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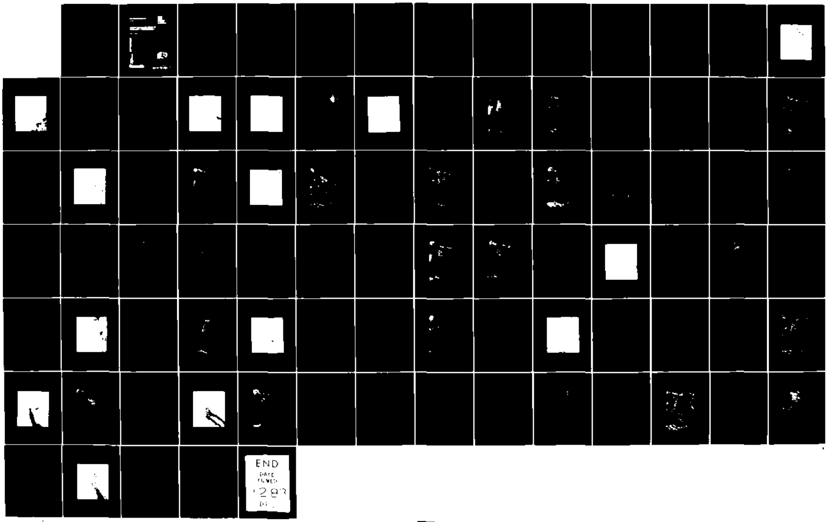

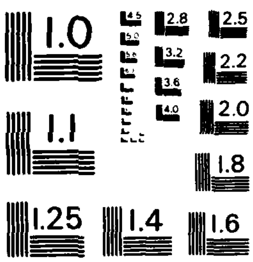

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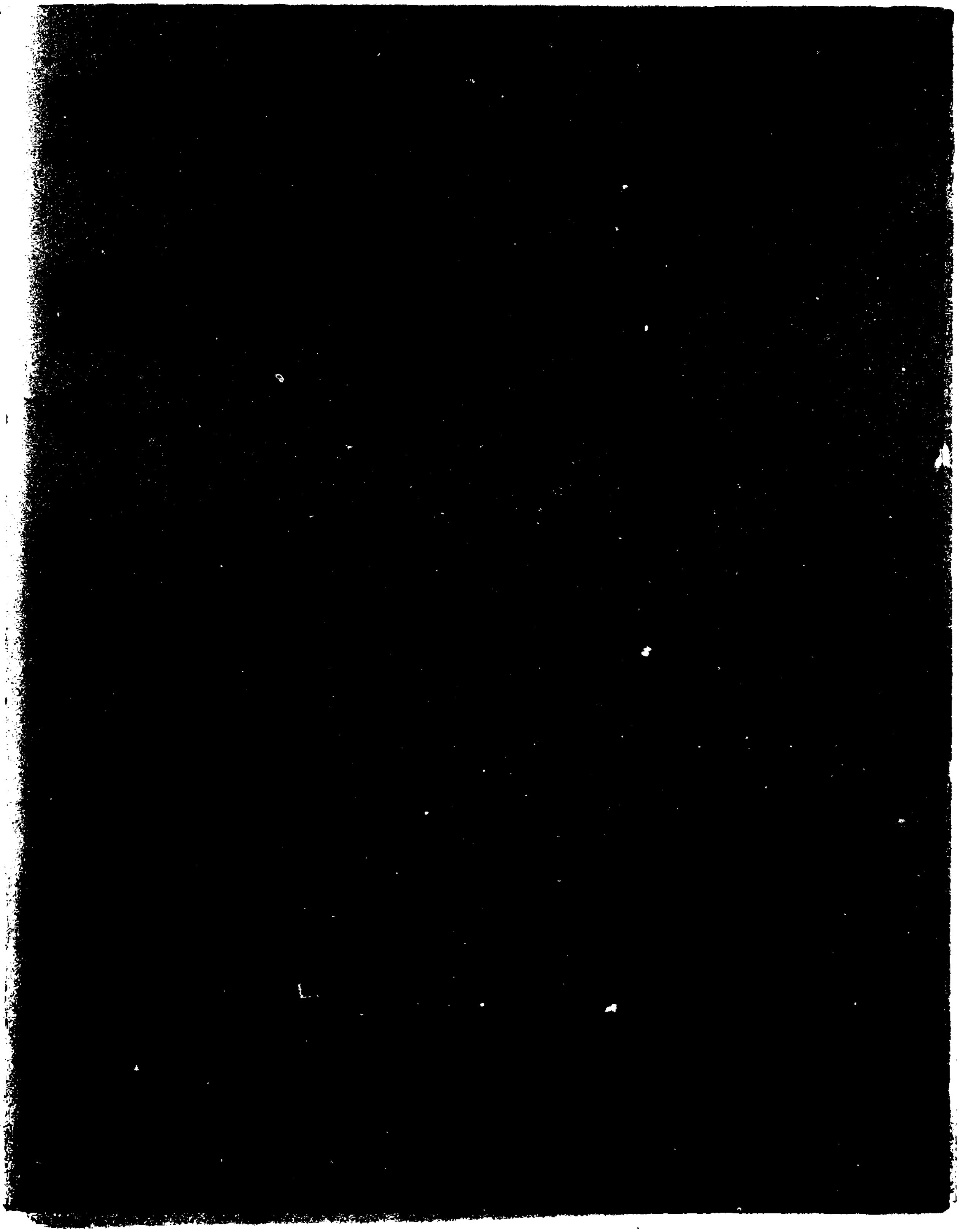

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The daily atmospheric systems and weather fronts that traversed the northeastern United States during the SNOW-ONE-A Field Experiment from 30 November to 20 December 1981 and from 3 January to 10 February 1982 are summarized. This experiment is the second of a series of winter measurements of the influence of atmospheric obscurants on electro-optical system performance. The analysis of the large-scale synoptic weather patterns that developed during the field test period constitutes a critical component of the research program. Precipitation in northern Vermont during SNOW-ONE-A was near normal for the region. Numerous

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20. Abstract (cont'd)

separate snowfall events, including some with substantial amounts of snow, were recorded during the experiment period. Almost all of the storms that produced more than 6 cm of snow resulted from coastal cyclogenesis or developing waves that deepened as they moved north or northeastward along the Atlantic coastline. The majority of the other events with lighter amounts of freezing precipitation were caused by less intense storm systems, troughs, or fronts that traversed the region from the west or northwest and often moved quite rapidly.

PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, formerly of the Geophysical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was performed under DA Project 4A762730AT42-B-E1-5, Winter Battlefield Climatology.

The basic surface weather maps and upper air charts used in this study were provided by the National Weather Service Office at Burlington Airport, Vermont, the National Oceanic and Atmospheric Administration in Washington, D.C., and the U.S. Air Force Weather Service Office at Plattsburgh Air Force Base, New York.

This investigation was performed in conjunction with the SNOW-ONE-A Field Experiment conducted under the supervision of George Aitken, Chief, Geophysical Sciences Branch. The author thanks Dr. Edgar Andreas and Walter Tucker of CRREL for their technical review of the report.

The author wishes to express his appreciation and thanks to the following CRREL employees for their valuable contributions to this study: Stephen Bowen for his professional editorial review of the text, Donna Murphy for her expertise in assembling the report, Nancy Richardson for her patience and cooperation during the typing of the drafts and final manuscript, and Edward Perkins and Matthew Pacillo for their excellent drawing of some of the weather charts.

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SNOW-ONE-A FIELD EXPERIMENT

Michael A. Bilello

INTRODUCTION

The SNOW-ONE-A Field Experiment held from 30 November to 20 December 1981 and from 3 January to 23 February 1982 at Camp Ethan Allen Training Center (CEATC) near Underhill, Vermont, was the second of a series of winter exercises in the U.S. Army Corps of Engineers Winter Battlefield Obscuration Program. The horizontal propagation measurement phase of SNOW-ONE-A ended on 10 February, and a snow cover subtest portion of the experiment continued until 23 February. Since the daily synoptic weather summaries were not required for the latter tests, they are not included in this report. Two of the objectives of the horizontal propagation phase of the experiment were to: 1) extend the data base for electromagnetic energy propagation through falling and blowing snow, and 2) determine the effect of winter hydrometeors on electro-optical system performance (Aitken 1982). To accomplish these objectives measurements were made of airborne-snow mass concentrations and detailed descriptions were compiled of the crystal habit of falling snow.

Forecasts of the probable starting time, areal coverage, duration and intensity of winter storms are principally contingent on the synoptic weather patterns that develop prior to and during each event. The type of frozen precipitation that may be expected, including snowflake size, shape and aggregation, and riming, is strongly dependent on the characteristics of the air masses in which they formed and through which they fell. For example, Jiusto and Weickmann (1973) observed that snowflake aggregates are most common in vigorous mid-latitude storms. And Bilello (1982) noted that cloud droplet attachment (or riming) on falling snow crystals occurs frequently within moist and relatively warm winter air masses. Further studies reported in U.S. Army CRREL (1983) also indicated that atmospheric conditions such as snowfall concentration, aggregation, and riming are key factors in investigations of the absorption and scattering of electromagnetic energy.

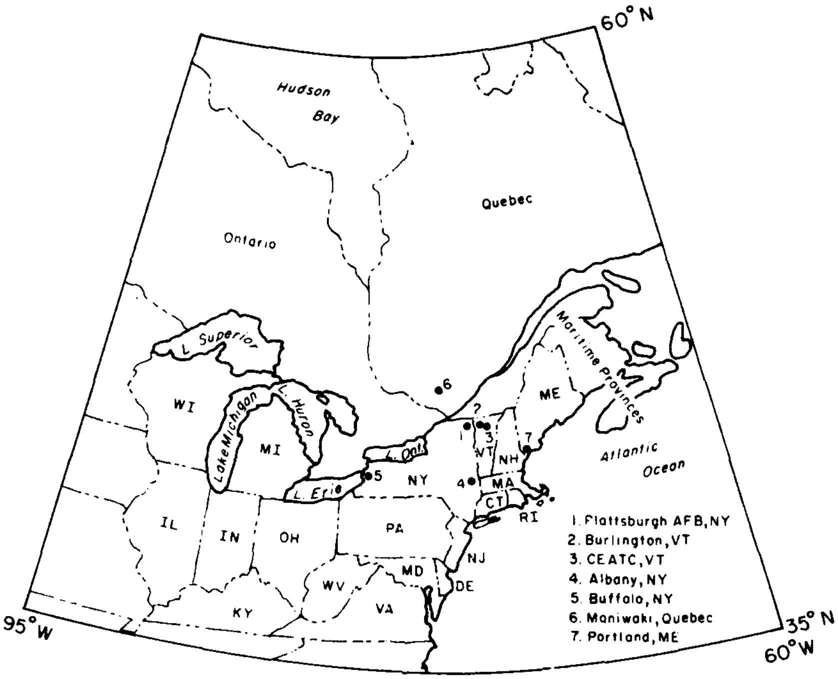

Figure 1. Northeastern United States and southeastern Canada.

Thus, a review and documentation of the atmospheric pressure systems and types of weather fronts that traversed the northeastern United States during the SNOW-ONE-A Field Experiment should be an essential component of the research program. Such information constitutes a part of the chain that links the large-scale weather patterns with the on-site measurement of snow mass concentration and frozen particle characterization and with the data obtained concurrently by the electro-optical sensor systems.

Although some of the basic surface weather maps used in this study are drawn for all of the 48 contiguous states and parts of Canada and Mexico, only the region within a few hundred miles of the SNOW-ONE-A field site in northern Vermont will be discussed here (Fig. 1). This region includes the northeast United States and part of southeast Canada.

The purposes of this report are to: 1) describe the synoptic meteorological conditions that developed over the area of interest during the

SNOW-ONE-A field experiment, and 2) summarize the locally observed surface weather reports issued during the passage of the storms*.

DATA BASE

The daily synoptic summaries presented in this report for the periods 30 November to 20 December 1981 and 3 January to 10 February 1982 are based principally on surface weather maps analyzed by National Weather Service (NWS) personnel. Facsimiles of these weather maps were obtained from the weather office at the Burlington International Airport, Burlington, Vermont, which receives them every three hours.

For many periods, especially when no precipitation fell at the experiment site, the synoptic summaries are brief, so these NWS maps were sufficient for the analysis. However, for periods of heavier snowfall at the site, the surface and atmospheric weather conditions are described in more detail. During these events additional information was used, such as the Plattsburgh Air Force Base, New York, surface sectional weather maps, the NWS upper-air weather charts, and other relevant large-scale meteorological data.

Since further details and, possibly, additional large-scale meteorological data may be required by other SNOW-ONE-A investigators, arrangements were made with the Burlington and Plattsburgh personnel to collect and forward copies of the following surface and upper-air weather data to CRREL:

1. National surface weather maps (every three hours).
2. Sectional surface weather maps (every three hours, but less frequently during fair weather periods).
3. Temperature and height contour charts for the 850-, 700- and 500-mb pressure levels (twice daily).
4. Numerically coded radiosonde data transmissions for Buffalo and Albany, New York; Portland, Maine; and Maniwaki, Quebec, Canada (twice daily).
5. National weather depiction charts (every three hours).
6. Satellite weather analysis (daily).

*Hourly records of the various CEATC and Burlington International Airport meteorological observations discussed in this report were taken respectively from Aitken (1982) and the U.S. Department of Commerce (1981-82).

Reference to portions of the above information is made throughout this report. All of the listed data for the periods 30 November to 20 December 1981 and 3 January to 10 February 1982 have been chronologically archived at CRREL and are available to all SNOW-ONE-A participants.

SYNOPTIC METEOROLOGY SUMMARIES

Significant changes in the synoptic weather patterns for a localized region generally do not occur within short periods of time. In most cases an interval of 12 hours is used in the daily summaries. More frequent time intervals are given for periods of inclement weather or when a frontal system was moving rapidly across the area of interest.

The following daily descriptions of the surface weather conditions are presented chronologically. Times throughout the report are based on 0000 to 2400 hours Eastern Standard Time. Definitions of the meteorological terms used in the study are given in Appendix A of Bilello (1981).

NOVEMBER AND DECEMBER 1981

0700, 30 November

A high pressure cell centered over West Virginia brought fair weather conditions across all of the northeastern United States. Skies over New England were clear to partly cloudy and surface air temperature ranged between -2° and -8°C.

1900, 30 November

The high cell moved east-northeast and fair weather continued throughout New England. A deep low pressure cell (986 mb at its center) formed over the central United States and rain or snow was reported over a large region.

0700, 1 December

The high moved further east as the low to the west tracked northeast toward the Great Lakes. Skies over New England became more cloudy, and the leading edge of the precipitation associated with the approaching storm reached western New York and Pennsylvania.

1900, 1 December

As the high cell moved off the east coast, the low to the west continued northeast and was located over the central Great Lakes. Winds over most of New England changed from northerly to southerly, and light rain or snow showers were occurring over parts of the northeast. Locally, the air temperature increased to near 0°C and precipitation changed from light freezing rain to light drizzle, with only trace amounts being recorded.

0700, 2 December

The high and low pressure cells both stalled somewhat, and local weather conditions, except for a steady increase in air temperature to near 5°C, continued as before. The sky remained overcast and little or no precipitation had occurred during the past 12 hours.

1900, 2 December

The trough zone associated with the low over the Great Lakes crossed the local region at about 1300 hours. The atmospheric pressure started to rise, the air temperature fell slightly, and the wind direction shi briefly from southeast to southwest. No precipitation occurred in immediate area during the transition. A residual low pressure zone however, remained over North Carolina behind a weak cold front that extended southward from the main low.

0700, 3 December

A shallow cyclonic wave formed within the residual low pressure zone and the system moved to about 250 km off the Virginia-Delaware coastline. Skies over New England remained mostly overcast and air temperatures were above freezing. Precipitation was limited mostly to regions along the northeast coastline. A satellite image of the cloud pattern associated with this coastal storm (taken at 1030 EST on 3 December) is shown in Figure 2. This image and all other such figures in this report are from the visible region of the electromagnetic spectrum obtained by the Geosynchronous Operational Environmental Satellite-East (GOES-E) system*. These images were recorded at Plattsburgh AFB, New York, and were made available for use in this report by the Air Weather Service personnel.

1900, 3 December

The cyclonic wave off the coast deepened and slipped rapidly northward toward Nova Scotia. The system brought light rain, light drizzle, or light rain showers with periods of fog to northern Vermont. Air temperatures remained above freezing and visibility at the site occasionally decreased to 3.2 km. Another shallow low located in the central United States had meanwhile tracked northeastward and was centered south of Lake Michigan.

*Further information on the sensor characteristics and details of the GOES-E satellite are given in a guide to environmental satellite data prepared by Cornillon (1982).

Figure 2. Satellite image of the cloud pattern over the eastern United States taken at 1030, 3 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

Figure 3. Satellite image of the cloud pattern over the eastern United States taken at 1300, 4 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

0700, 4 December

The coastal wave continued northward into the Canadian Maritimes. The shallow low south of the Great Lakes had started to track eastward and was positioned over Ohio. The weather between these two systems (i.e. over most of New England) ranged from clear to overcast skies with no reported precipitation. A GOES-E satellite image taken at 1300 EST on 4 December shows the cloud shield surrounding the low pressure system over Ohio, and the cloud pattern with the disturbance off the New England coast and into the Maritime region (Fig. 3). Overnight air temperatures in the local region were near freezing.

1900, 4 December

The shallow low pressure zone over Ohio reached the coast and a definite cyclonic wave formed at its center. The peak of the wave was over

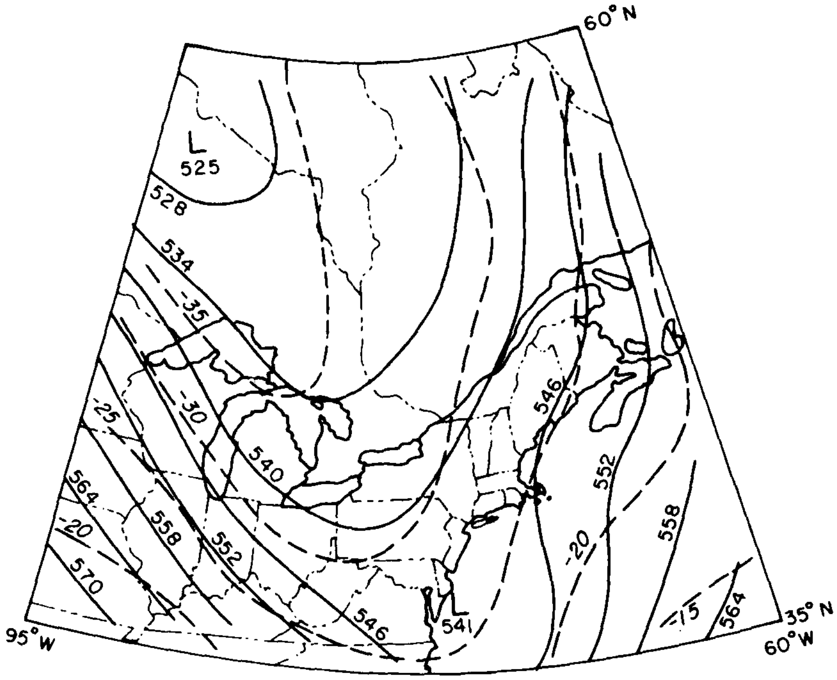

Figure 4. Weather chart for 500-mb level, 0700, 5 December 1981. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

Cape Hatteras, and moderate rain due to this system had broken out over the central coastal states. Rain, snow, or snow showers were still being reported at many locations around the Great Lakes. Over northern Vermont skies remained mostly cloudy but air temperatures started to fall to below freezing.

0700, 5 December

The cyclonic wave over Cape Hatteras had moved slightly eastward and was about 400 km out to sea. A deep trough along the Atlantic seaboard at the 500-mb level indicated further deepening and a northward track of this system (Fig. 4). Skies over northern Vermont had become overcast and air temperatures hovered near freezing. Precipitation continued in parts of the central coastal states and the Great Lakes. An excellent view from space of this developing storm made at 1301 EST on 5 December is shown in Figure 5.

1900, 5 December

The cyclonic wave off the east coast deepened rapidly and raced northward toward the New England coast. The central pressure of the system had decreased from 996 mb to 980 mb in 12 hours, and the storm exhibited several characteristics typical of a classic New England "nor'easter." Intermittent light snow had begun across northern Vermont during late afternoon and the atmospheric pressure was falling. Air temperatures remained at or just below freezing and northerly surface winds started to increase in strength.

0700, 6 December

The center of the intense storm off the New England coast continued to deepen to 966 mb as it tracked very slowly northward. The system produced significant rainfall in the coastal region and snow in the interior. Snowfall across northern Vermont became steady, and the ceiling, visibility, and atmospheric pressure decreased rapidly. Air temperatures ranged between -3° and -7°C at the site, and wind speeds in the area were strong, with periods of blowing snow. The intensity of this storm is indicated by the massive cloud pattern and compact cyclonic swirl shown in the GOES-E image taken at 1431 EST on 6 December (Fig. 6).

