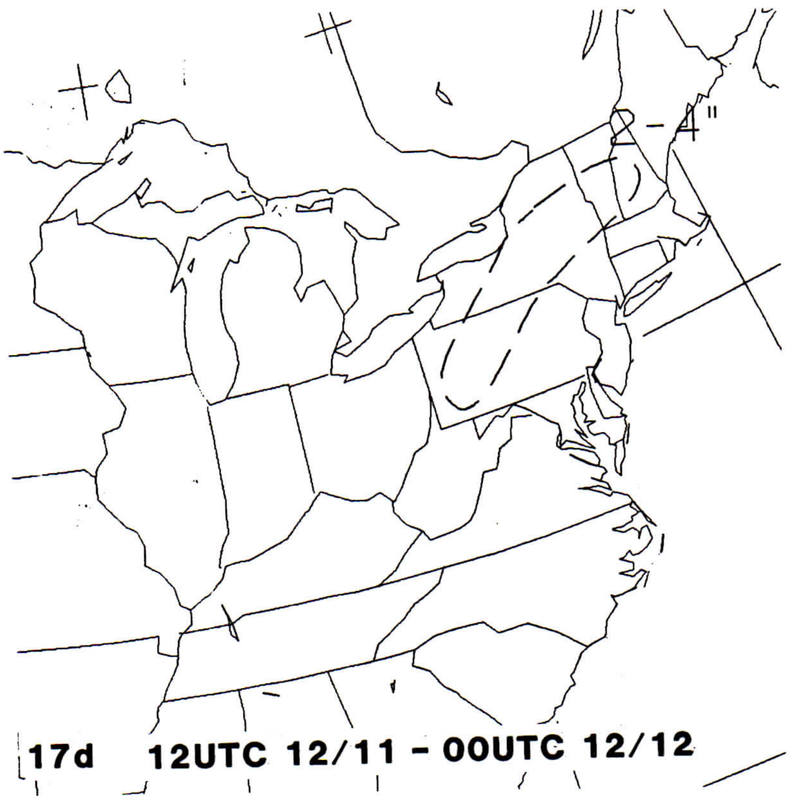

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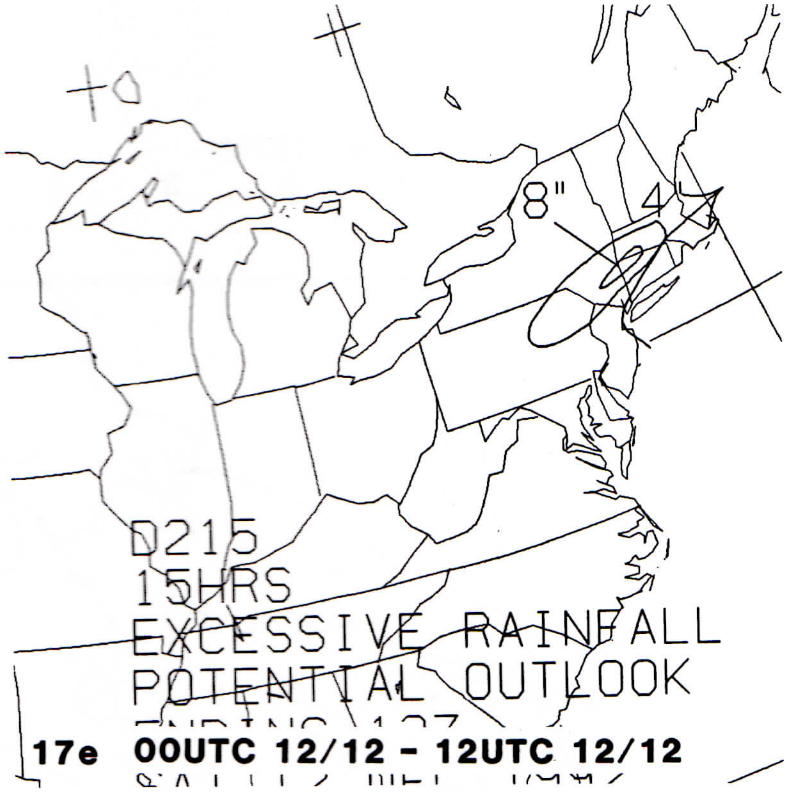

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