1900, 6 December

The center of the intense coastal storm stalled over the Gulf of Maine (Fig. 7) and poor weather conditions persisted across most of New England

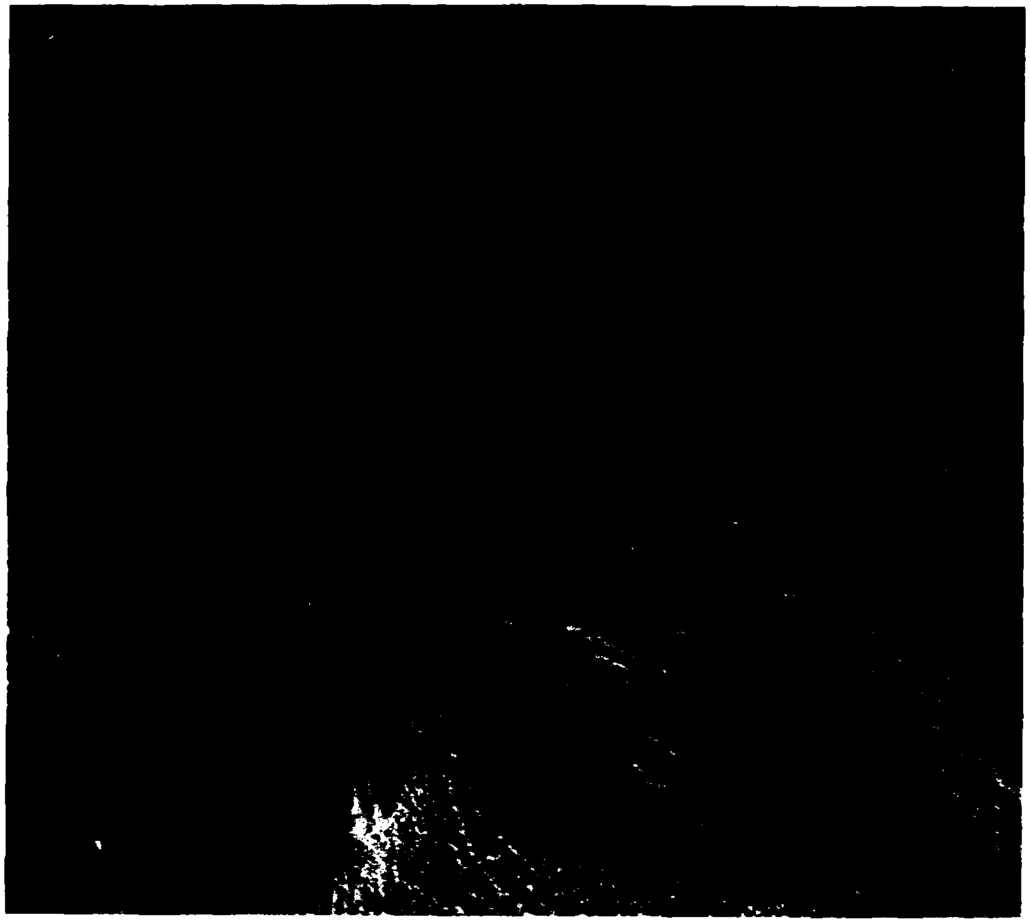

Figure 5. Satellite image of the cloud pattern over the northeastern United States taken at 1301, 5 December 1981. *Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.*

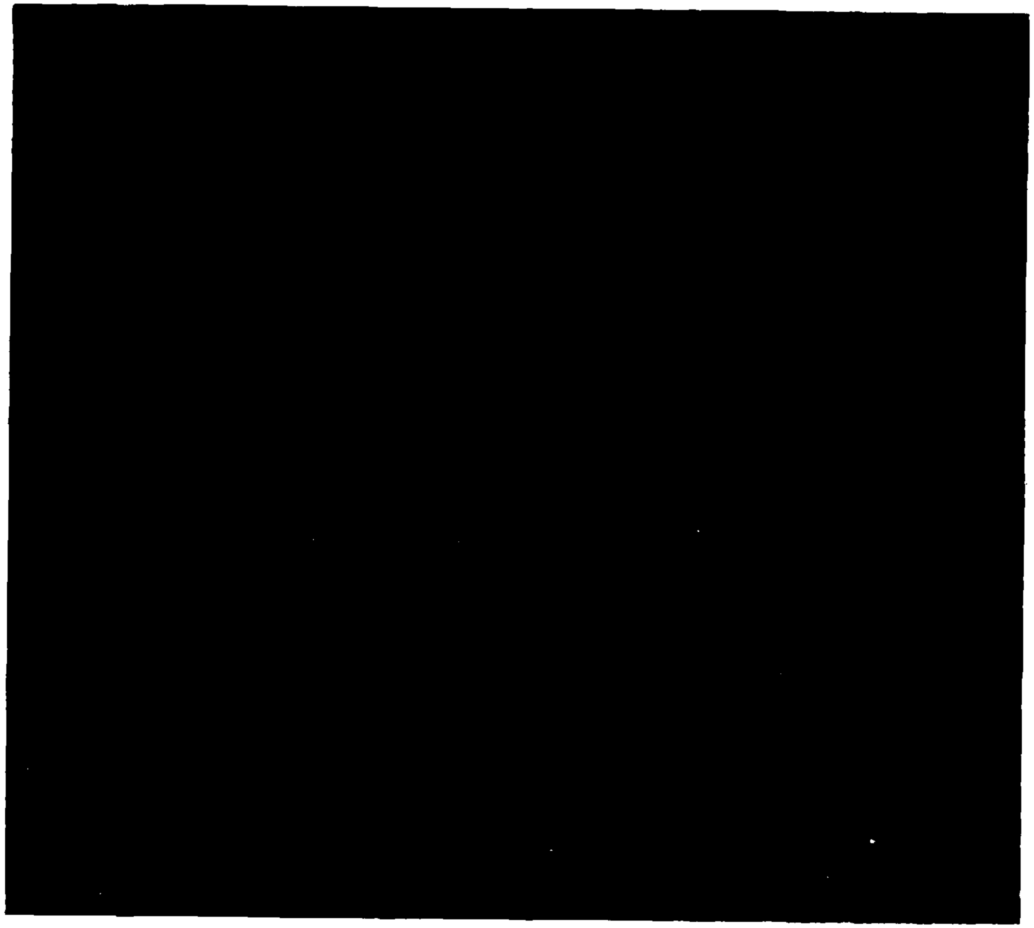

Figure 6. Satellite image of the cloud pattern over the northeastern United States taken at 1431, 6 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

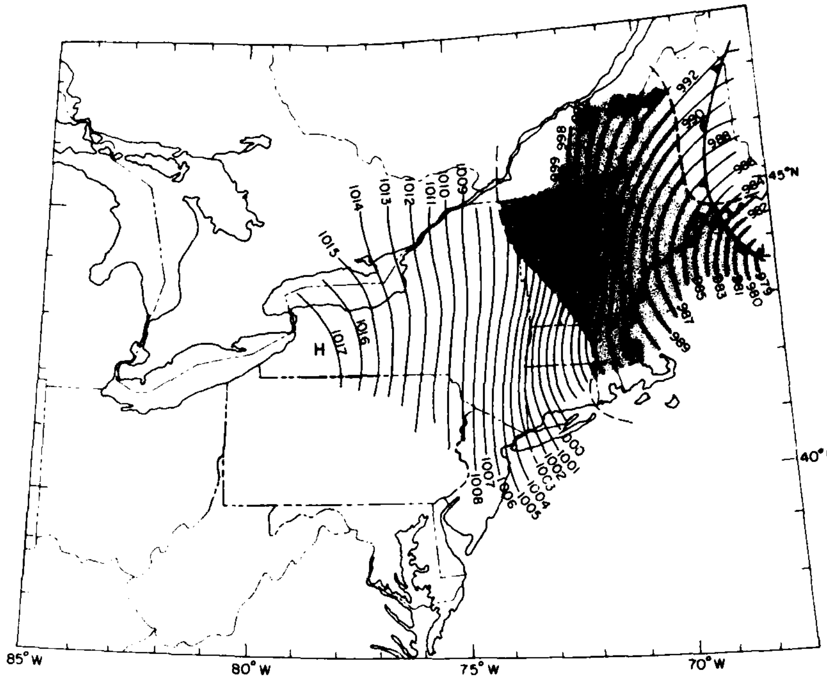

Figure 7. Surface weather map, 1900, 6 December 1981. The precipitation zone is shaded.

throughout the day. Snowfall at the site peaked during the midday hours, with airborne snow mass concentration of over 1.0 g/m^3 occurring between 1712 and 1732 hours, as recorded by Lacombe (Aitken 1982). Visibility at the site decreased to less than 1.5 km in snow and fog during much of the day and cloud base heights frequently lowered to less than 1000 m. The observed cyclonic northeasterly wind flow, the influx of oceanic moisture, and the uniform air temperatures (at -4° to -6°C) were characteristic of a "nor'easter."

0700, 7 December

During the preceding 12 hours the center of the coastal storm remained almost stationary, and the system rapidly weakened. The atmospheric pressure at its center rose to 980 mb and the weather around the low improved considerably. The center of the storm as seen from space at 1201 EST on 7 December was off the south coast of Nova Scotia (Fig. 8). Snowfall in northern Vermont tapered off after midnight. However, total snowfall

Figure 8. Satellite image of the cloud pattern over the northeastern United States taken at 1201, 7 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

accumulation for the storm reached 36.0 cm at the site, with a water equivalent value of 28.0 mm. This one-day snow total was one of the highest recorded at the site during SNOW-ONE-A*.

1900, 7 December

As the coastal storm continued to weaken and drift off to the northeast, another shallow low pressure zone over the Great Lakes tracked eastward. Skies over northern Vermont became partly cloudy, visibility was excellent, winds abated, and the air temperature started to decrease.

0100, 8 December

The low pressure zone located over the Great Lakes caused snow to fall in scattered sections of New York. A warm front associated with this storm extended southeast across central New York, and a cold front ran south across Lake Erie and through eastern Ohio. The air masses surrounding this low appeared moist and relatively warm, as indicated by the numerous rain showers, fog, and above-freezing air temperatures reported around the system.

0700, 8 December

The center of the Great Lakes low drifted southeast to over Lake Ontario, and the warm front extended east over southeastern New York and southern New England. Meanwhile the cold front spread east to central Pennsylvania and south through Virginia (Fig. 9). The precipitation shield associated with this storm reached eastern New York, skies over northern Vermont became overcast, and air temperatures increased slowly through the night.

1600, 8 December

The low center over Lake Ontario passed south of the local region and moved rapidly off the coast of New England. The system then started to deepen, and an extensive surface flow of air from the north and northwest started to build over the Northeast. Snow began to fall in the late afternoon across northern Vermont, and the ceiling and visibility decreased rapidly. The mid-afternoon air temperatures across the local area were near -3°C.

*Further analyses were made of the atmospheric conditions, including upper-air temperature and humidity data, and the snow crystal types observed during this event and during the storms of 9-10, 16 and 18 December 1981; 11, 13, 23 and 31 January 1982; and 1 and 9 February 1982 by Bilello and O'Brien (1983).

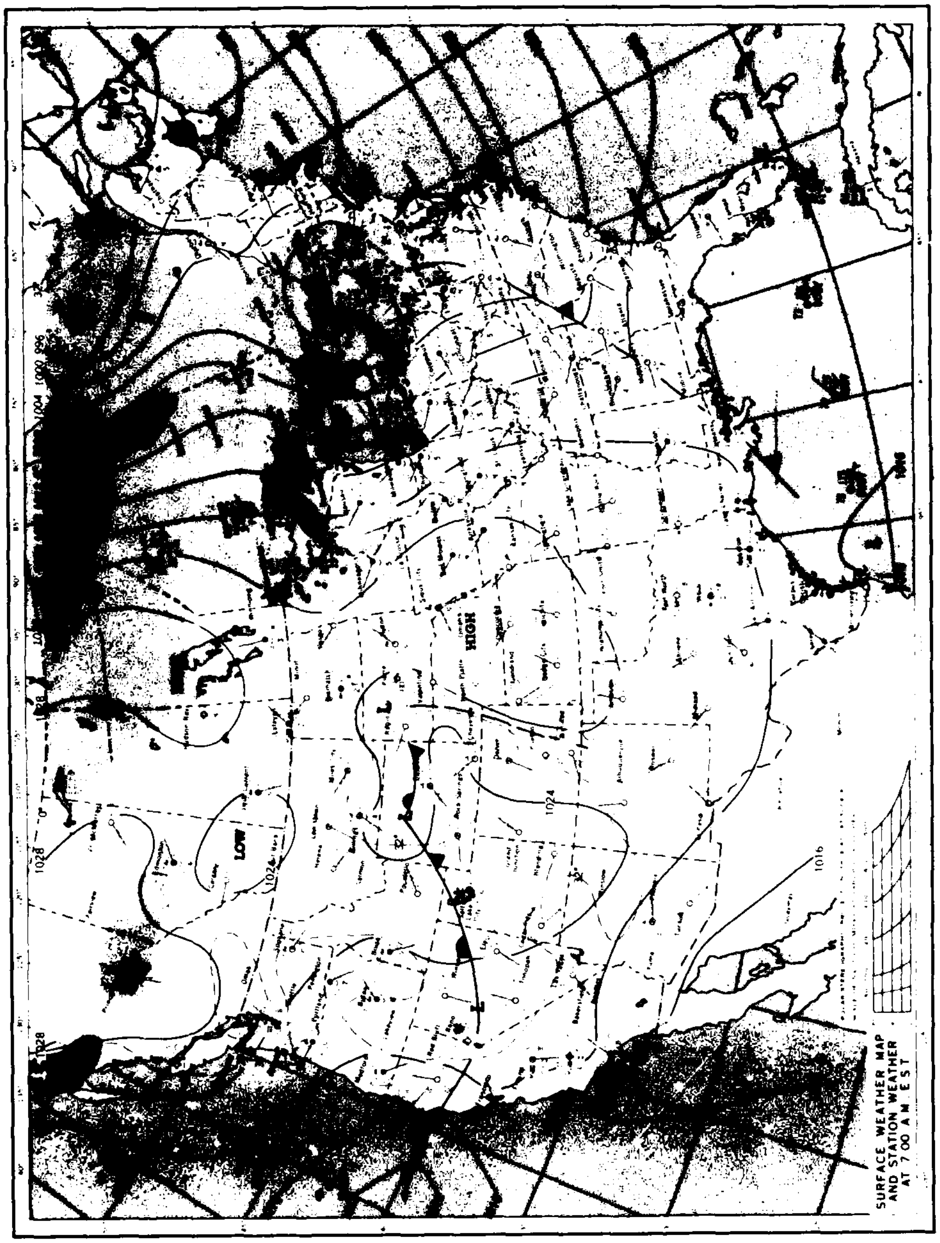

Figure 9. Surface weather map and station weather, 0700, 8 December 1981.

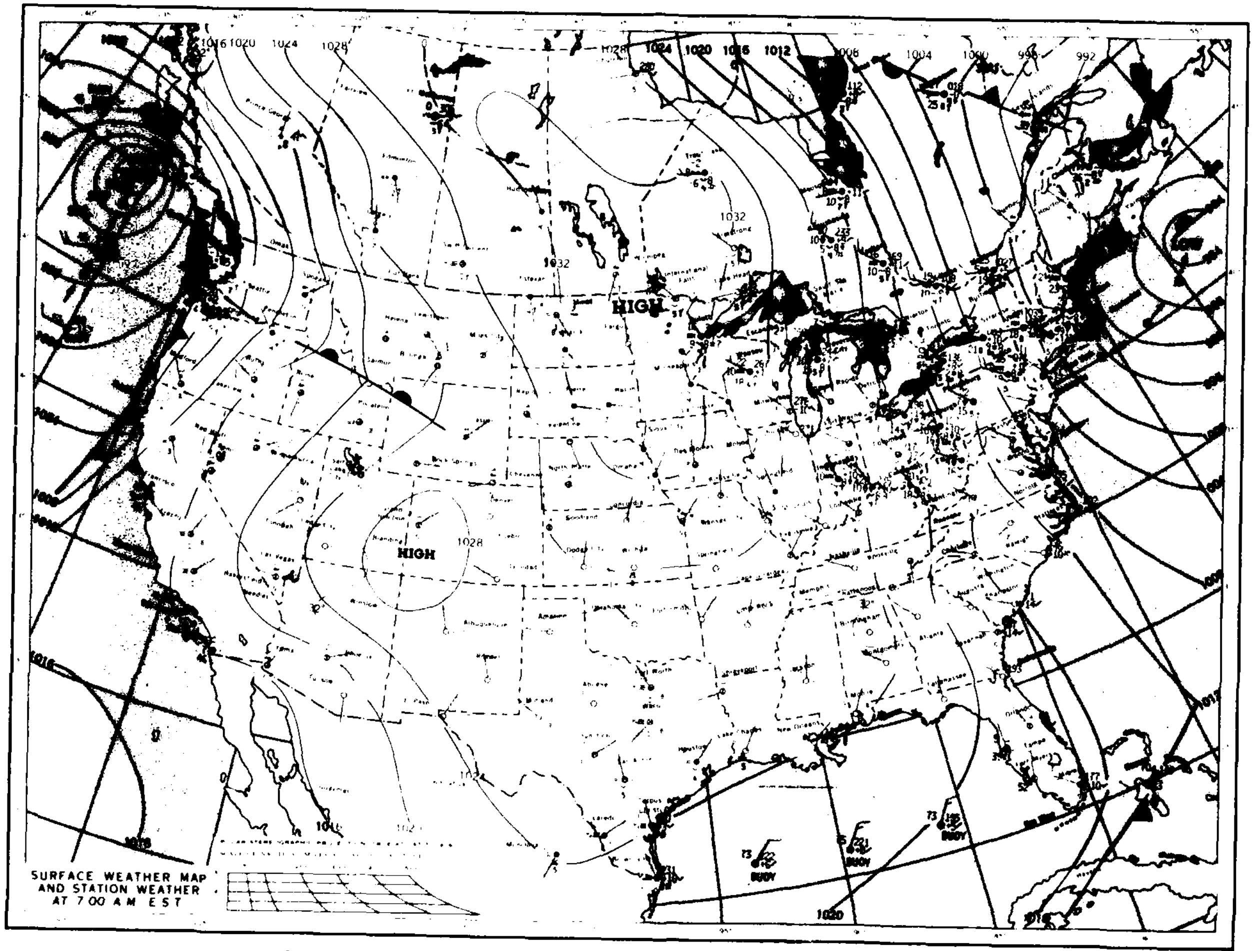

Figure 10. Surface weather map and station weather, 0700, 9 December 1981.

0100, 9 December

Light snow continued to fall throughout the evening hours and occasionally reduced the visibility to as low as 1.6 km at Burlington Airport, Vermont*. As the low off the coast became more intense the atmospheric pressure gradient across New England and westward to the Great Lakes steepened, and the northerly wind at Burlington increased. Air temperatures, however, fell only slightly to about -7°C, with dew points near -9°C at the experiment site.

0700, 9 December

The low center gradually moved further out to sea toward Nova Scotia, but the extensive northerly flow of air behind this system continued to influence all of the northeastern United States and southern Canada (Fig. 10). Light snow or snow showers were reported throughout much of this region of unstable air. Wind gusts of over 10.3 meters per second (m/s) were recorded at Burlington Airport from 0400-0700, and periods of blowing snow were observed. Little change in air temperature or relative humidity occurred at the site.

1900, 9 December

The surface synoptic weather pattern remained essentially unchanged throughout the day. The strong northerly flow of air caused by the steep pressure gradient across the region persisted, and light snow or snow showers fell at most locations within this unstable zone, including northern Vermont. The relatively strong winds and lack of discontinuity in the characteristics of the air mass kept the air temperatures near -7°C, with dew points of -8° or -9°C at the experiment site. Visibility during the daylight hours at the site ranged from 1.6 to 3.2 km, and cloud base heights were under 500 m in light snow showers.

0400, 10 December

Since the low pressure system over the Canadian Maritimes remained more or less stationary, the northerly flow of air continued to dominate most of New England, New York, and southern Quebec. Light snow or snow showers were still reported in many regions, but visibility improved and the air temperature decreased slightly. Wind speeds at Burlington Airport continued strong, with gusts of up to 10.3 m/s. Snowfall accumulations for

*Burlington Airport surface weather observations are given when CEATC data are missing or incomplete.

the entire period were light, with mostly trace amounts being reported during each hour. At the site only 5.0 mm in water equivalent of snow was recorded for 9 December.

<u>1600, 10 December</u>

Although the atmospheric pressure gradient across New England slackened slightly, the unstable north or northwest winds continued to flow across the region. Light snow showers were observed at the site through most of the day, but daytime visibility improved to between 3.2 and 6.4 km. The cloud base increased to between 350 and 700 m in height. Hourly precipitation amounts in water equivalent ranged from a trace to a maximum of 0.2 mm.

<u>0700, 11 December</u>

The surface synoptic weather picture across New England remained essentially unchanged during the preceding 15 hours. The northerly flow of air continued as the wind speed slowly abated. Skies remained mostly overcast and light snow or snow showers persisted within the air mass. Air temperatures in northern Vermont stayed between -5° and -7°C during the period, and hourly snowfall amounts ranged from a trace to 0.4 mm in water equivalent.

<u>1900, 11 December</u>

A wedge of high pressure that had drifted southward from Canada was centered over the Great Lakes. The eastward progress of this system was blocked by the remnants of the storm, which had hardly moved from its position over the Canadian Maritimes during the previous two days. Skies over most of New England remained overcast and light snow and snow flurries continued across northern Vermont. Variations in air temperature, visibility, and cloud height in the local region had been minimal. Hourly snowfall totals at the site continued to range between a trace and a maximum of 0.5 mm in water equivalent.

<u>0700, 12 December</u>

Although the high pressure cell over the Great Lakes had showed a slight eastward movement toward New England, the weather conditions across the region remained unchanged. Overcast skies with light northerly winds and intermittent light snow or snow showers persisted. Visibility continued to improve and a slight warming trend began.

1900, 12 December

The eastern edge of the high pressure cell centered over Ohio started to influence most of New England. The snow flurries over northern Vermont finally ended and visibility became excellent.

0700, 13 December

The high pressure system drifted eastward and dominated most of the Atlantic seaboard. Although skies across northern Vermont stayed cloudy, no precipitation was recorded and visibility was excellent. The air temperatures in the region were between -3° and -6°C and winds were light and variable in direction.

1900, 13 December

The surface synoptic map and the weather conditions across northern Vermont were similar to those given in the preceding summary.

0700, 14 December

The high pressure cell over the central east coast started to break down as two troughs developed around the system. One trough extended southward across the central Great Lakes, and snow broke out over parts of the region. The second trough extended across the southeastern states, and rain began over much of the area. Locally, except for an occasional light snow flurry, the weather remained mostly unchanged.

1900, 14 December

The trough over the Great Lakes drifted eastward, and the snowfall line reached eastern New York and Pennsylvania. A cyclonic wave meanwhile developed within the trough over the southeastern states and the rain shield spread northward to West Virginia, Virginia, and southern New Jersey. Skies over northern Vermont remained overcast and an occasional light snow flurry was recorded. The winds became southerly and the air temperatures at midday reached 0°C. The atmospheric pressure started to fall as the two troughs approached New England.

0100, 15 December

A second cyclonic wave developed along a line of temperature discontinuity that formed in the trough over the southeastern states. The peak of the leading wave was located over southern New Jersey and Delaware, and the rain reached southern New England. The trough east of the Great Lakes weakened but snow continued in parts of central and northern New England. In northern Vermont the snowfall had been intermittent and very light

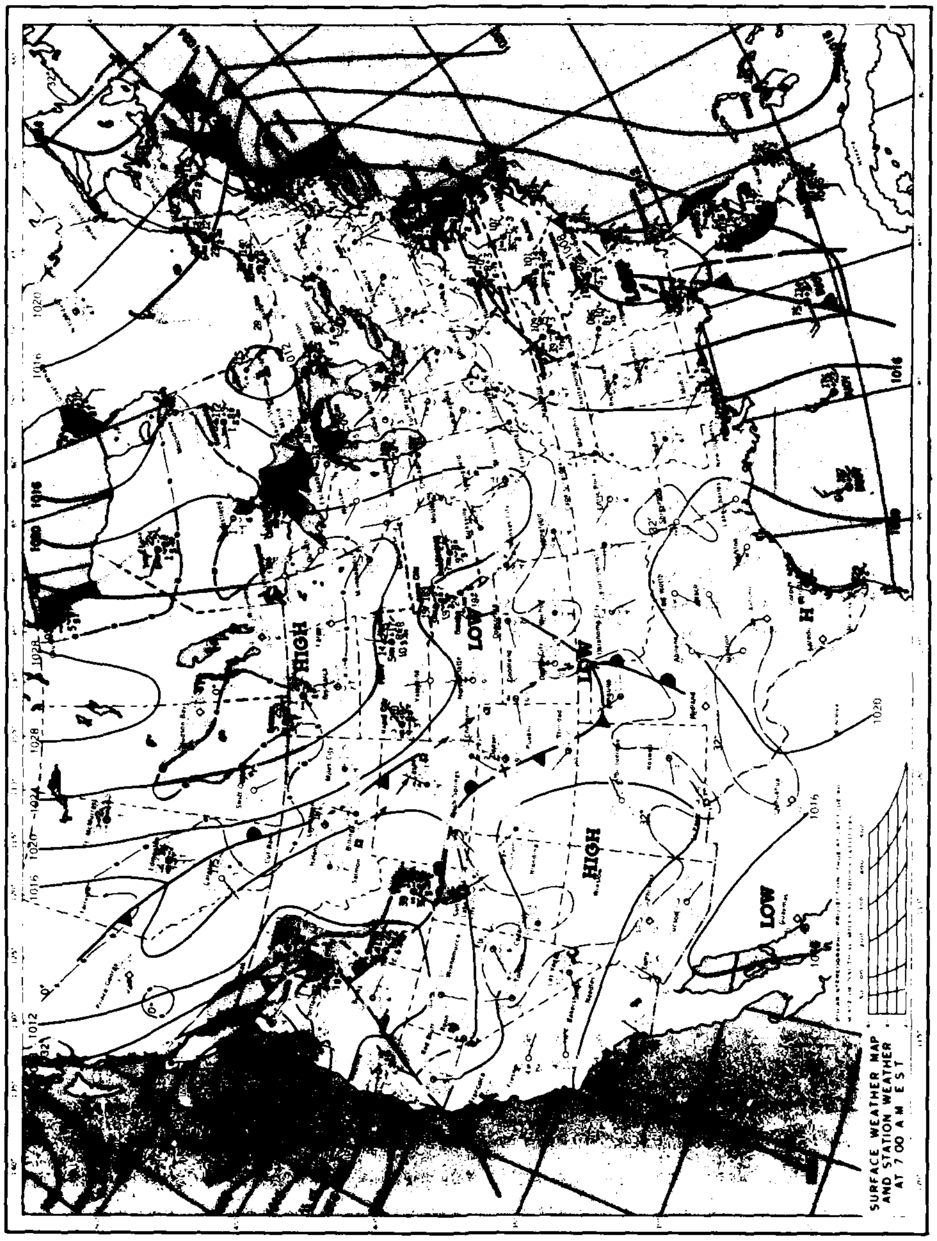

Figure 11. Surface weather map and station weather, 0700, 15 December 1981.

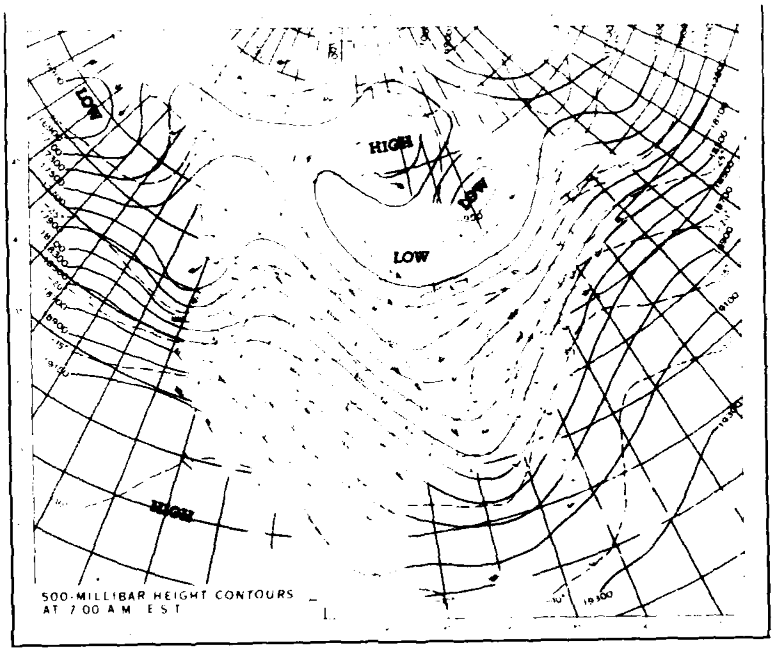

Figure 12. Weather chart for 500-mb level, 0700, 15 December 1981. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

during the previous 12 hours and had caused only a slight reduction in visibility. Skies remained overcast and the air temperature remained near freezing.

<u>0700, 15 December</u>

The leading wave slipped northeastward to Cape Cod, Massachusetts, and continued to cause rain along the coast and snow in northeastern New England (Fig. 11). Snow in northern Vermont ended during the night, but overcast skies remained, with good visibility. The peak of the second wave that formed along the front on the east coast was located over Georgia and was bringing heavy rains to much of the Southeast. The upper level (500-mb) winds (Fig. 12) along the east coast were from the southwest, which indicated continued movement of the second surface wave toward the northeast. A GOES-E image taken at 1230 EST on 15 December shows the massive cloud coverage associated with these developing cyclonic waves (Fig. 13).

Figure 13. Satellite image of the cloud pattern over the eastern United States taken at 1230, 15 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

1900, 15 December

The center of the second wave had traversed rapidly northeastward along the east coast and was situated just off the Delaware-Maryland coastline. Rain was widespread over the entire coastal area, and light to heavy snow was falling in most of the Northeast except northern New York, Vermont and New Hampshire. Locally, the skies were overcast and the ceiling had decreased considerably. Air temperatures were near the freezing point.

0700, 16 December

The second coastal wave, having deepened considerably (from 1008 to 988 mb) over the previous 24 hours, was centered just north of Cape Cod over the Gulf of Maine (Fig. 14). Snow had begun over northern Vermont around midnight and was falling at a moderate rate. Visibility decreased to 1.6 km at the site and the ceiling was 200 m. The air temperature had remained fairly high, between -1° and -4°C, since 0100 hours. Although the atmospheric pressure had started upward, little change in either the air temperature or wind direction had occurred. The wind increased in speed and continued mainly from the north. Dew point temperatures during this time period (0100 to 0700 hours) ranged from -2° to -5°C, which indicated that there was considerable moisture within the air mass. An excellent view of this storm over the Gulf of Maine taken from space at 1001 EST on 16 December is shown in Figure 15.

2200, 16 December

The coastal storm continued its rapid northeast movement and was located over the Gulf of St. Lawrence. Snow continued over northern Vermont until about 1300 hours. Although the air pressure continued to increase rapidly in the area, the air temperature remained high, between -1° and -4°C. The wind became strong and gusty from the west and northwest and visibility improved markedly. Total snowfall at the experiment site for the entire storm amounted to 20 cm, with a water equivalent value of 18 mm.

0700, 17 December

As the preceding major coastal storm over the Gulf of St. Lawrence continued its northeastward track, another depression that had formed over the south-central states was centered over southern Illinois and Indiana (Fig. 16). Snow associated with this storm spread across a large area

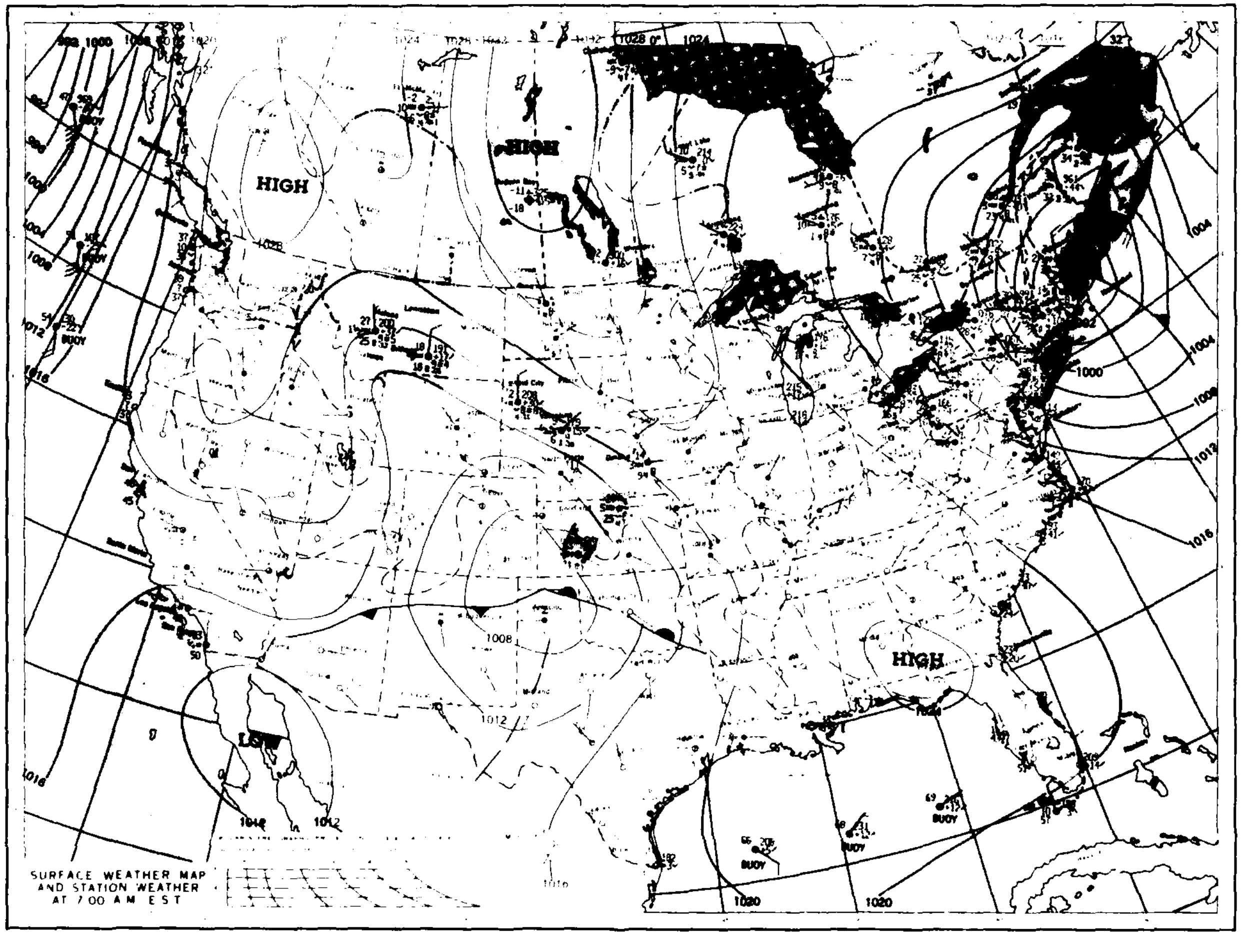

Figure 14. Surface weather map and station weather, 0700, 16 December 1981.

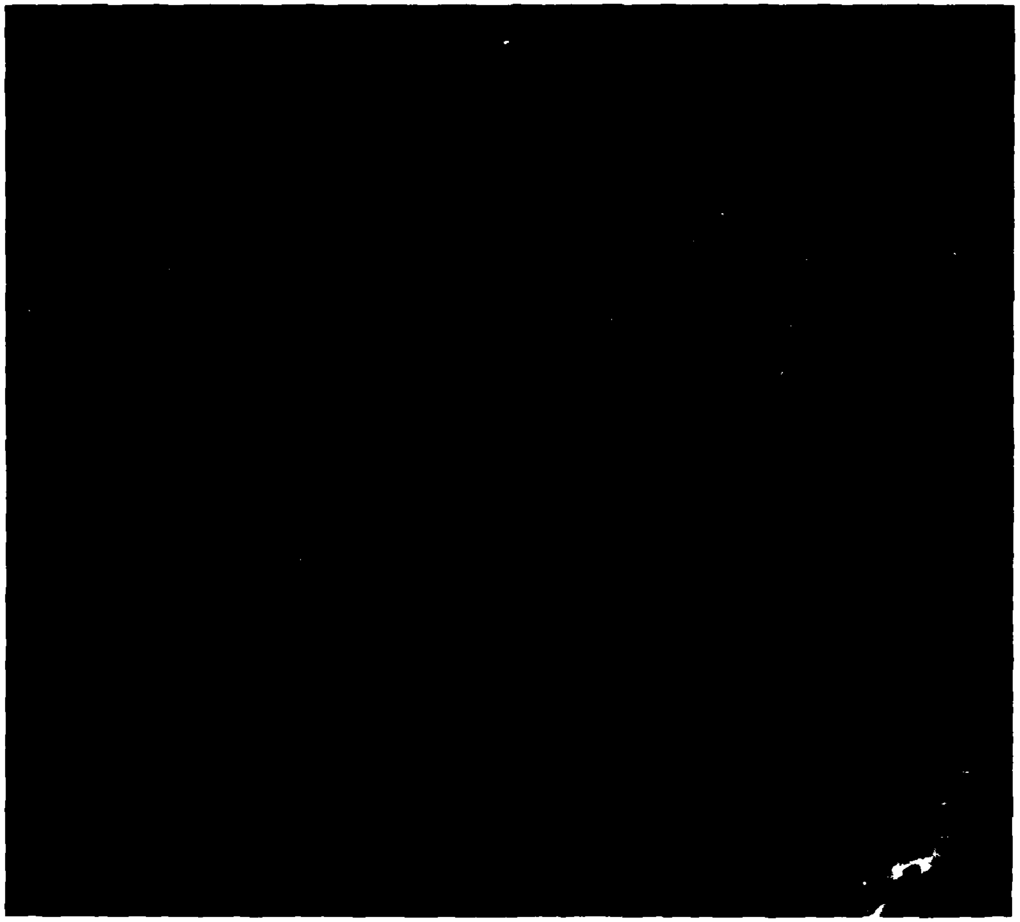

Figure 15. Satellite image of the cloud pattern over the northeastern United States taken at 1001, 16 December 1981. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

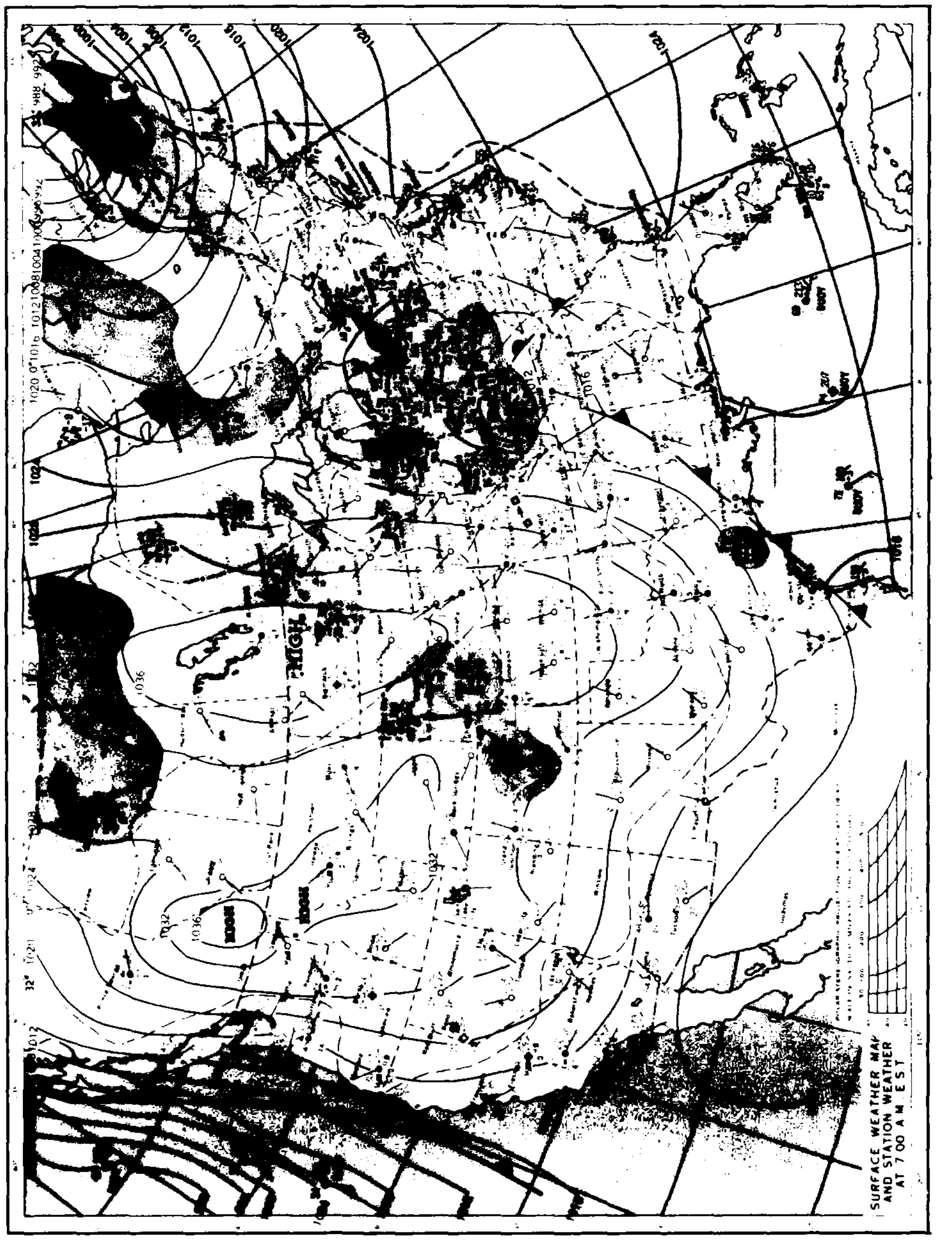

Figure 16. Surface weather map and station weather, 0700, 17 December 1981.

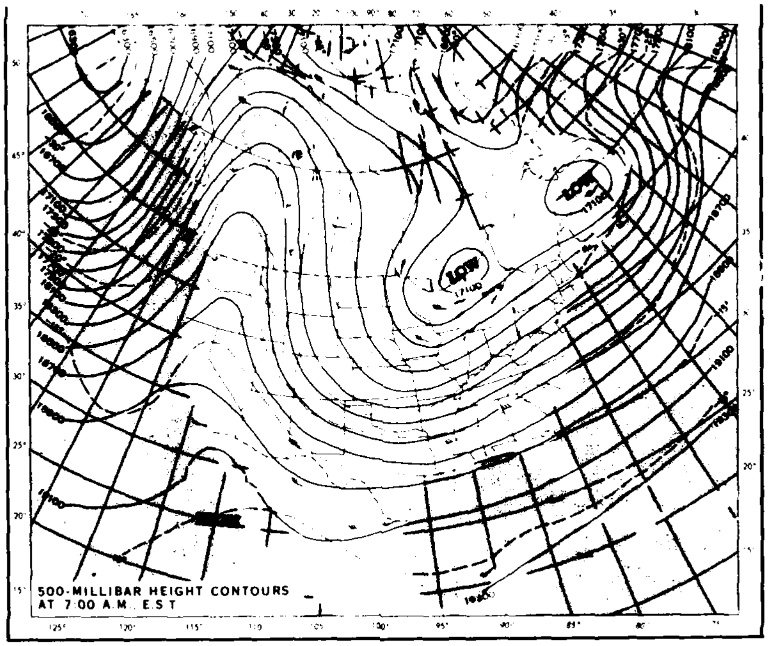

Figure 17. Weather chart for 500-mb level, 0700, 17 December 1981. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

south of the lower Great Lakes and into western New York and Pennsylvania. The definite west-to-east flow of air at the 500-mb level (Fig. 17) indicated a direct eastward movement of this system. In northern Vermont the weather was fair, with scattered to partly cloudy skies and excellent visibility, and air temperatures ranged from -5° to -9°C.

2200, 17 December

The center of the depression in Illinois and Indiana moved eastward to central Pennsylvania. Warm and cold fronts extended from the low and caused snow to fall throughout most of Ohio, Pennsylvania, New York and Connecticut. The snow line had reached southern Vermont and was expected to move across the local region soon. Locally, air temperatures were near -8°C, with dew point values of -11° to -13°C.

0700, 18 December

The low over Pennsylvania and its associated fronts moved steadily eastward and out to sea just east of Long Island, New York (Fig. 18).

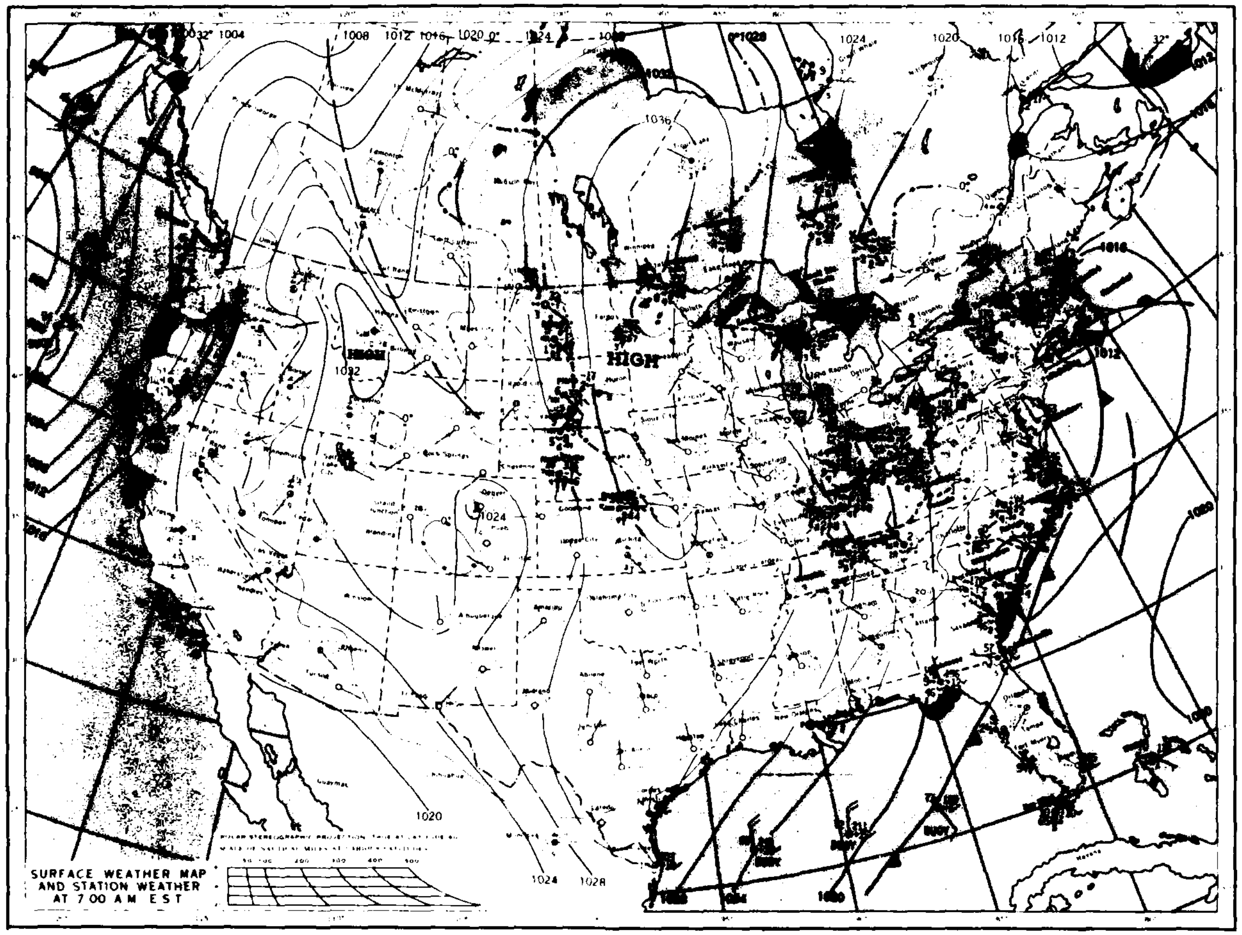

Figure 18. Surface weather map and station weather, 0700, 18 December 1981.

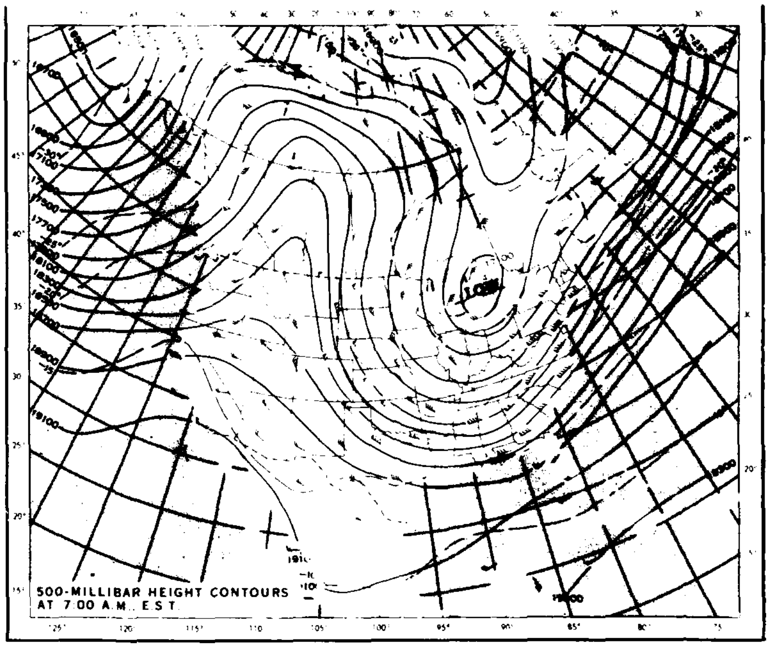

Figure 19. Weather chart for 500-mb level, 0700, 18 December 1981. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

Light snow started to fall in northern Vermont about 2230 on the 17th and continued through the night. Temperatures across the region remained steady at -6° to -8°C, and the air was rather dry (relative humidity between 70% and 84% at Burlington Airport). Only a trace or less than 0.1 cm of snow fell at the airport during each hour, and visibility stayed above 3.2 km during the snowfall periods. The base of the clouds remained at about 450 m or higher. The 500-mb closed low associated with this storm was centered over the Great Lakes and exhibited a strong and extensive trough pattern (Fig. 19).