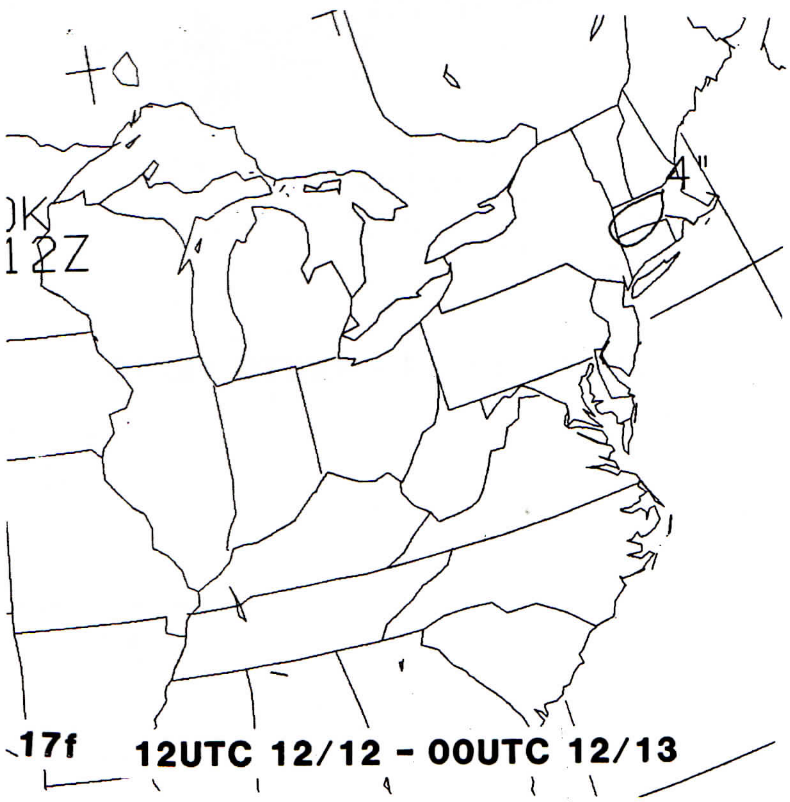

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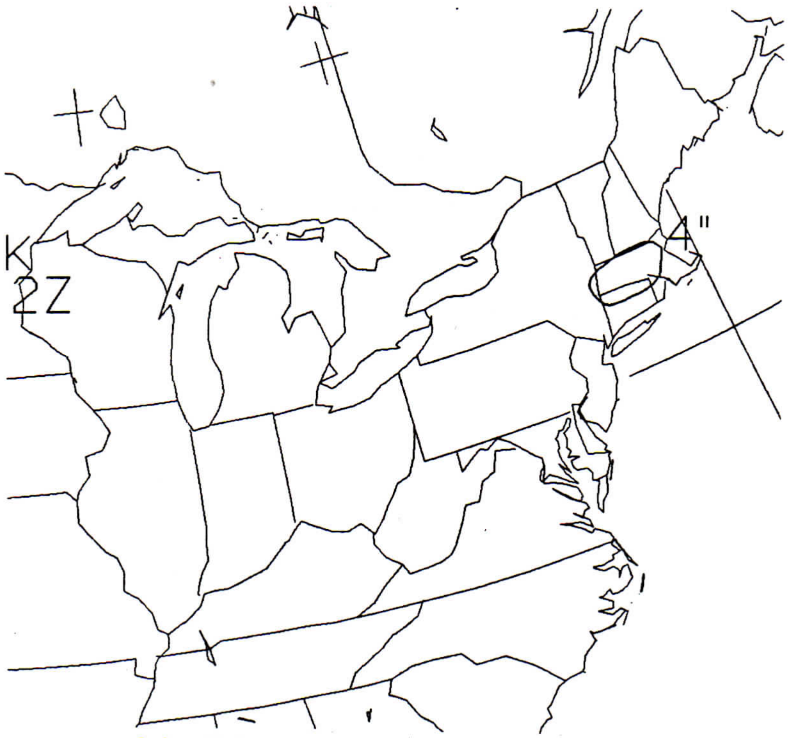

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