1300, 18 December

The depression off the southeast coast of New England stalled somewhat, and a low pressure trough started to form west of its center. Unstable conditions within this cyclonic flow continued to cause light snow or snow showers to fall over much of New England. Little change in any of

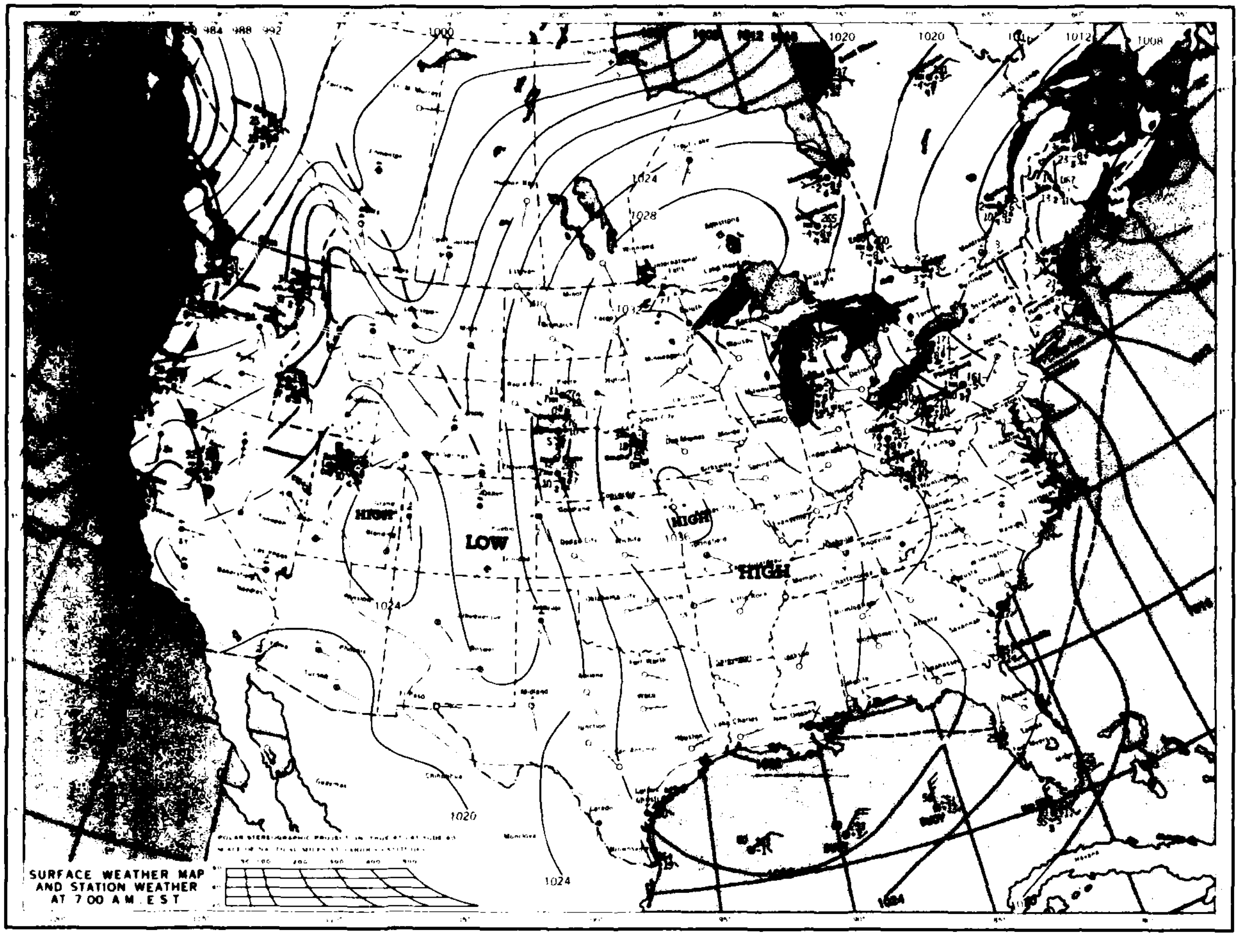

Figure 20. Surface weather map and station weather, 0700, 19 December 1981.

the key meteorological parameters occurred throughout this period of light snowfall. The temperature stayed between -6° and -8°C, the visibility between 1.6 and 6.4 km, ceilings between 300 and 750 m, and the wind at less than 5.2 m/s from the north and northeast at the Burlington Airport.

0700, 19 December

The low pressure trough that extended across New England and northern New York from the depression that lingered east of Nova Scotia caused intermittent light snow to persist in Maine and parts of Vermont and New Hampshire (Fig. 20). The only changes in the weather (as observed at the Burlington Airport) were lower air temperatures (down to about -11°C) and some shift in wind direction. Hourly snowfall accumulations remained limited to a trace or less than 0.3 cm (or about 0.3 mm in water equivalent).

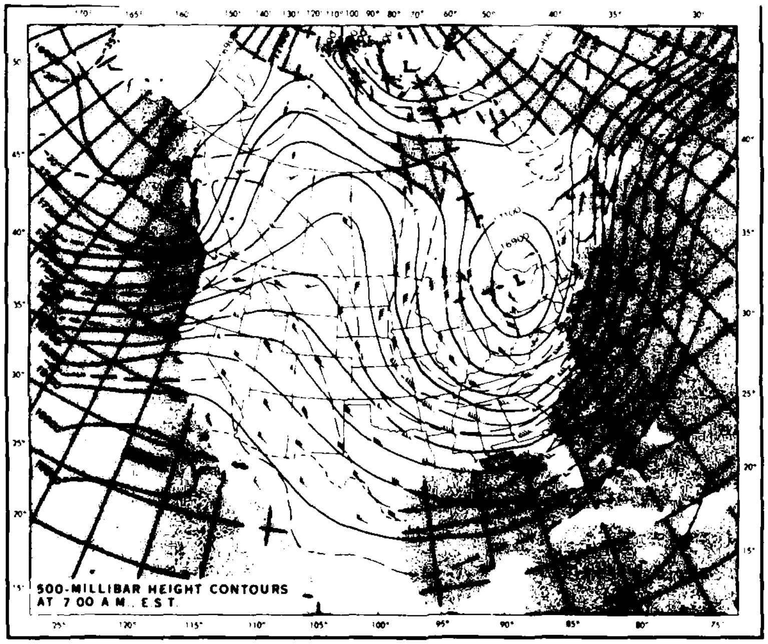

Figure 21. Weather chart for 500-mb level, 0700, 19 December 1981. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

1600, 19 December

Lines of atmospheric instability within the main trough that stretched across New England occasionally moved across the region from the northwest. These passages resulted in further light and intermittent snowfall in northern Vermont. Although a high pressure cell moved southward into the United States from central Canada, its movement toward New England was blocked by the almost stationary trough. The center of a closed low aloft (at 500 mb) over the Great Lakes also showed very little movement between 0700 on the 18th (Fig. 19) and 0700 on the 19th (Fig. 21).

0700, 20 December

A ridge of high pressure finally moved in behind both the trough and the lines of instability, and the numerous series of light snowfalls in the area ended. The atmospheric air pressure across northern Vermont increased markedly. The wind became stronger and changed to a west-northwesterly flow. At no time during the previous two days did the hourly snow amounts exceed 0.3 cm at the Burlington Airport. A total of 3.0 cm of snow was recorded at the site on the 18th, and only 2.0 cm on the 19th.

1600, 20 December

A ridge of high pressure that extended from a main cell centered over West Virginia and Kentucky reached the local region. Only scattered clouds were observed and visibility was excellent.

JANUARY AND FEBRUARY 1982

0700, 3 January 1982

A ridge of high pressure extended southward over New England from a massive high cell (1040 mb) centered over southeastern Canada. Clear skies over the region gave way to a high, thin overcast as an elongated north-to-south trough across the Great Lakes drifted eastward. Snow caused by this system was reported north of the Lakes region, and rain or drizzle to the southeast. Overnight temperatures were quite low (below -18°C), and the atmospheric pressure was starting to fall rapidly.

2200, 3 January

As the ridge drifted off to the northeast, the north-to-south trough over the Great Lakes divided in two and a deep low formed over southern Illinois. A well-developed cyclonic wave could be identified within this depression, and precipitation had spread over a wide area of the north-central states. In northern Vermont the air pressure continued to fall,

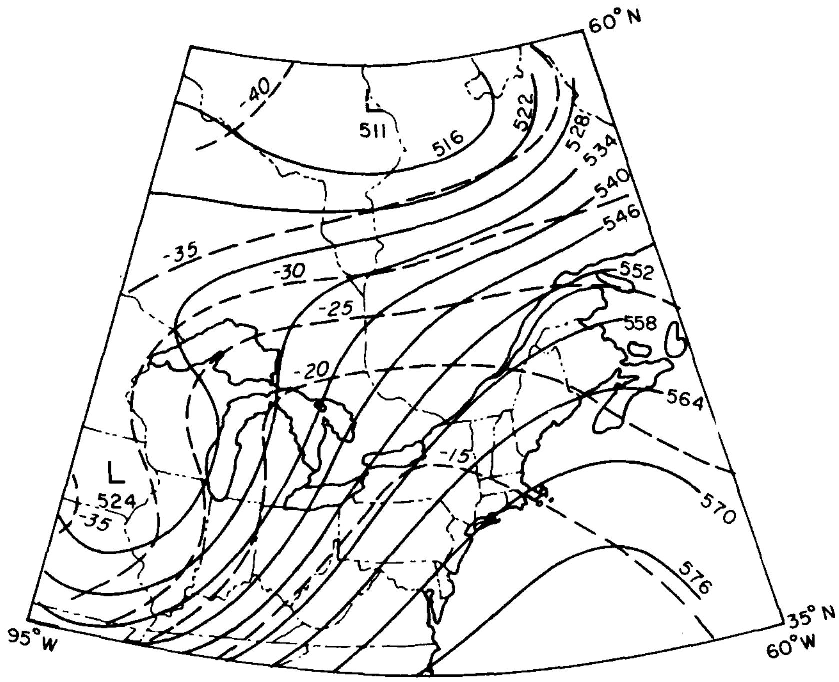

Figure 22. Weather chart for 500-mb level, 0700, 4 January 1982. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

but precipitation had not started. Winds became southerly and increased in speed, and the air temperature rose markedly to near -2°C.

0700, 4 January

The low over northern Illinois moved slowly northeastward and became quite intense, with a central pressure of 982 mb. The cyclonic wave occluded, and the strong southerly surface winds that preceded the snow advected warm and moist air into New England. The upper level (500 mb) winds at this time also showed a definite southerly influx of air into the region (Fig. 22). Freezing rain was recorded at Burlington Airport starting at 0246 on the 4th, with air temperatures of -1° or -2°C.

2200, 4 January

Although the center of the low continued its rather slow movement across Lake Huron, the occluded front associated with the storm developed

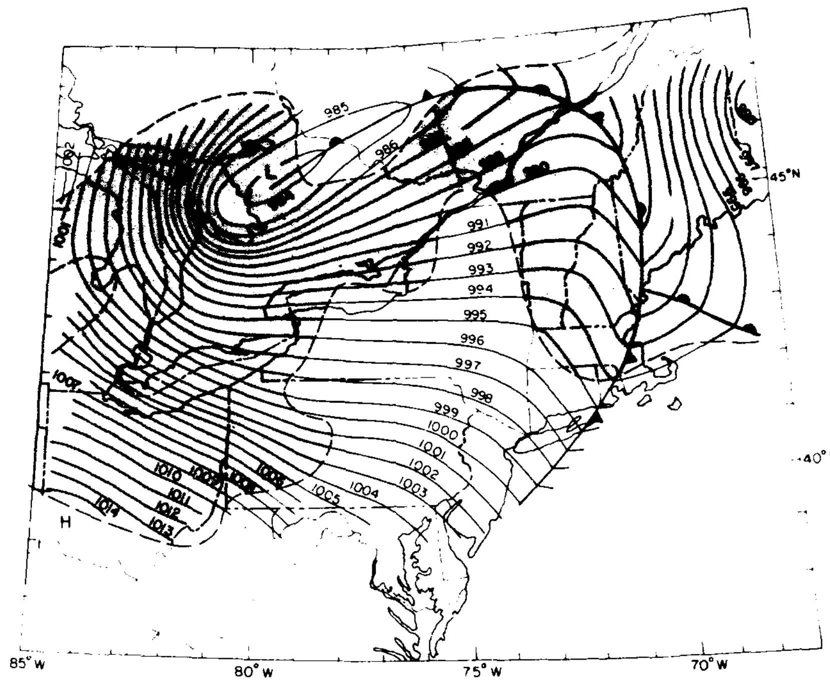

Figure 23. Surface weather map, 2200, 4 January 1982. The precipitation zone is shaded.

rapidly, raced quickly northeast, and formed an elongated trough across southern Quebec and southward through central New England (Fig. 23). During the day the air temperatures continued to rise, and the air pressure decreased rapidly. The precipitation changed to rain or drizzle, and winds at Burlington Airport occasionally gusted to over 12 m/s. Visibility remained at 6.4 km or better, and ceilings at 400 m or greater. Hourly precipitation amounts during the day at the Burlington Airport ranged from a trace to over 0.3 cm in water equivalent.

<u>0700, 5 January</u>

The storm continued to track toward the northeast, passing Maine and extending across southeastern Quebec and the Canadian Maritimes. The air behind the system gradually cooled, and rain at the airport changed to light snow flurries. The atmospheric pressure started to increase rapidly and the wind shifted to the southwest but was still strong and gusty. Total precipitation for the storm exceeded 2.7 cm in water equivalent, most of which was in the form of rain.

1900, 5 January

As the storm left New England, a ridge extending northward from a high pressure center over the southeastern states influenced northern Vermont. Skies over the region cleared, visibility was excellent and the air temperature continued to decrease. Winds at the Burlington Airport became westerly and persisted strong and gusty. Meanwhile, a shallow low moved into the western Great Lakes region, but precipitation around the system was light.

0700, 6 January

The ridge over northern New England drifted eastward as the shallow low tracked quickly across the Great Lakes. Skies over northern Vermont progressed from clear to partly cloudy overnight, and winds abated to light and variable. Air temperatures dropped to a minimum of near -13°C, and visibility remained excellent.

1900, 6 January

The shallow low and the occluded, cold, and warm fronts associated with the system moved toward New England (Fig. 24). Light snow began at the experiment site at 1520 and visibility occasionally decreased to 1.6 km. Snowfall accumulation recorded on a snow board at the site at 1800 hours was near 1.3 cm. A large high pressure cell located over the north-central states spread rapidly southeastward from Canada.

0700, 7 January

Light snow continued through the night over northern Vermont as the low traversed New England. Hourly snowfall amounts in water equivalent ranged from a trace to near 0.7 mm at the site, and visibility on occasion lowered to 1.6 km. Air temperatures through the night were mostly near -2°C, but a pressure rise across the region and a marked wind shift (at the Burlington Airport) indicated a frontal passage, and the air became colder. The high pressure cell covered most of the central portion of the United States.

1900, 7 January

The eastern edge of the high pressure cell over the central United States pushed into New England, and the weather over northern Vermont gradually improved. As the air pressure increased, the winds became northerly, and air temperatures across the region continued to fall.

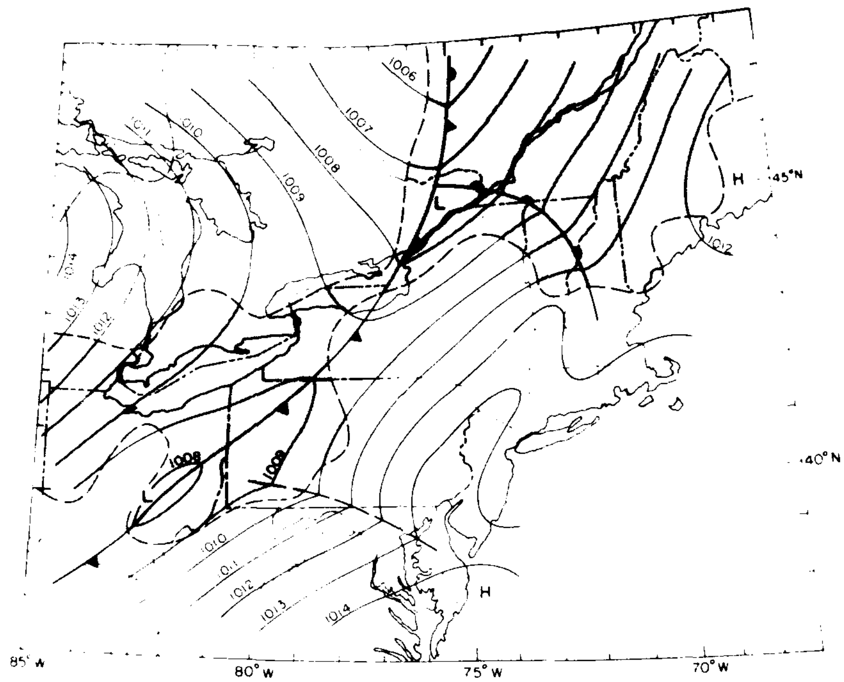

Figure 24. Surface weather map, 1900, 6 January 1982. The precipitation zone is shaded.

<u>0700, 8 January</u>

The fringe of the high pressure zone over New England started to dissipate as a shallow low over the western Great Lakes moved eastward. Light snow and snow showers broke out in scattered areas across the Lakes region. Locally the skies became more cloudy, and air temperatures at the site decreased to near -20°C.

<u>1900, 8 January</u>

The shallow low with a weak cyclonic wave at its center passed across the Great Lakes and was located over southeastern Ontario. Scattered light and brief snow showers were reported around the system, but skies over northern Vermont remained mostly cloudy. Minor changes in air temperature and good visibility (except during brief periods of light snow) were recorded at the site during the day.

<u>0700, 9 January</u>

The shallow low with its associated weak wave reached the local area, and intermittent light snow or snow showers were reported around the system (Fig. 25). The hourly snowfall amounts were mostly traces, and there were

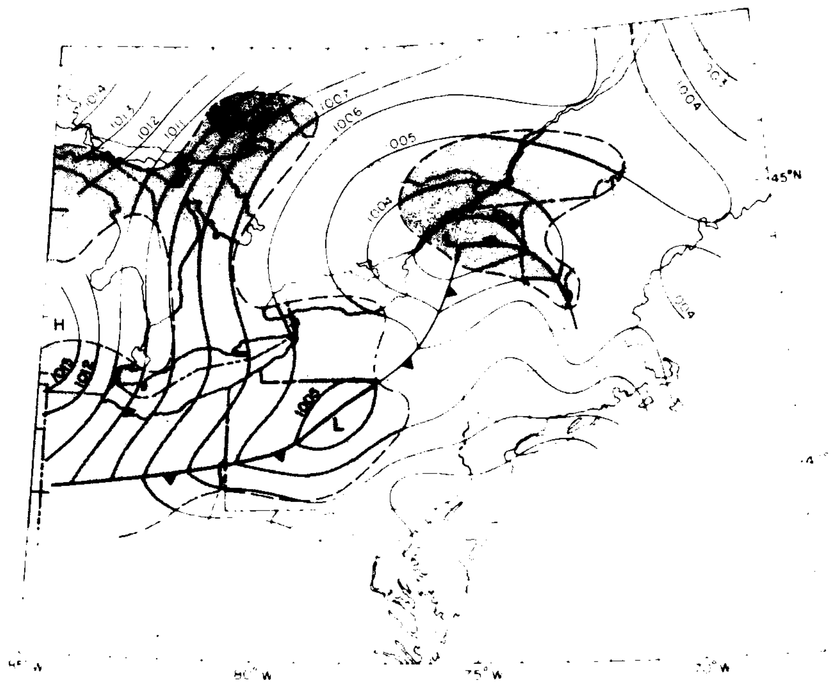

Figure 25. Surface weather map, 0700, 9 January 1982. The precipitation zone is shaded.

frequent intervals when breaks in the overcast or only scattered or broken layers of clouds were observed. Air temperatures at the site hovered near -14°C, and winds in the area stayed light and variable.

1900, 9 January

The low over New England tracked eastward off the coast and continued to bring brief periods of light snow to scattered sections of the region. Weather conditions remained relatively unchanged over northern Vermont, except that the air temperatures started to decrease as a ridge of high pressure started to build northwest of the region.

0700, 10 January

The weak low off the New England coast deepened as it moved off to the northeast and caused considerable snowfall in parts of Maine and the Canadian Maritimes. Although a ridge of high pressure had started to form over interior New England, lines of instability that formed behind the redeveloping coastal storm continued to cause light snow to fall across northern Vermont. The hourly snowfall amounts, however, never exceeded 0.3

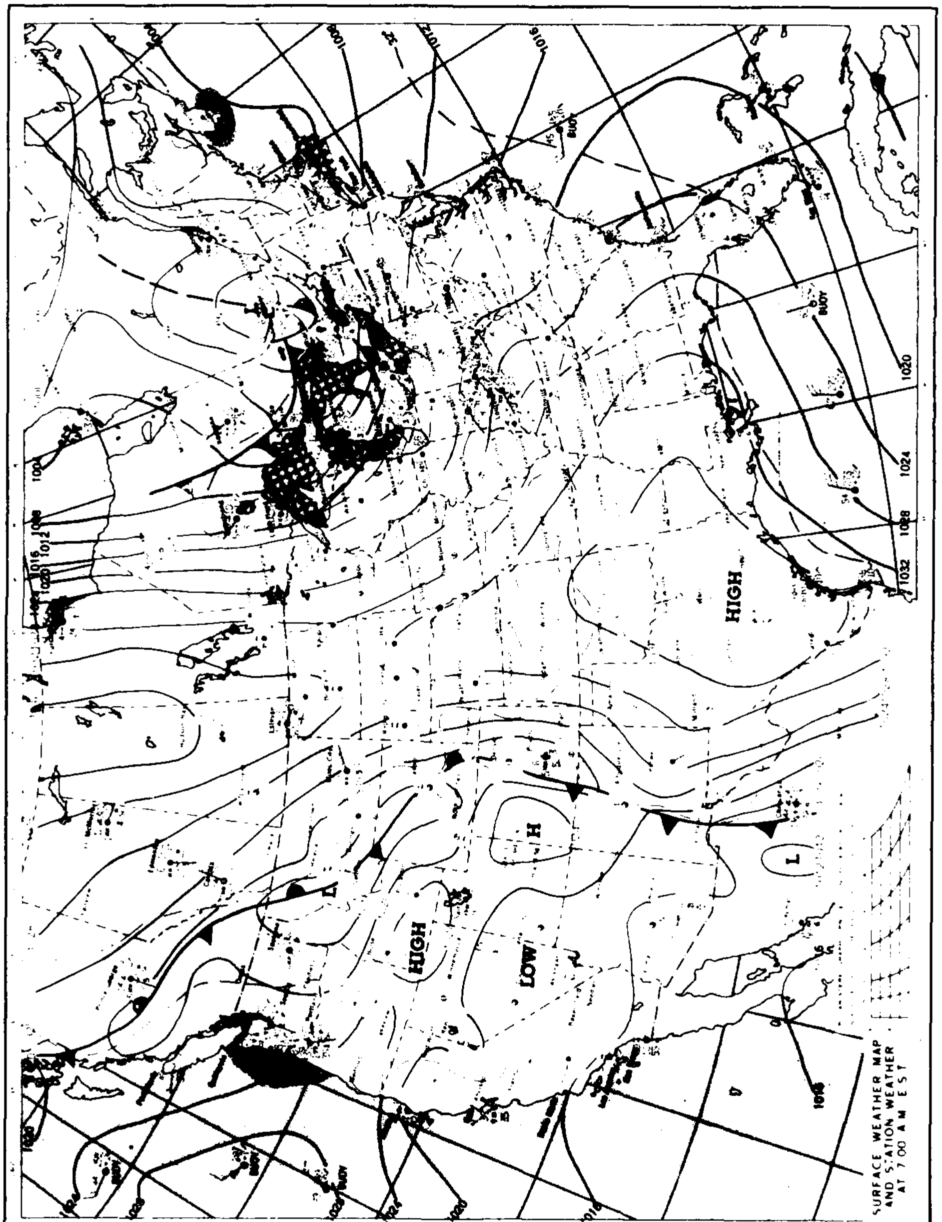

Figure 26. Surface weather map and station weather, 0700, 11 January 1982.

mm in water equivalent. Air temperatures in the local region continued to fall overnight, and reached a minimum of near -27°C at the site.

1600, 10 January

The ridge of high pressure that had briefly influenced northern New England started to break down as a major trough extending southeastward from a low in northern Ontario, Canada, moved into north-central New York. Locally the intermittent periods of light snowfall ended, and weather conditions improved, with broken to scattered clouds and excellent visibility. The air temperature remained relatively low across the region, -19° to -24°C, and the atmosphere became quite dry (< 40% relative humidity at Burlington Airport and < 50% at the site).

0700, 11 January

The low in Canada slipped southeastward to southern Ontario and Quebec. Two weak frontal systems extended west and northwest from the low and caused snow to fall over most of the Great Lakes region (Fig. 26). The air temperature in northern Vermont was near -18°C and skies became overcast. Relative humidity remained low (near 55%) and visibility was good (over 11 km). The wind speed increased markedly, however, with an hourly average of 8.8 m/s and gusts of over 15.5 m/s reported at Burlington Airport. A large, closed cyclonic flow of air became established at the 500-mb level (Fig. 27). The center of the low aloft was mainly over Quebec, but the anticlockwise movement of air covered much of the eastern third of Canada and the northeastern United States.

1900, 11 January

A front identified only as a trough on the Plattsburgh AFB sectional surface weather map passed over northern Vermont between 1400 and 1800 hours. Light snow and snow showers began at 1450 and occasionally reduced visibility to less than 1.6 km. Peak airborne-snow mass concentrations of 0.4 to 0.5 g/cm^3 were recorded between 1731 and 1734 hours at the experiment site during one brief but particularly heavy snow squall.

0700, 12 January

Very light snow fell intermittently during the night across northern Vermont as the air pressure continued to build rapidly. This increase came as a result of a high pressure bubble that had developed over Lake Ontario. Hourly snowfall totals in water equivalent during this snow event were traces or amounts of less than 0.5 mm. By 0900 the relatively shallow

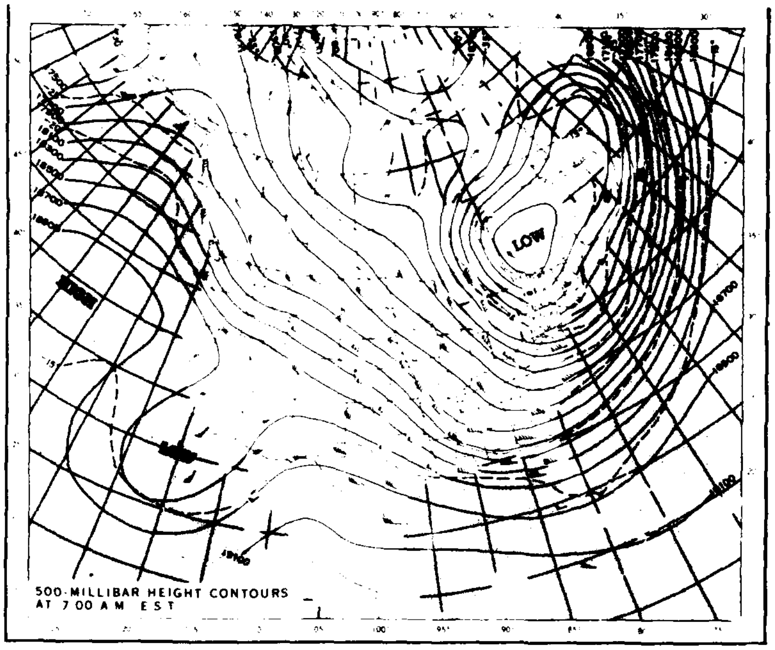

Figure 27. Weather chart for 500-mb level, 0700, 11 January 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

high pressure bubble (1027 mb) had crossed northern New England and brought mostly clear skies and excellent visibility to the region. Light snow across northern Vermont ended at about 0730 hours.

<u>1600, 12 January</u>

The shallow high maintained its position along the eastern seaboard states and continued to provide fair weather to New England. Skies varied from clear to scattered clouds, and air temperatures across the northern sections remained quite low (daytime maximum values of near -17°C). Meanwhile, a large area of precipitation broke out in the Mississippi River Valley due to a low pressure zone that had developed over the northwestern part of the Gulf of Mexico.

<u>0700, 13 January</u>

Two elongated shallow troughs stretched northward from a wave that had formed in the low over the Gulf of Mexico. One trough extended toward the Great Lakes, the other along the east coast. These systems together caused precipitation to spread over much of the eastern third of the nation, but it had not yet reached New England (Fig. 28). The precipitation was snow north of Tennessee and North Carolina, and either drizzle or a mixture of snow, freezing rain, and rain in the south. Locally the skies became overcast during the night and the pressure started to fall. Air temperatures were on the rise after having reached a minimum of -29°C at the experiment site overnight.

1900, 13 January

A series of shallow depressions developed within the elongated trough zones. The center of one depression was located over western Pennsylvania, another was over Cape Hatteras, and a third was still farther south. Wedged between the first two depressions was a ridge of high pressure that persisted across New England. This synoptic weather pattern produced light to moderate snowfalls from southern Maine westward to Lake Michigan and from Virginia and West Virginia northward to southern Ontario. Light snow began at the site at 1245, and at about 1600 reduced visibility to a minimum of 1.6 km. Air temperatures during the snowfall period remained near -14°C, but relative humidity ranged from less than 55% near noon to more than 80% after 1700. Hourly snowfall amounts in water equivalent up to this time were 0.2 mm.

0700, 14 January

The ridge of high pressure over New England moved off to the northeast. Meanwhile the two shallow depressions that straddled the ridge joined as they drifted toward each other, and a wave developed within the resultant low center as it moved out to sea. Another trough associated with this new low center extended northeast along the southeast coast of Nova Scotia (Fig. 29). The cyclonic flow around this trough caused snow to continue through the night across northern New England. Atmospheric pressure fell steadily at Burlington Airport, and visibility remained near 4 km in light snow. Air temperature remained uniform near -15°C, with northwest winds at 2.7 to 4.5 m/s. Snow continued to fall at rates of a trace to 0.2 mm in water equivalent during each hour. The upper air (500 mb) flow over the eastern and southeastern United States (Fig. 30) indicated probable further development and northeast movement of a second wave located off the coast of Georgia. The extensive cloud coverage

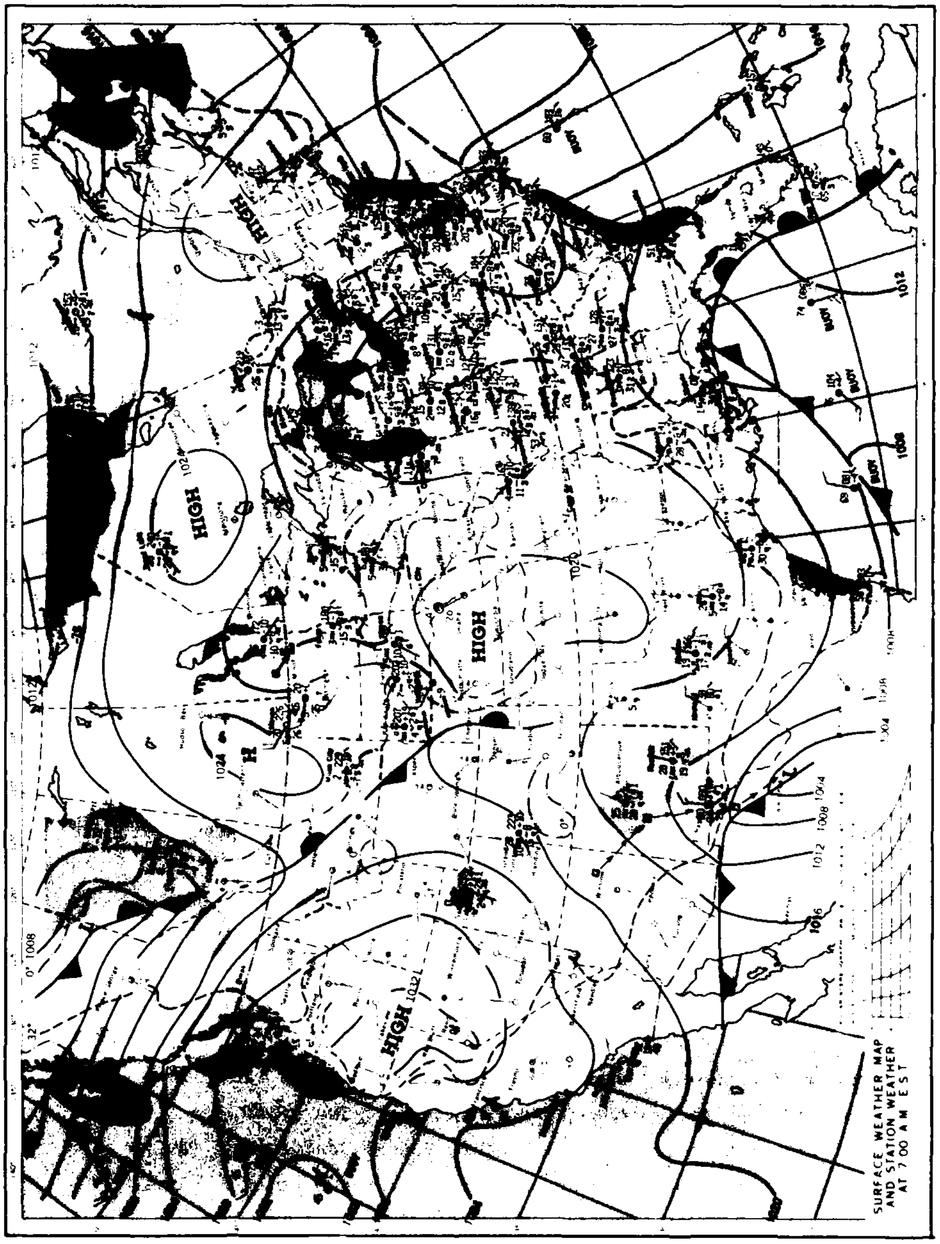

Figure 28. Surface weather map and station weather, 0700, 13 January 1982.

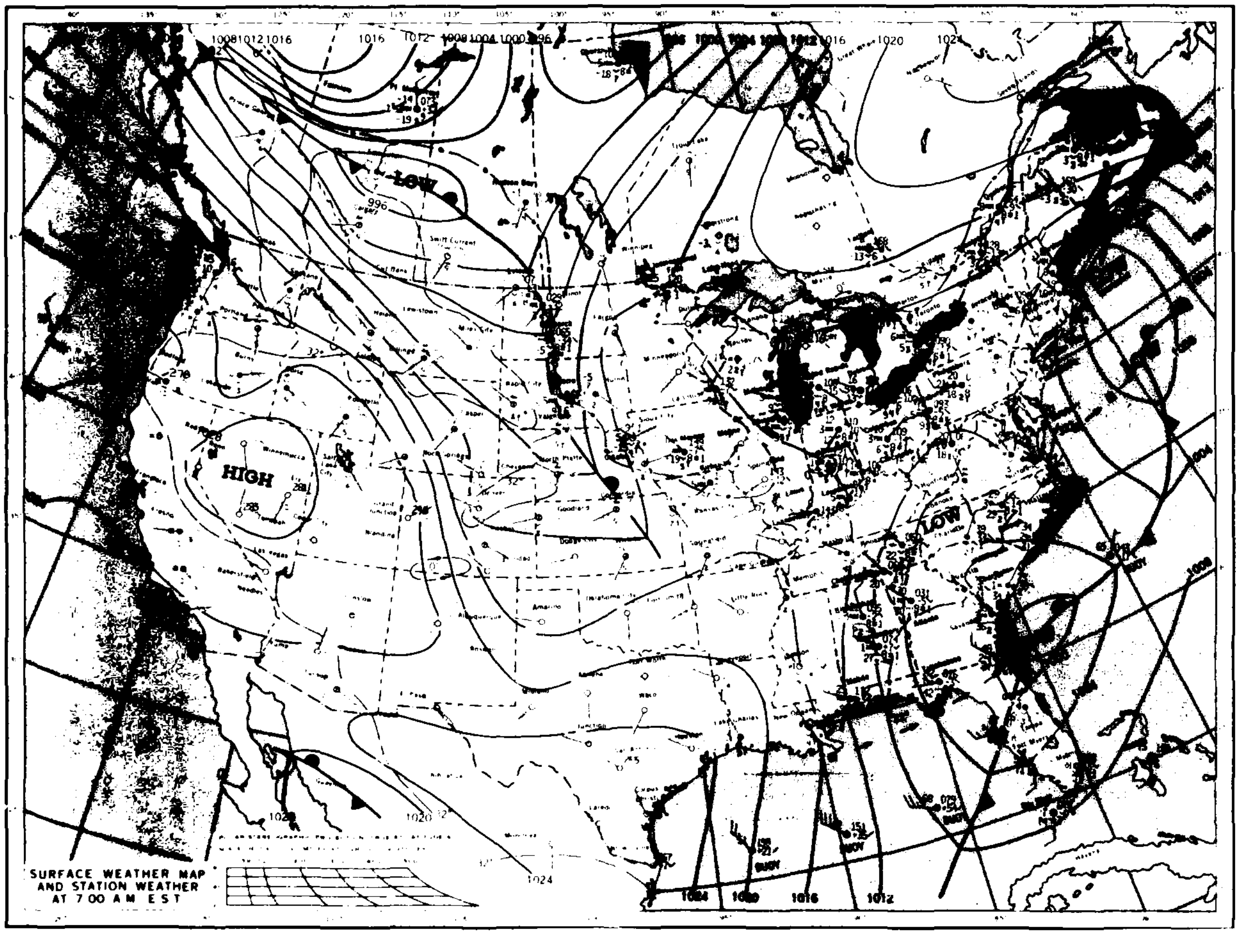

Figure 29. Surface weather map and station weather, 0700, 14 January 1982.

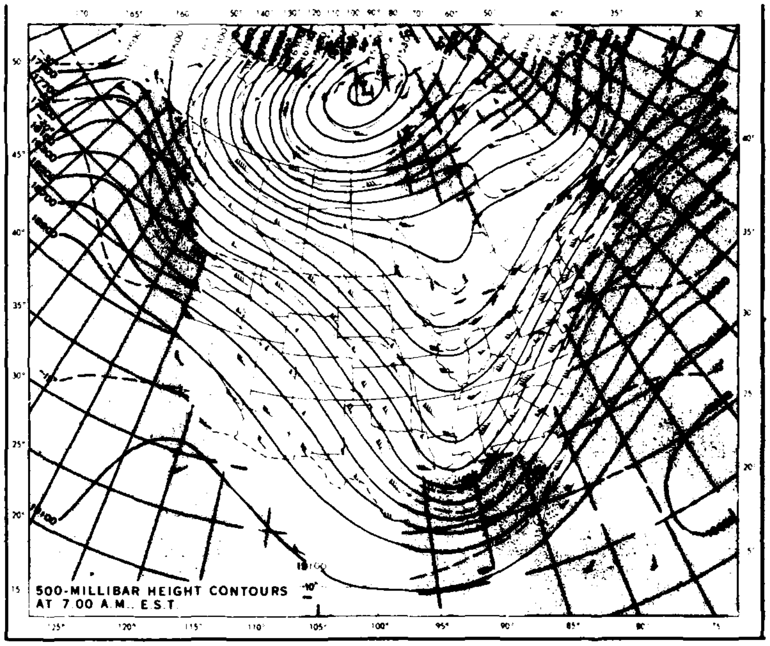

Figure 30. Weather chart for 500-mb level, 0700, 14 January 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

associated with these various low pressure systems is revealed in a GOES-E image taken at 1430 EST on 14 January (Fig. 31).

1600, 14 January

The second wave off the coast of Georgia moved northeastward to Cape Hatteras, and the atmospheric pressure ahead of it was decreasing rapidly. The cyclonic flow around this coastal storm extended over most of the eastern states, so that snow continued to fall over much of the region. Locally, light snow was observed throughout the day, with visibility ranging from 1.6 to 6.4 km. Air temperature was relatively low, -12° to -15°C during the previous 9 hours, with relative humidity values of 72 to 83%. Snowfall in water equivalent during this period at the site ranged from a trace to a maximum of about 0.5 mm per hour.

0300, 15 January

The coastal low, having continued its northeastward track, was centered off Cape Cod. This second storm showed the characteristics of a

Figure 31. Satellite image of the cloud pattern over the eastern United States taken at 1430, 14 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

typical "nor'easter" and caused significant snowfall over much of New England, New York, New Jersey and Pennsylvania. Although the snow fell steadily, local amounts remained rather light, as less than 1 mm in water equivalent was recorded during any one hour. Visibility at Burlington Airport stayed at 3.2 km or better, air temperatures were near -13°C, and relative humidity remained low (near 60%).

1600, 15 January

The coastal storm moved rapidly northeastward toward the Maritime Provinces of Canada, and a ridge started to build across the region. Snow ended at 1530 at the experiment site after about 48 hours of continued light snowfall over northern Vermont. Total snowfall recorded for this entire period amounted to 15.0 cm, with a total water equivalent value of 6.3 mm. The atmospheric pressure started to increase as the ridge began to influence New England. Another trough in south-central Canada tracked eastward to the central Great Lakes. Snow was reported at many locations around the occluded, cold, and warm fronts associated with this trough.

0100, 16 January

The ridge over New England weakened as the trough over the Great Lakes advanced eastward. Skies over northern Vermont cleared, and air temperatures again fell to below -20°C.

1000, 16 January

The storm over the Great Lakes has reached southeastern Ontario, and its associated occluded and cold fronts stretched southward through Lake Erie, western New York, and Pennsylvania (Fig. 32). A warm front that extended eastward from the storm stretched across northern New York and into New England. Air temperatures rose dramatically during the previous few hours (from -20° to -7°C) and light snow started to fall in the local region. Winds at Burlington Airport shifted to the south and became strong and gusty. Ceilings and visibility decreased sharply across northern Vermont as the storm approached.

1900, 16 January

The center of the storm was over central Quebec, and the occluded and cold fronts had reached the local region. Light snow occurred intermittently throughout the day, and winds became strong, with drifting and blowing snow being frequently reported. Except during these events, visibility was generally greater than 3 km. Air temperatures at the site

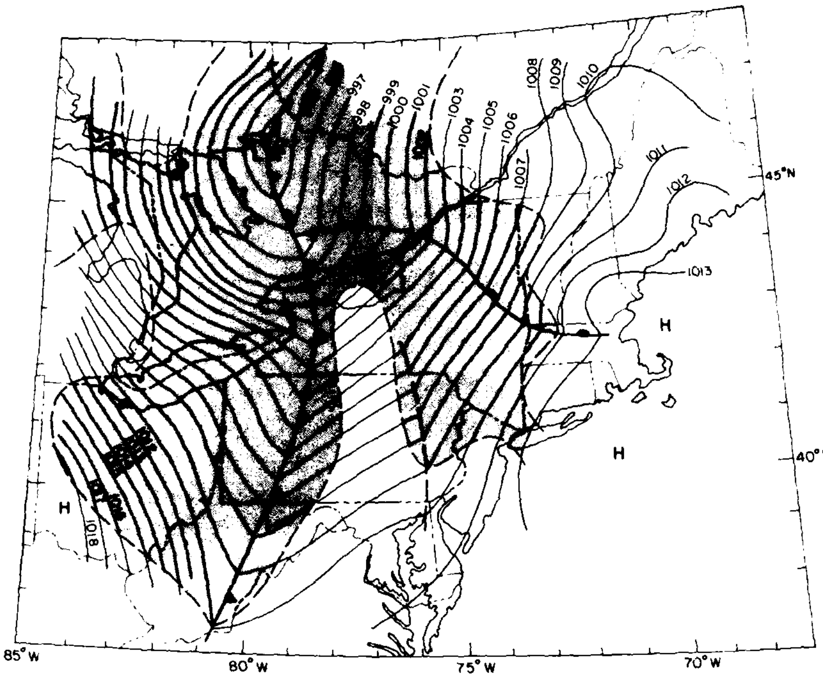

Figure 32. Surface weather map, 1000, 16 January 1982. The precipitation zone is shaded.

started to decrease after having reached a maximum of near −5°C. Hourly snowfall amounts were very light, with mostly a trace being recorded. This storm was being pushed quite rapidly eastward by a massive high pressure cell that covered most of the central United States.

<u>0700, 17 January</u>

The storm moved quickly eastward as portions of the high cell moved in behind it. Snow across northern Vermont ended during the night, winds shifted to the north, and air temperatures began falling rapidly. Visibility returned to excellent but the skies across the region remained mostly cloudy. Snowfall at the site during this frontal passage totaled only 1.5 mm in water equivalent.

<u>1900, 17 January</u>

As the high continued to track eastward, weather conditions across northern Vermont remained essentially unchanged. However, since the surface pressure gradient had steepened across the region, strong northwest winds with gusts of near 14 m/s were recorded at Burlington Airport. Skies stayed cloudy and visibility was excellent.

0700, 18 January

The center of the high had crossed the Atlantic coastline and was off Virginia, and the pressure gradient over northern New England slackened. Skies over the area were less cloudy and air temperatures dropped markedly to a minimum of -27°C at the airport and near -30°C at the site. A minor cyclonic wave south of Lake Superior caused snow to break out at numerous stations around the Great Lakes.

1900, 18 January

A series of unstable cyclonic waves developed south of the Great Lakes. The leading wave was over Ohio and Indiana, and light snow showers were observed at widely scattered locations north of the almost stationary frontal system. Skies over northern Vermont became cloudy and there were periods of very light snow or snow showers. Air temperatures remained low (daytime values of near -15°C); visibility at the site was 4 to 6 km during the snowfall periods and 8 to 11 km at other times. Hourly snow amounts were mostly traces.

1000, 19 January

As the series of waves slipped further south, remnants of a high pressure bubble over the northeastern states suddenly started to build and dominate the region. The brief intervals of light snow over northern Vermont ended during the night and skies started to clear. Overnight temperatures continued low, and visibility became excellent.

1900, 19 January

The shallow high pressure cell hardly moved and it continued to control the weather over northern New England. Skies over the local region were clear during much of the day, with generally cold and dry atmospheric conditions. Meanwhile, a low through central Ontario and the Great Lakes produced snow over a limited area around the system (Fig. 33).

0700, 20 January

The shallow high over the region quickly dissipated as the low over Ontario progressed rapidly southeastward toward New England. The system was rather weak, and no definite fronts were identified within the trough. Light snow was still reported around this system and started in the local region at about midnight. An interesting scaly-wave-like cloud pattern

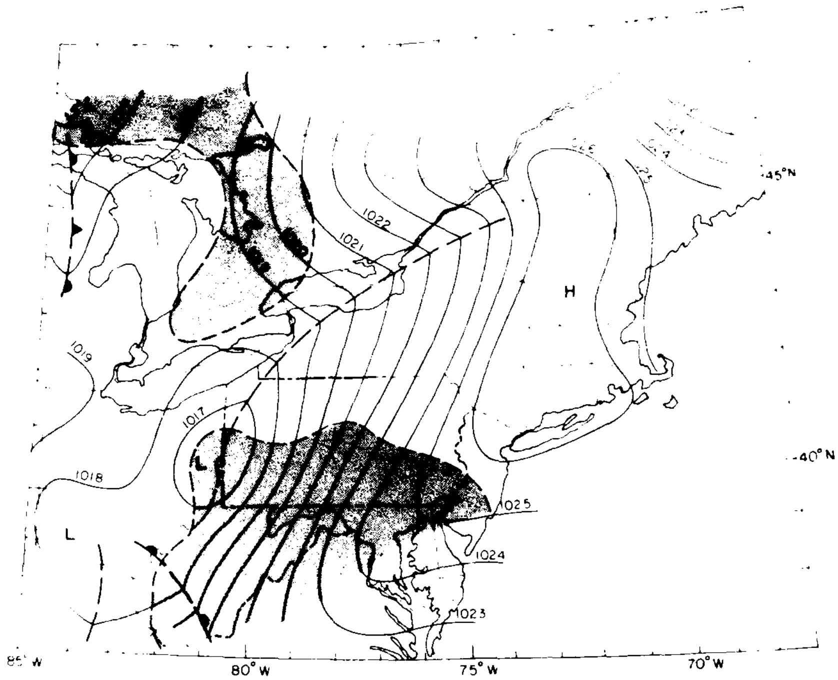

Figure 33. Surface weather map, 1900, 19 January 1982. The precipitation zone is shaded.

formed along this trough as it crossed northern New England from the northwest, as shown in a GOES-E image taken at 1201 EST on 20 January (Fig. 34). Winds at Burlington Airport shifted to the south, and air temperatures increased to near -9°C.

1900, 20 January

The trough sped rapidly through the region in advance of a large, cold high pressure cell that stretched across south-central Canada and toward New England. As the trough passed the region, snow occasionally fell at moderate rates at the site, but the total amount for the event reached only 2.0 mm in water equivalent. Visibility at the site reached a minimum of 0.8 km near noon as the atmospheric pressure started to rise and the wind at the Burlington Airport shifted sharply from southerly to westerly. Skies across the region cleared rapidly, and the air temperatures again started to decline.

Figure 34. Satellite image of the cloud pattern over the northeastern United States taken at 1201, 20 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

0700, 21 January

The eastern edge of the massive high pressure cell in Canada penetrated northern New England. Locally the weather continued cold (overnight temperature down to -30°C at the site). There were high clouds of variable coverage and visibility was excellent.