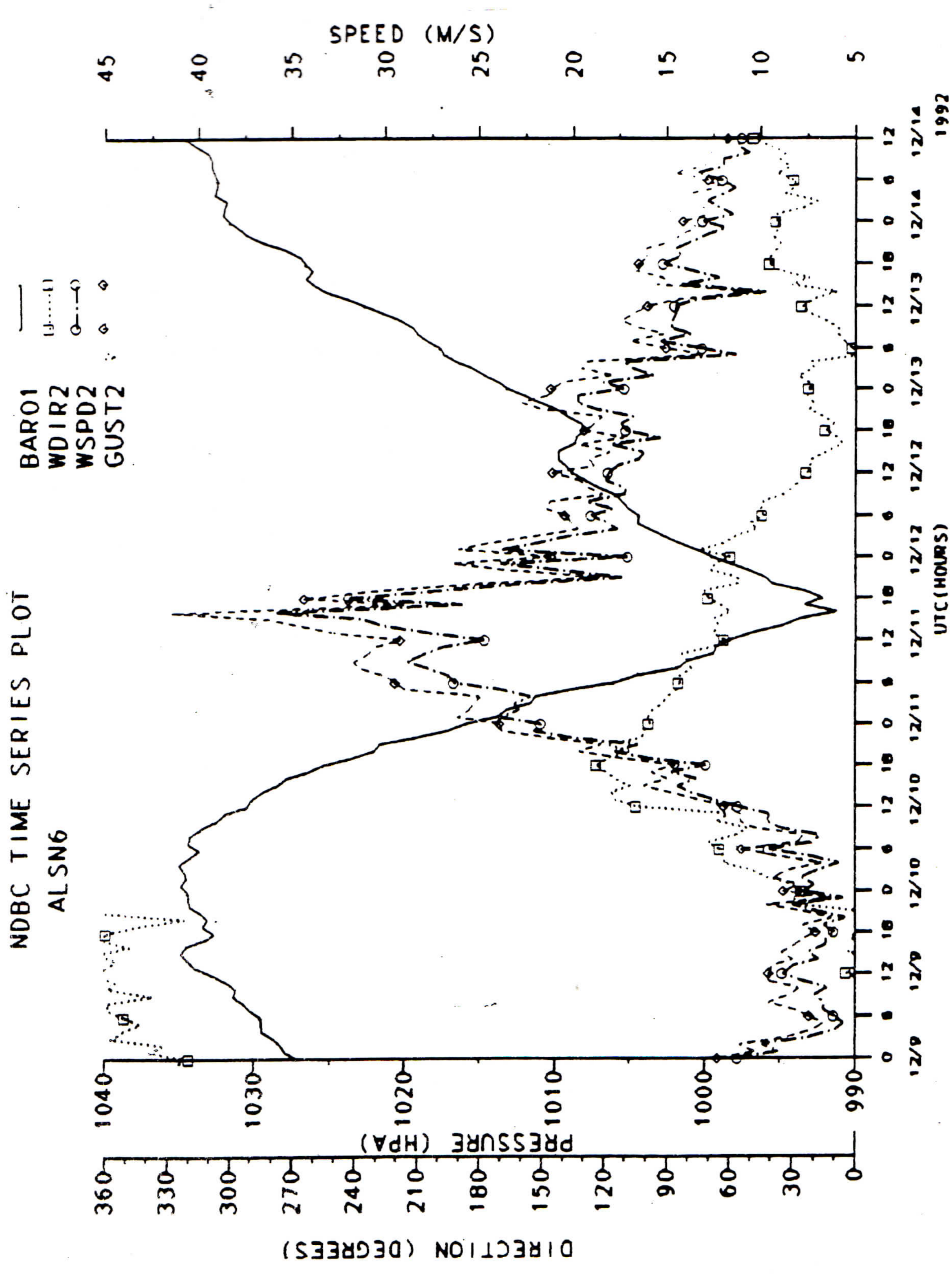
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BARO1
WDIR2
WSPD2
GUST2
SPEED (M/S)
PRESSURE (HPA)
DIRECTION (DEGREES)
UTC(HOURS)
1992