1900, 21 January

The surface synoptic map pattern as well as the weather conditions over northern New England remained essentially unchanged. Daytime solar radiation, however, increased the air temperature to a high of near -18°C at the site.

0700, 22 January

The massive cold Canadian high pressure cell divided into two sections, with the southeastern part centered over southern Ontario and Quebec. Almost all of the northeastern United States was affected by this system, and the weather across the region became mostly clear, cold and dry, with excellent visibility.

1900, 22 January

The southern part of the large (1045 mb) high pressure cell centered over Quebec covered all of New England. Skies continued mostly clear, with a maximum daytime temperature of -18°C and a minimum nighttime temperature of -35°C at the site. A major storm was located in the central United States, and a very strong pressure gradient had developed across the entire Great Lakes region. This storm moved northeastward, headed toward New England. The leading edge of the precipitation shield was almost at the western borders of New York and Pennsylvania.

0700, 23 January

The atmospheric pressure across most of the Northeast fell rapidly as the major storm that covered all of the Great Lakes continued its northeastward movement. Winds veered sharply from the north to the east, and finally began to blow from the south or southeast across northern Vermont. They became much stronger, with gusts of over 10.3 m/s reported at Burlington Airport. Light snow began just before 0700 at the airport. The air temperature increased steadily after midnight. The occluded, cold, and warm fronts associated with this storm stretched from the low center near Lake Superior south and southeastward toward the southeastern states (Fig. 35). Unusually strong winds surrounded much of this intense depres-

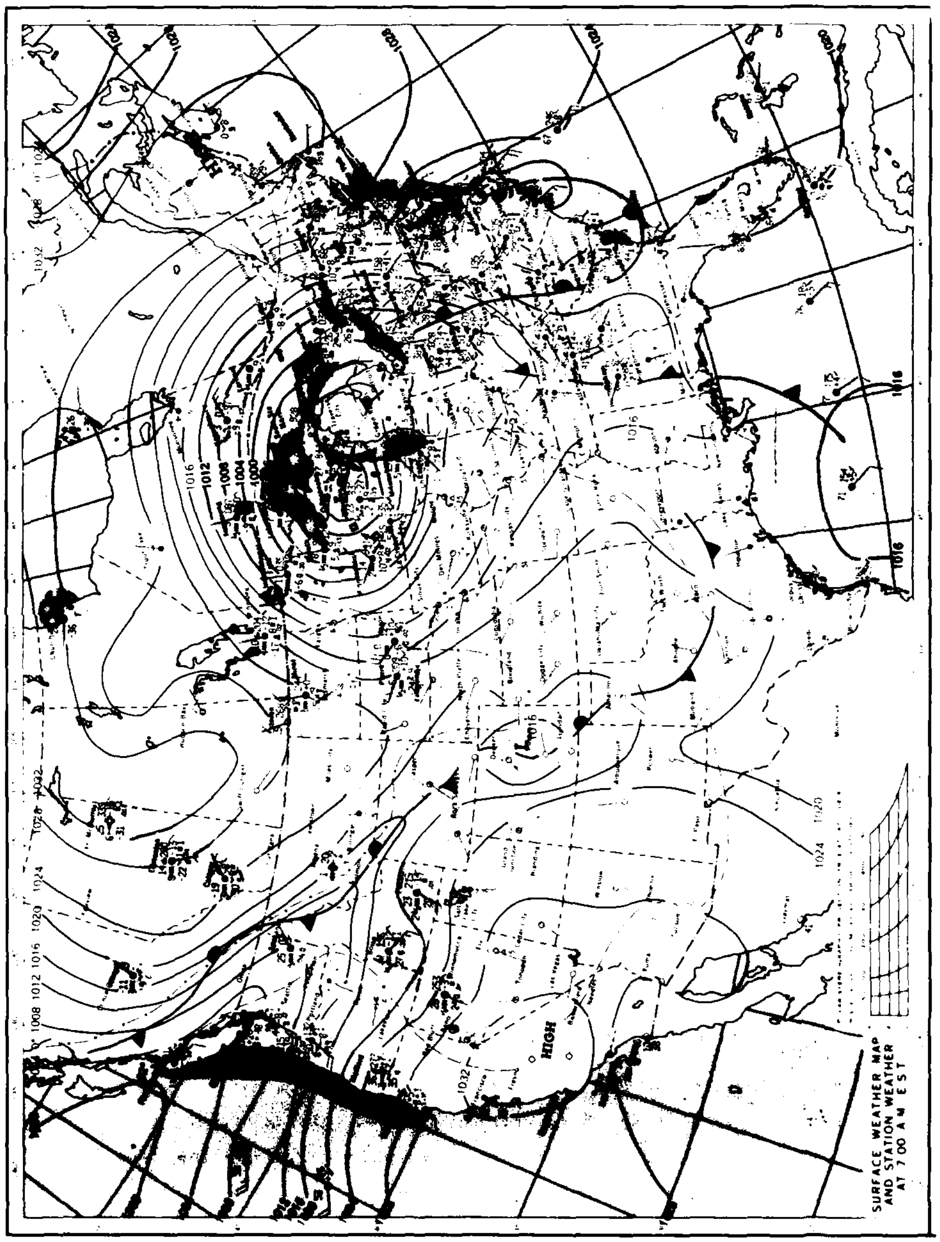

Figure 35. Surface weather map and station weather, 0700, 23 January 1982.

Figure 36. Satellite image of the cloud pattern over the eastern United States taken at 1330, 23 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

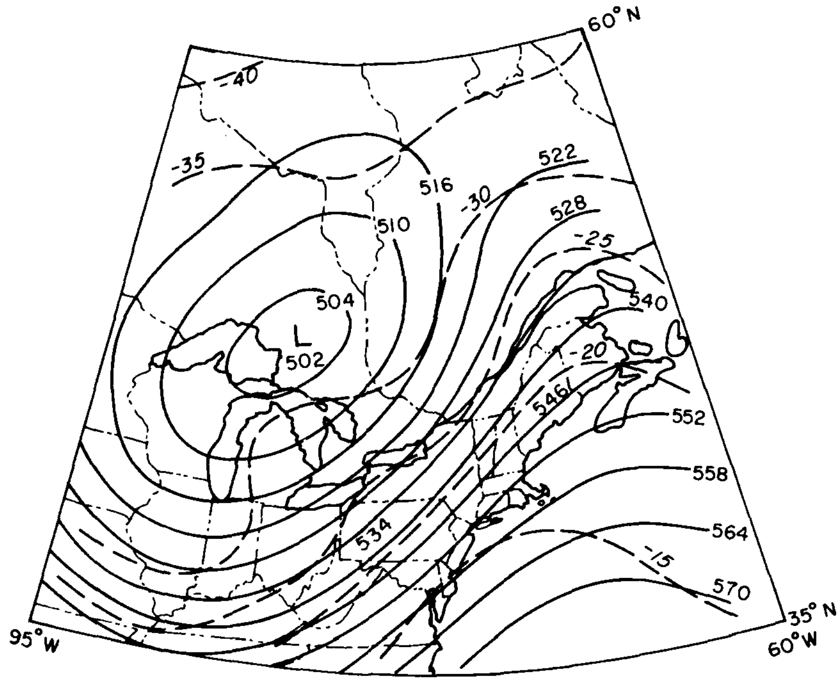

Figure 37. Weather chart for 500-mb level, 1900, 23 January 1982. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

sion. An excellent view from space taken at 1330 EST on 23 January revealed a classic textbook example of the distribution of clouds that can be expected with this type of frontal system (Fig. 36).

1900, 23 January

As the center of the large storm over the Great Lakes tracked northeastward into southern Ontario, the three fronts associated with it moved rapidly eastward. Meanwhile, a secondary low (with some indication of cyclogenesis) formed in advance of the main storm, with its center located over southern New England. This combination of systems brought extremely poor weather conditions to northern Vermont. Hourly wind speeds averaged 13 to 18 m/s, with gusts of over 30 m/s. The ceiling lowered to about 30 m at times, and visibility decreased to 1.6 km or less for most of the day. There was light to moderate snowfall and blowing snow. The pressure fell rapidly, air temperatures rose from near -25° to -5°C at Burlington Airport between midnight and 1900 hours, and the humidity increased steadily. The intensity of this storm is obvious from the steep gradient seen in the upper levels of the atmosphere (500 mb) along the eastern United States in Figure 37. The following statements were made by the weather observers on site: "Unable to read rain gage [for snowfall and water-equivalent data] or measure snow depth due to high winds." And "Barometer indicators fluctuating erratically due to the strong wind."

0700, 24 January

The newly formed wave over southern New England merged with the fronts that were moving rapidly eastward across the region, and the entire system tracked northeastward. Two closed-low centers were identified with the storm, one over central Quebec and the other over the Maritime Provinces. Some instability behind the system still existed, as indicated by the residual depression north of the Great Lakes and trough lines passing from the northwest through the Lakes (Fig. 38). Snowfall continued intermittent and light during the night at Burlington Airport, where 10.8 cm of new snow accumulated. The strong winds persisted through the night at the airport, with drifting snow and gusts of up to 13.4 m/s. Visibility improved to about 8 km or more, with only scattered clouds. The closed low on the 500-mb chart was centered over the Ontario-Quebec border, and wind speeds at this level over the New England coastline exceeded 50 m/s (Fig. 39).

1900, 24 January

The center of the storm advanced northeastward to the Gulf of St. Lawrence, and unstable air behind the system prevailed across New England. Surface winds were westerly, and scattered snow flurries were reported at numerous locations, including northern Vermont. Only trace amounts of snow in water equivalent were recorded during the previous 12 hours of atmospheric instability. Skies stayed overcast, winds remained strong and gusty, and air temperatures fell gradually.

0700, 25 January

The weather conditions over northern Vermont slowly improved as the storm over southeastern Canada drifted northeastward. Surface winds abated somewhat, some breaks in the sky were observed, and the light snow flurries ended. Air temperatures decreased to near -20°C, the atmosphere became much drier, and visibility was excellent.

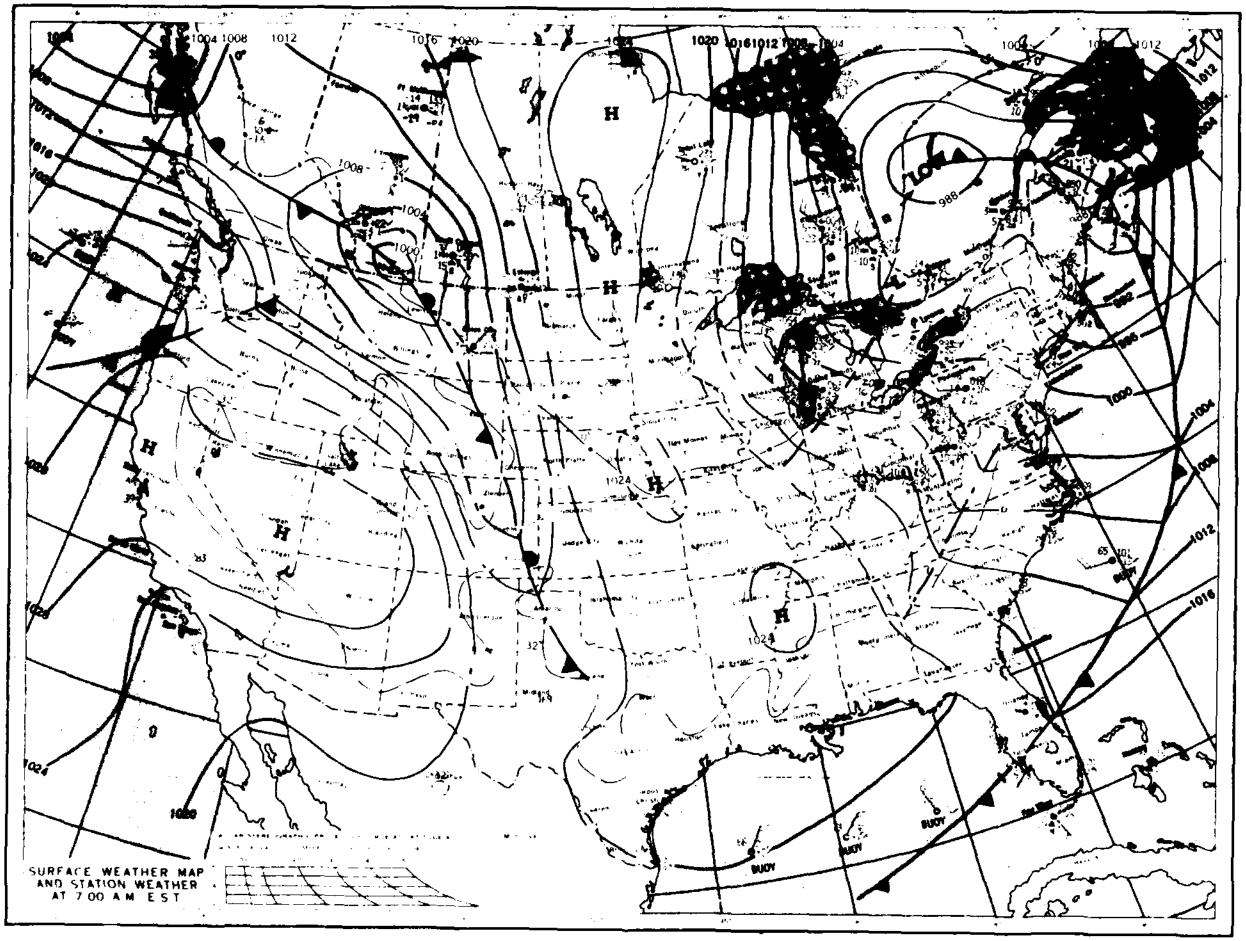

Figure 38. Surface weather map and station weather, 0700, 24 January 1982.

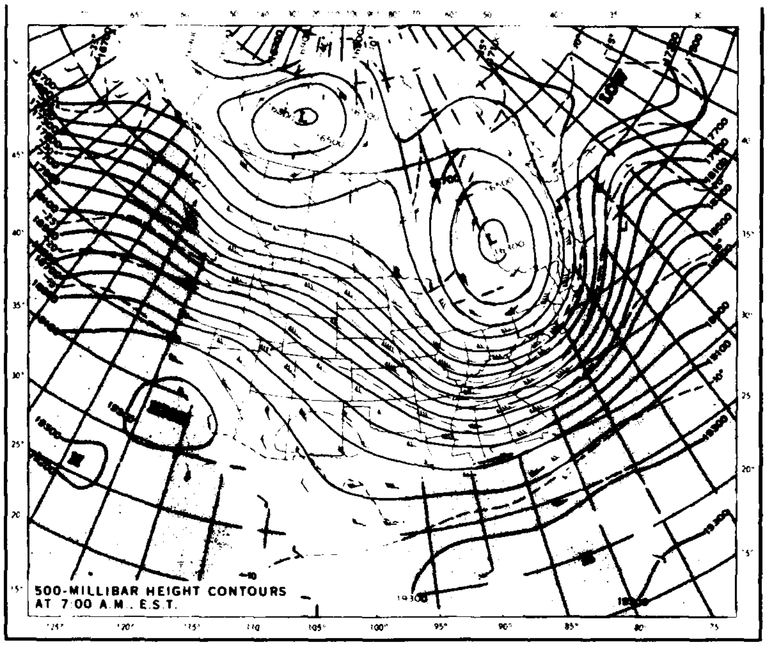

Figure 39. Weather chart for 500-mb level, 0700, 24 January 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

<u>1900, 25 January</u>

Little change in the surface synoptic map or the weather conditions across northern New England occurred during the previous 12 hours.

<u>0700, 26 January</u>

A cyclonic wave developed over the southeastern states and moved across Cape Hatteras and out to sea. This disturbance did not influence the weather in New England. The eastern edge of high pressure behind this disturbance centered over central Illinois had pushed across the local region. Consequently, the weather over northern Vermont continued partly cloudy and cold (overnight temperatures near -26°C). Visibility was excellent.

<u>1900, 26 January</u>

The high pressure cell over Illinois tracked eastward, and fair weather spread across the eastern third of the country. Skies over most of

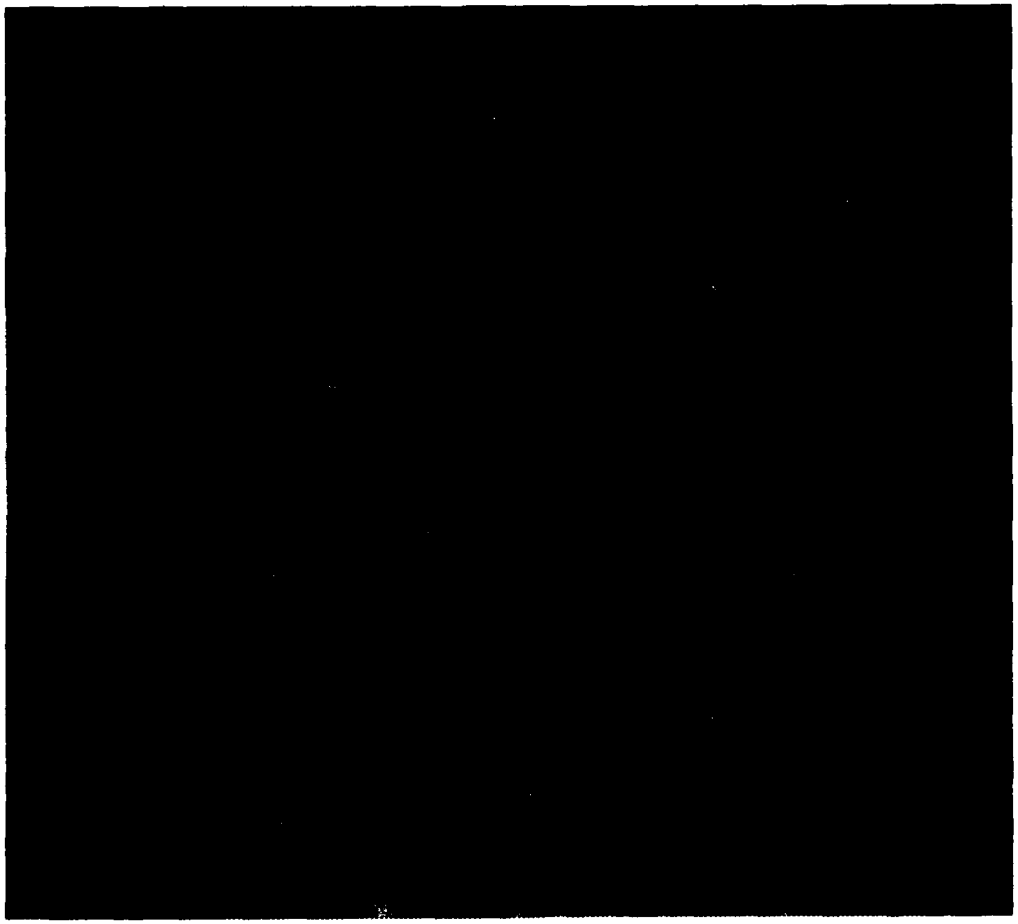

Figure 40. Satellite image of the cloud pattern over the northeastern United States taken at 1331, 28 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

the Northeast cleared, and the air remained cold and mostly dry, with excellent visibility.

0700, 27 January

Little change in the surface synoptic map or the weather conditions across northern New England occurred during the previous 12 hours.

1900, 27 January

The main center of the high cell that had been influencing the east coast was over Cape Hatteras, and a wedge extended northward into New England. A strong pressure gradient started to build across the eastern Great Lakes region in advance of a deep trough that extended from a low in Ontario. Some high thin clouds started to form over northern Vermont, but essentially the local weather conditions, except for a slight warming trend, showed little variation.

0700, 28 January

As the trough and its associated occluded, cold, and warm fronts tracked eastward across the Great Lakes, cloudiness over northern Vermont steadily increased. The local winds strengthened from the south, and the air temperature rose sharply to near -6°C. Visibility remained excellent, and the air was still relatively dry. The extensive cloud coverage over southeastern Canada and most of the northeast United States is shown in a satellite image taken at 1331 EST on 28 January (Fig. 40). The streaked pattern of cloudiness across the southern edge of the cloud shield in this image also indicated the existence of strong southerly winds.

1900, 28 January

The major trough that extended southward from the low centered over Quebec reached the eastern border of the Great Lakes. The frontal systems associated with this system had also tracked eastward, and were located over parts of Quebec, New York, and Pennsylvania (Fig. 41). Southerly winds in advance of the trough because quite strong (e.g. gusts of 15 m/s at Burlington Airport), and light snow broke out throughout northern Vermont, with periods of blowing or drifting snow. Local air temperatures continued to increase to near -2°C, and visibility (except during the occasional snow showers) stayed above 11 km. Hourly precipitation values did not exceed a trace, and the atmospheric pressure started to rise.

0700, 29 January

The low in Quebec and its associated trough and frontal systems sped quickly eastward to the Canadian Maritimes. Winds across northern New

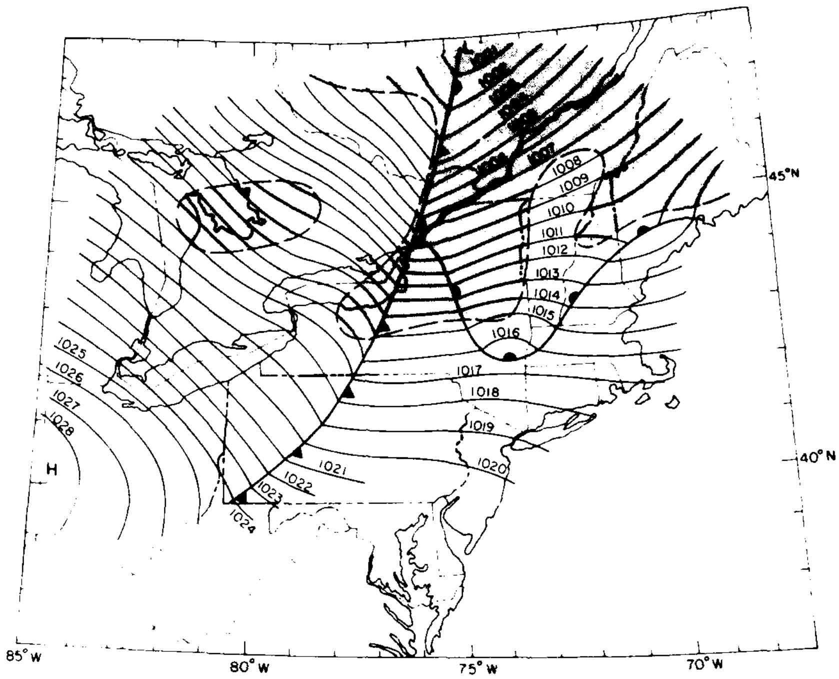

Figure 41. Surface weather map, 1900, 28 January 1982. The precipitation zone is shaded.

England became westerly and continued strong and gusty. Snow flurries continued across northern Vermont due to the unstable air behind the frontal passage. Although the air pressure indicated frontal passage about 12 hours earlier, the air temperature had fallen only slightly. A high pressure cell in the central United States moved eastward to a position over the Appalachian Mountain chain.

<u>1900, 29 January</u>

Since the trough and fronts that had passed through New England slowed as they reached the Canadian east coast, the weather during the previous 12 hours across northern Vermont continued as before. Brief snow showers with poor visibility were occasionally recorded, and winds were still quite strong and gusty during most of the day. However, skies over the local region started to clear, winds lightened and shifted to the northwest, and the air temperatures fell. The high pressure cell was over the central east coast and had taken control of the weather over most of the Atlantic seaboard.

0700, 30 January

The center of the high pressure cell tracked northeastward and passed south of New England as skies remained clear over northern Vermont for most of the night. Air temperatures fell to below -12°C, and good visibility was reported at Burlington Airport. A region of low pressure developed over southeastern Ontario and parts of the Great Lakes. A cold front within this region moved southeastward in advance of another very cold high pressure cell over south-central Canada. A warm front through the Ohio Valley moved northward toward the advancing cold front. These systems caused rain or snow to break out over most of the eastern half of the Great Lakes and surrounding regions (Fig. 42). The wide band of major cloudiness associated with these systems stretched northeastward from the central states across to New England, as seen from space at 1330 EST on 30 January (Fig. 43).

1900, 30 January

As the region of low pressure tracked eastward to central Quebec, the cold front with its associated trough line joined the northward-moving warm front in the vicinity of western New York and Pennsylvania. The leading edge of the snowfall from these systems reached the site at 1030 hours, and light to moderate snow fell during most of the day. Visibility was reduced to 0.8 km on occasion, and the wind speed increased sharply. Air temperatures during the snowfall period remained between -2° and -4°C, and the ceiling was estimated at about 900 m through most of the snowfall period. Only a trace of snow was recorded during each hour at the site.

0700, 31 January

The low over Quebec and the frontal systems that tracked into New York and Pennsylvania moved quickly northeastward and through the Gulf of St. Lawrence. The eastern edge of the high pressure cell in south-central Canada grazed northern New England, and weather conditions improved. Snow in the area decreased to light flurries, and visibility increased to 9.6 km or more. The air temperature at Burlington Airport remained high (above -7°C) through the night. However, another large region of low pressure with a wave at its center moved from Texas to western Tennessee and Kentucky (Fig. 44). Rain, snow, or mixed precipitation broke out north and northwest of the center of this storm. The upper-air (500 mb) flow pattern indicated further movement of the storm toward the Northeast (Fig. 45).

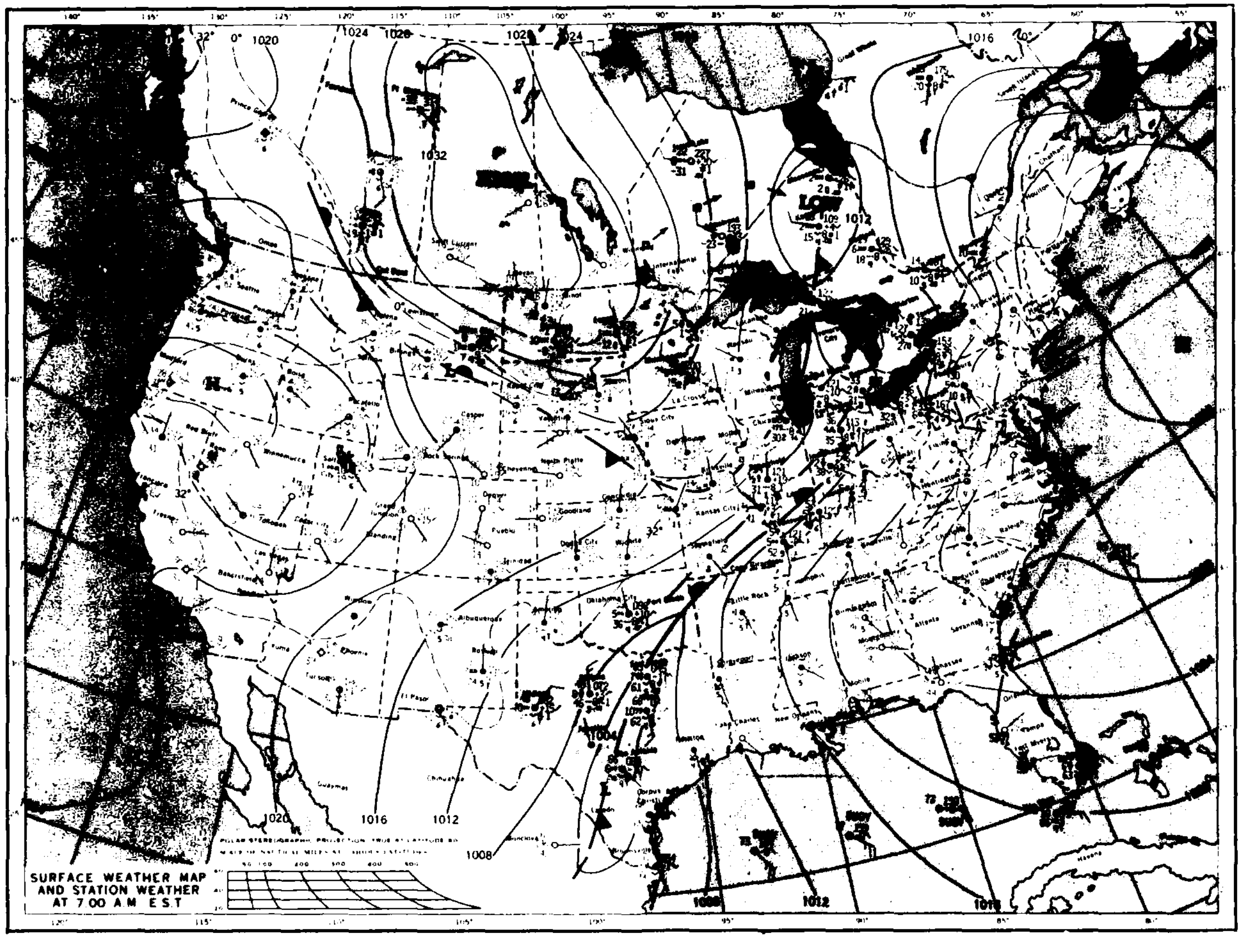

Figure 42. Surface weather map and station weather, 0700, 30 January 1982.

Figure 43. Satellite image of the cloud pattern over the eastern United States taken at 1330, 30 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

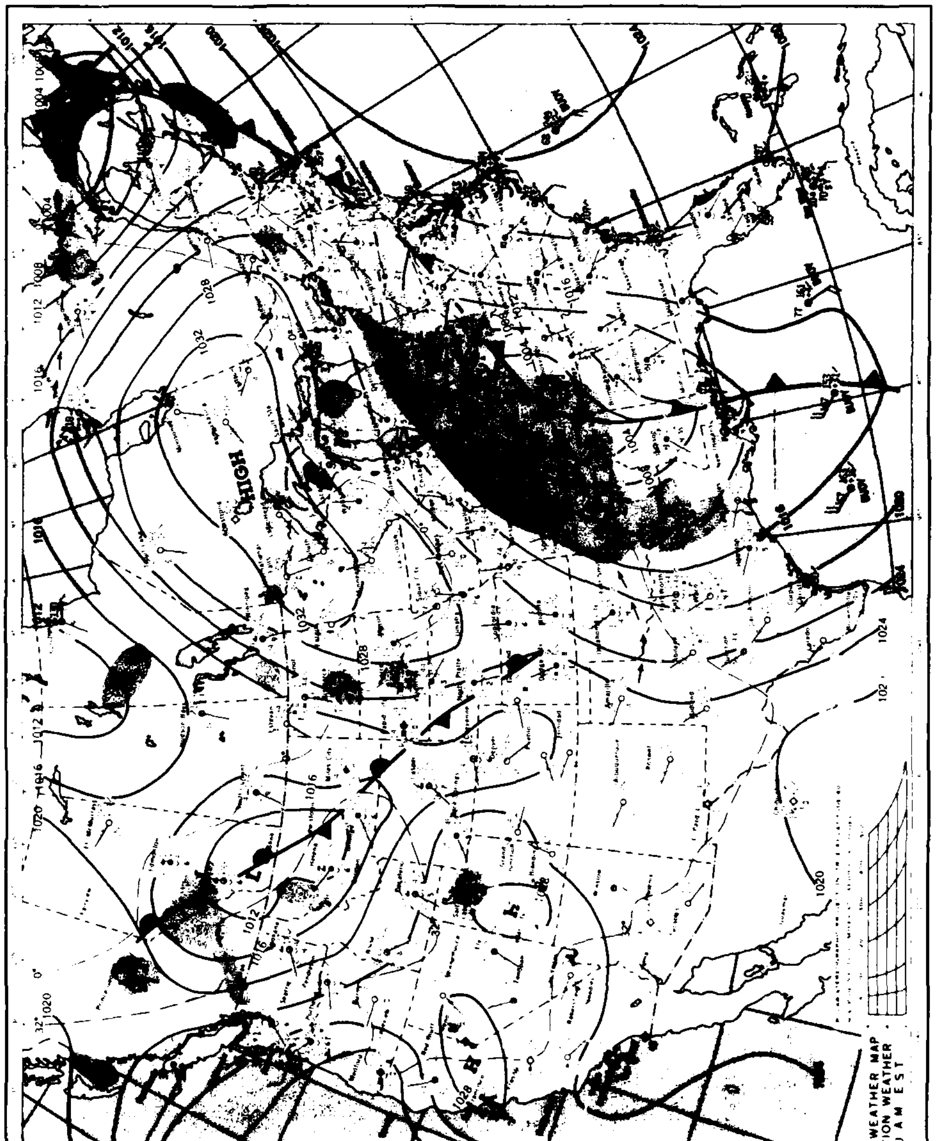

Figure 44. Surface weather map and station weather, 0700, 31 January 1982.

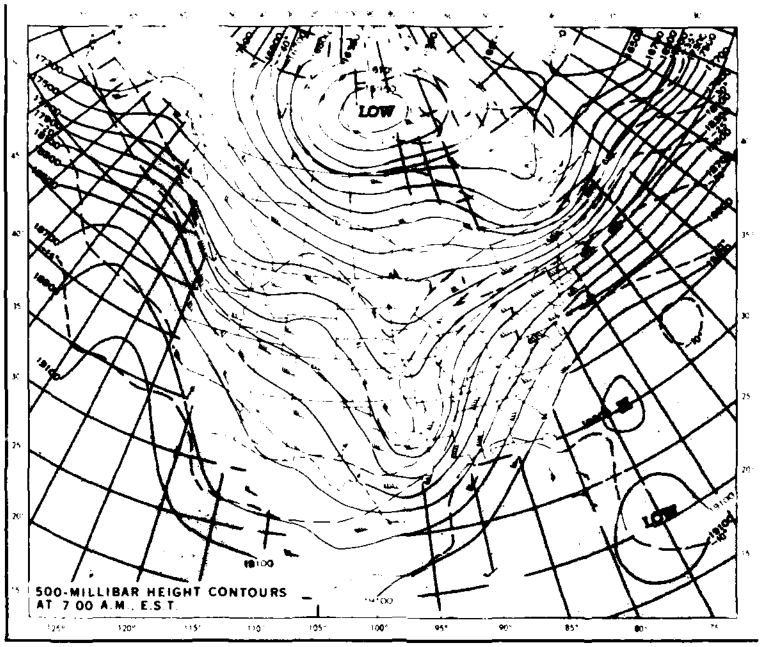

Figure 45. Weather chart for 500-mb level, 0700, 31 January 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

The severity of this developing storm is indicated by the major cloud coverage displayed on the GOES-E image taken at 1330 EST on 31 January (Fig. 46).

0100, 1 February

As the low center over western Tennessee and Kentucky tracked northeast, precipitation became widespread throughout the region. Snow began to fall across northern Vermont between 1500 and 1600 on 31 January and continued through the day. As warmer air began to overrun the region at upper levels, the precipitation (after midnight) changed to freezing rain and freezing drizzle at Burlington Airport, and to ice pellets at the experiment site. The wind increased in speed to 10-12 m/s, with gusts to 17 m/s, and visibility was down to 0.5 km in blowing snow. The ceiling was often ragged and low (about 90 m), and from the start of snowfall to 0100 air temperatures increased from -11° to near 0°C. Hourly snowfall amounts

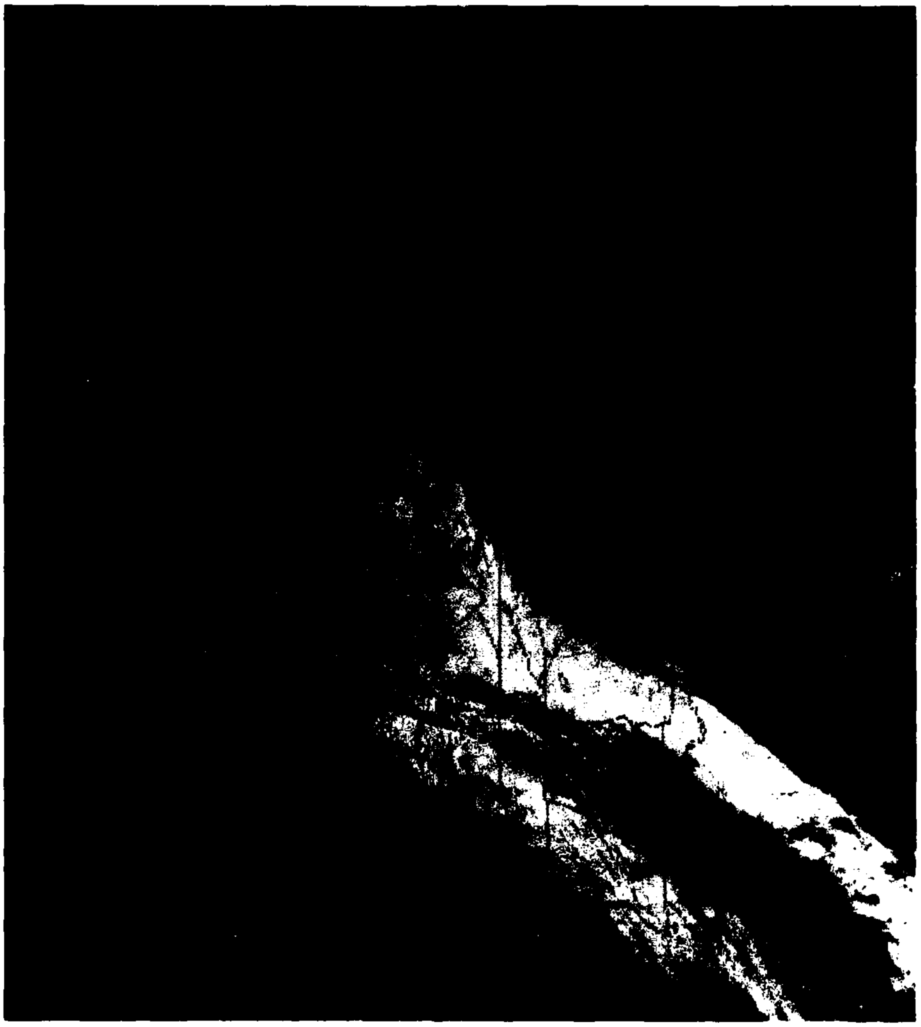

Figure 46. Satellite image of the cloud pattern over the eastern United States taken at 1330, 31 January 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

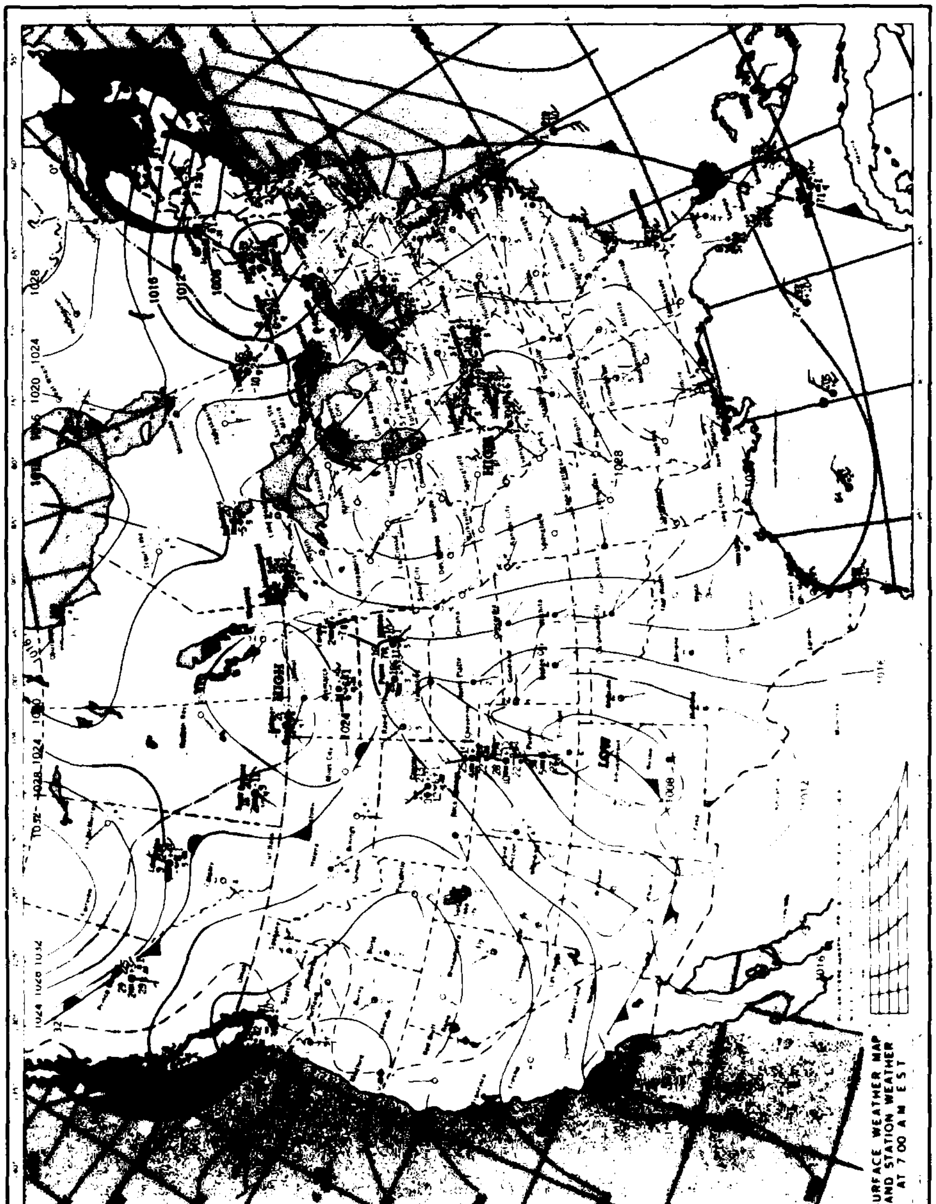

Figure 47. Surface weather map and station weather, 0700, 1 February 1982.

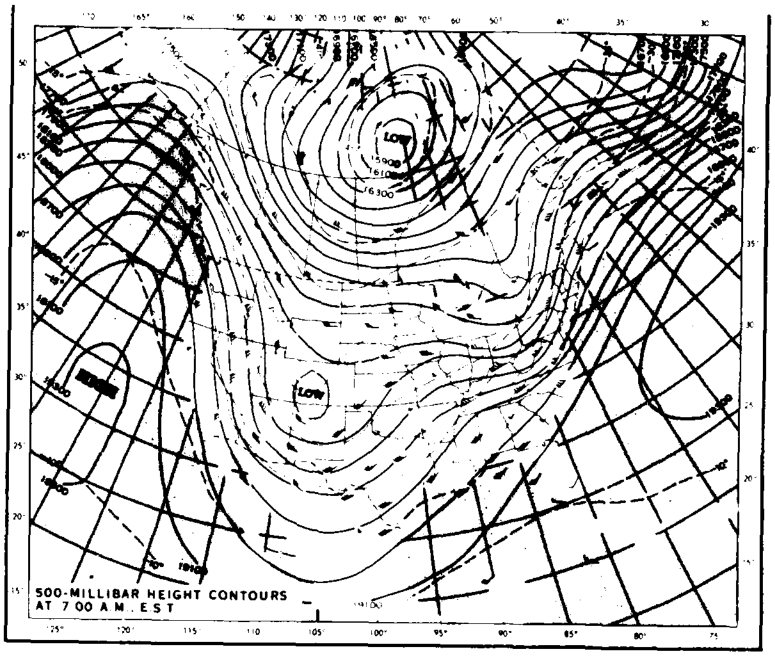

Figure 48. Weather chart for 500-mb level, 0700, 1 February 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

were occasionally appreciable, with over 10.0 mm of new snow in water equivalent, for example, accumulating during a 7-hour period at the site.

<u>0700, 1 February</u>

The low was centered over northern Vermont, and the peak of the wave associated with it was over Cape Cod. Rain, snow, or mixed precipitation covered most of New England and parts of New York (Fig. 47). As the air temperature continued to increase to above freezing, the precipitation changed from ice pellets to light rain. Strong southerly winds persisted through the night, with hourly values of 11 to 12 m/s and gusts of 18.5 m/s. Visibility was occasionally reduced to 0.5 km or less in blowing snow at the site.

<u>1900, 1 February</u>

Strong southwest winds aloft, as shown on the 500-mb chart at 0700 on this date (Fig. 48), swept the surface low over New England quickly toward the Maritime Prcvinces, and precipitation over northern Vermont ended during the afternoon. The air pressure started to rise rapidly, the air temperature decreased sharply, and skies became clear, with good visibility. A high pressure cell approaching from the southwest began to influence the Northeast. Precipitation at the site during the 31 January and 1 February storm totaled about 18.5 mm in water equivalent. Hourly precipitation measurements occasionally had to be estimated, however, due to the high winds that accompanied the storm.

<u>0700, 2 February</u>

The high pressure cell built to 1040 mb and was centered directly over northern Vermont and New Hampshire. Local weather overnight was clear and cold, with excellent visibility.

<u>1900, 2 February</u>

As the high pressure cell gradually drifted across New England a deck of high clouds started to cover the region. Area winds again shifted to the south, and the air temperatures increased markedly from near -20° to near -2°C during the previous 12 hours. The atmospheric pressure started to fall as a series of minor cyclonic waves followed behind the high cell. One wave, centered over James Bay, Canada, caused snow to fall over parts of the Great Lakes, and a series of waves strung along the southeastern states produced rain over much of that region.

<u>0800, 3 February</u>

Although a wedge of high pressure persisted over parts of northern New England, the series of waves in the southeast slipped quickly northeastward along the east coast. The leading wave was located over eastern Virginia, and the trough associated with a following second wave stretched northeastward over the Appalachian Mountains and into Pennsylvania and New York (Fig. 49). Air temperatures across northern Vermont increased to slightly above 0°C, and precipitation changed from light snow and freezing rain to light rain during the previous 6 hours. Gradually the cloud base lowered and visibility decreased across the region. The atmospheric pressure started to fall rapidly.

<u>1900, 3 February</u>

As the leading wave weakened along the New England coastline, the following wave became more dominant, and was centered in the trough that had formed along the Appalachian crest and through Pennsylvania and New York. Warm, moist air was being advected into most of New England as a

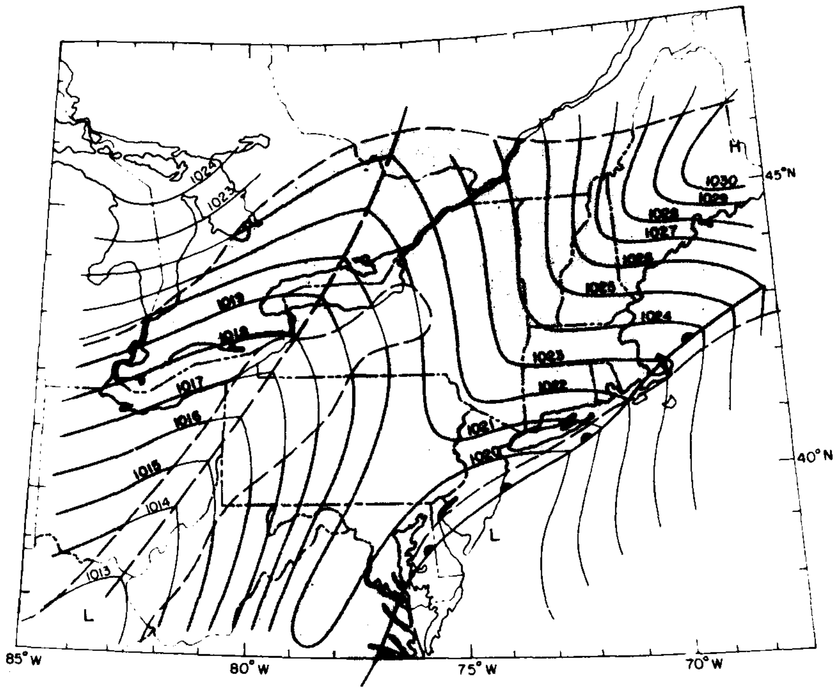

Figure 49. Surface weather map, 0800, 3 February 1982. The precipitation zone is shaded.

strong southerly flow became established over the region at the upper levels (500 mb) of the atmosphere (Fig. 50). The system brought light to occasionally moderate rainfall to northern Vermont during most of the day.

The cloud base was often very low and ragged, and visibility frequently was reduced to less than 1.0 km in rain and fog at Burlington Airport. Air temperatures remained above 0°C, and although the air pressure continued to fall, wind speeds stayed steady but light. Hourly rainfall rates during the storm ranged from 0.2 to 0.4 mm at the experiment site.

<u>0700, 4 February</u>

The cyclonic wave and its associated trough glided swiftly northeastward to the Canadian Maritimes and the atmospheric pressure across northern Vermont started to rise rapidly. Light rain ended overnight and visibility improved as the clouds and fog lifted. Total rainfall amounts for the storm reached 17.8 mm at the site and 20.0 mm at Burlington Airport. Air

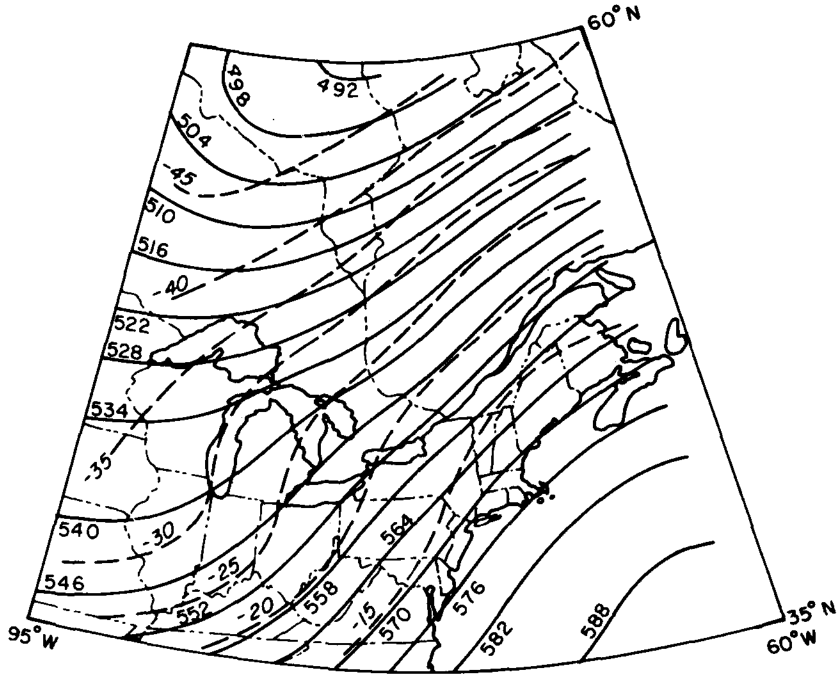

Figure 50. Weather chart for 500-mb level, 1900, 3 February 1982. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

temperatures began to decrease slowly, and winds at the airport increased slightly in strength and shifted to the north. A large high pressure cell moved south from central Canada and extended southeastward across the Great Lakes.

<u>1900, 4 February</u>

The position of the high pressure cell over the Great Lakes showed only slight movement eastward, and the weather over northern New England slowly improved. Brief periods of light snow (trace amounts) were recorded at the site, although some breaks in the overcast were noted, with excellent visibility. Air temperatures continued to fall, and the air became much drier as the day progressed.

<u>0700, 5 February</u>

A portion of the high pressure zone over the Great Lakes divided from the main Canadian high cell and passed over New England. The small bubble

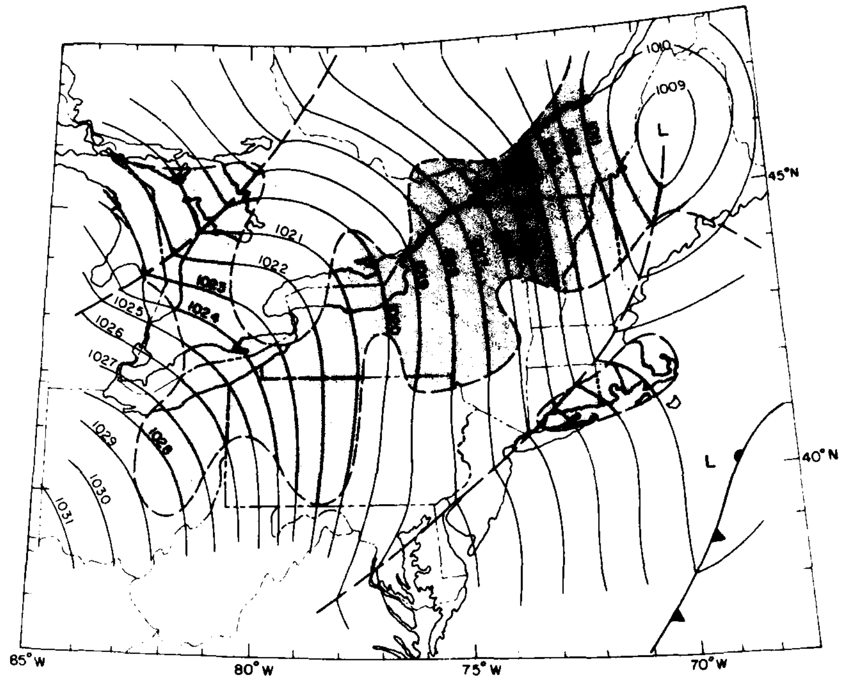

Figure 51. Surface weather map, 0700, 6 February 1982. The precipitation zone is shaded.

high provided a short interval of fair weather for northern Vermont. Overnight air temperatures fell to near −19°C and skies were mostly clear, with excellent visibility. Meanwhile, a shallow region of lower pressure developed across parts of the Mississippi River valley and the central Great Lakes, and snow broke out over much of these regions.

1900, 5 February

As the bubble of high pressure drifted northeastward, the shallow zone of low pressure moved across the Great Lakes toward New England. Skies over northern Vermont quickly became overcast during the day, and light snow started at the Burlington Airport during the previous hour. Winds backed from the north to the southwest and air temperatures were on the rise again. The snow shield from this shallow depression covered the four eastern Great Lakes, northern New York, and parts of western New England.

0700, 6 February

The shallow low with a poorly defined cold front that extended southeastward from its center and a weak wave located off the New England coast influenced northern Vermont (Fig. 51). Light snow was observed through the night at Burlington Airport, with visibility often down to 1.6 km. Although the snow shield due to this depression was widespread, locally the hourly amounts were light (e.g. from a trace to 0.5 mm in water equivalent at Burlington Airport). Air temperatures overnight rose to near -1.0°C, but started to fall again as the wind direction gradually became northerly. The northeast fringes of a large high pressure cell over the south-central United States meanwhile pushed toward the eastern Great Lakes.

1900, 6 February

The shallow depression tracked northeastward and the weather across northern Vermont gradually improved. Skies became partly cloudy, air temperatures steadied at near -8°C, and visibility became excellent. The ridge of high pressure from the high over the south-central United States continued to spread northeastward toward New England.

0700, 7 February

The high pressure cell covered most of the eastern third of the nation and continued to provide fair weather to New England. Few clouds and excellent visibility were observed, and minimum overnight temperatures were near -13°C. Surface winds became westerly and strengthened due to a pressure gradient that steepened as a low pressure zone and trough running through Ontario traveled rapidly southeastward.

1900, 7 February

Most of the northeastern United States was within a strong latitudinal (or zonal) pressure gradient that extended from the Canadian low (1002 mb) located in central Quebec southward to a surface pressure contour line of 1026 mb located across Pennsylvania and Ohio. The surface winds due to this flow were from the west or southwest at most locations, and the air was quite dry, since precipitation was occurring only at a very few locations. A weak occlusion moving rapidly eastward was identified just east of the Great Lakes. Winds across northern Vermont around noon were quite strong, gusting to over 15.5 m/s at Burlington Airport.

0700, 8 February

The weak occlusion east of the Great Lakes sped across northern New England and was followed by another minor trough that was located over northern Vermont (Fig. 52). These lines of instability produced brief periods of light snow showers that reduced the visibility to about 4 km and

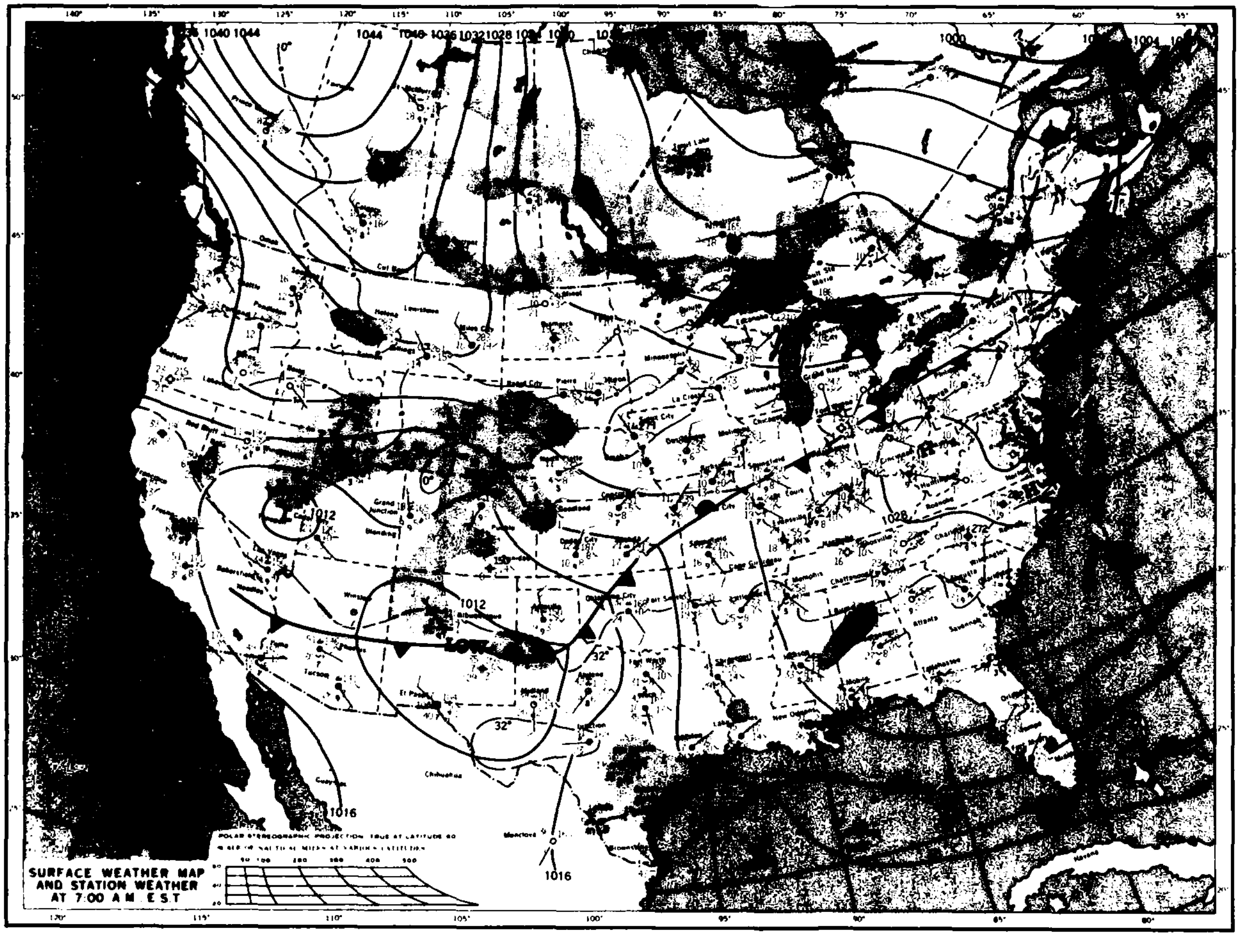

Figure 52. Surface weather map and station weather, 0700, 8 February 1982.

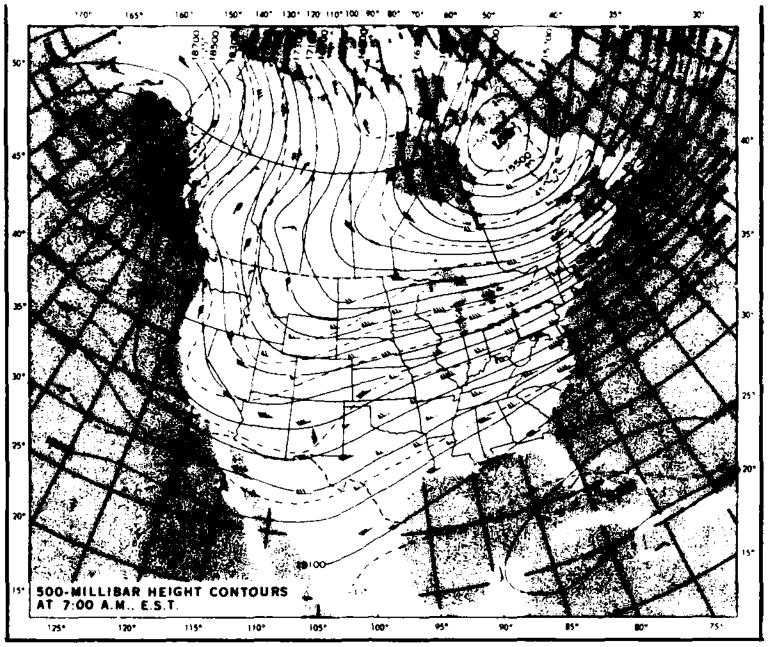

Figure 53. Weather chart for 500-mb level, 0700, 8 February 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

lowered the ceiling to about 250 m at Burlington Airport. Total snowfall due to these weak frontal passages amounted to 0.3 cm at most of the local sites. A continued strong zonal flow of air across New England was also evident on the 500-mb chart (Fig. 53).

1900, 8 February

Weather conditions across northern Vermont improved considerably. Only scattered clouds were observed, visibility became excellent, and the air temperature remained between -1.5° and -4.0°C at the airport but dropped to near -12°C at the site. The wind speed also abated. Meanwhile, a region of low pressure developed along a frontal zone that stretched from south of the Great Lakes to Texas. The center of of this depression tracked east-northeastward, and snow from the system reached western Indiana.

0700, 9 February

The region of lowest pressure along the frontal zone that extended along the .ppalachian Mountains was centered over West Virginia. This

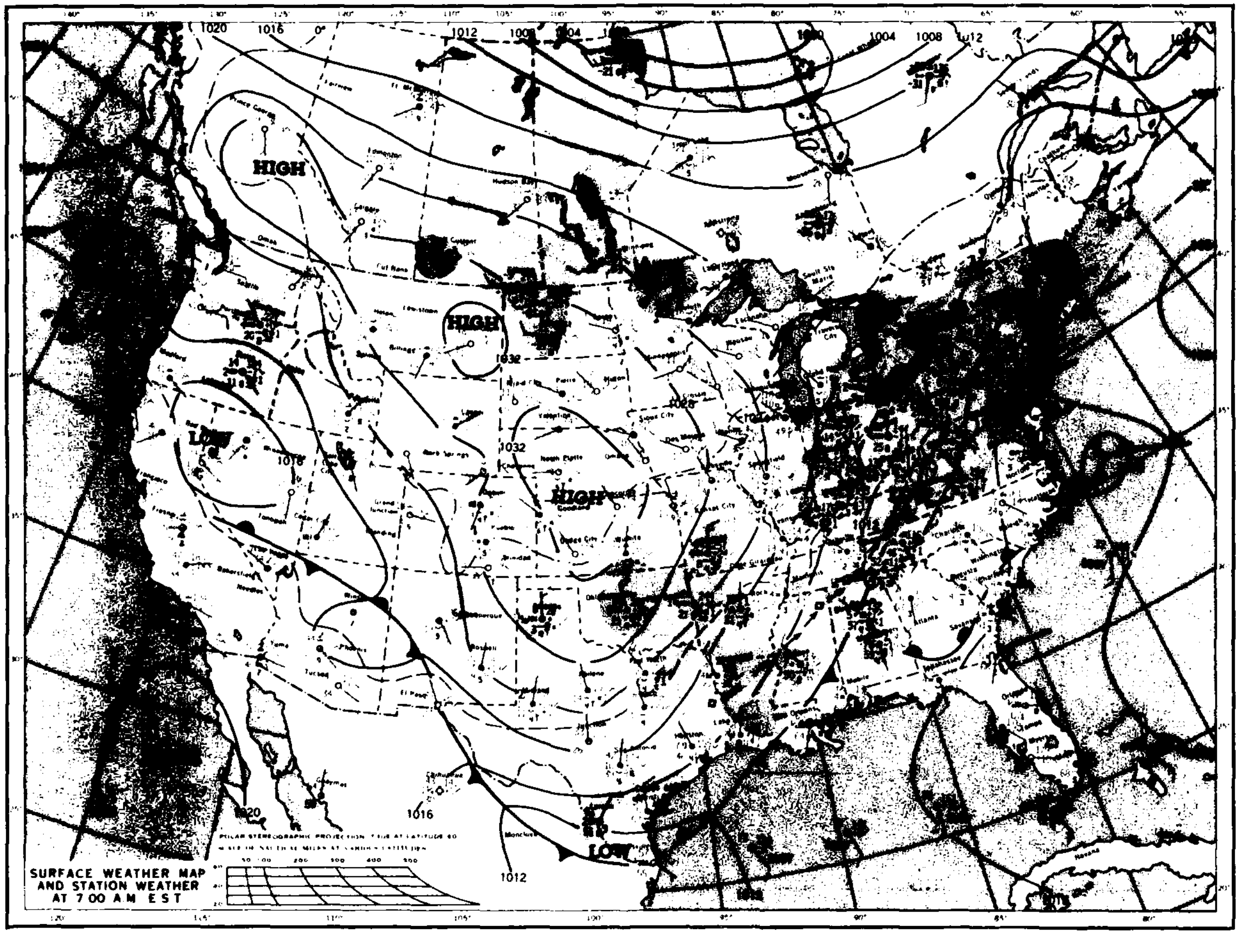

Figure 54. Surface weather map and station weather, 0700, 9 February 1982.

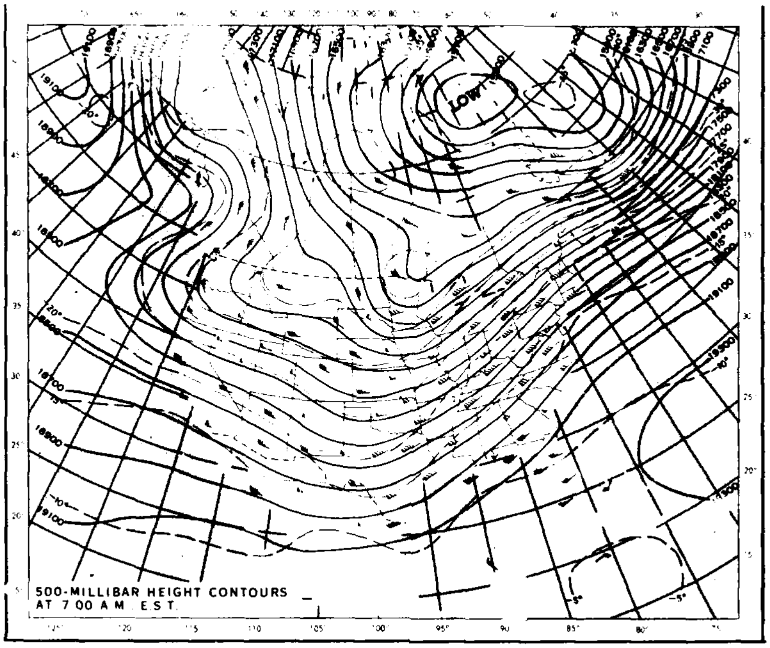

Figure 55. Weather chart for 500-mb level, 0700, 9 February 1982. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

depression and the elongated trough associated with it brought precipitation to a wide area surrounding the system (Fig. 54). Snow fell over Indiana, Ohio, Pennsylvania, and New York, and started at Burlington Airport at 0625 hours. Air temperatures across northern Vermont were near -7°C. Visibility began to decrease, and the wind started to back from its previous westerly quadrant into the south, and then into the east and northeast. The upper air (500 mb) wind flow at this time indicated continued movement of the depression toward the northeast (Fig. 55). The extensive coverage and the variety in cloud patterns shown in a satellite image taken at 1330 EST on 9 February (Fig. 56) indicated that complex atmospheric conditions existed over most of the eastern third of the United States at this time.

1900, 9 February

The center of the low pressure zone over West Virginia tracked northeastward to Long Island and Connecticut. A wave developed within this

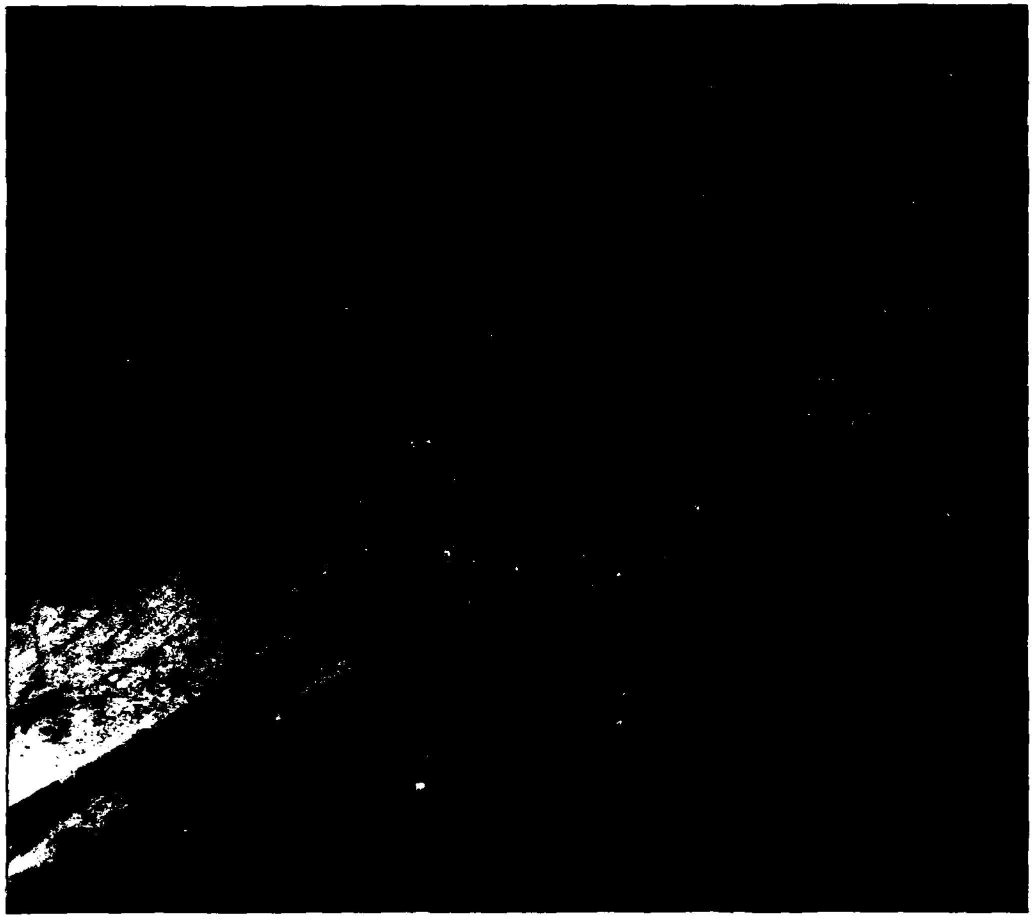

Figure 56. Satellite image of the cloud pattern over the eastern United States taken at 1330, 9 February 1982. Image obtained from the visible region of the electromagnetic spectrum by the GOES-E system.

depression, and the system brought a major snowstorm to the Northeast. Snow was observed in all the New England states, and fell almost continuously after 0630 in northern Vermont. Visibility was reduced to less than 1.6 km, with ragged ceilings of 150 to 250 m during most of the day at Burlington Airport. After the snow started, air temperatures ranged between -3° and -7°C, and relative humidity was between 81% and 100%. Although the snowfall was steady, the hourly amounts in water equivalent were relatively light, ranging from a trace to 1.6 mm at the site.

0700, 10 February

The wave continued to move off the New England coast to a position east of Nova Scotia. Light snow fell through the night across northern New England, at times accompanied by fog that reduced visibility to 0.8 km at Burlington Airport. The air pressure in the area started to rise around midnight, and the air temperature started to decrease gradually. The clouds over Burlington Airport started to break up and the snowfall became light and intermittent. This storm brought 9.2 cm of new snow with a 4.0 mm water equivalent to the experiment site.

1900, 10 February

A ridge of high pressure moved into the region, and the sky over northern Vermont cleared. As the air temperature decreased slightly the air became quite dry (near 50% relative humidity) and visibility became excellent.

LITERATURE CITED

Aitken, G., Ed. (1982) SNOW-ONE-A data report. USA Cold Regions Research and Engineering Laboratory, Special Report 82-8.

Bilello, M.A. (1981) Synoptic meteorology during the SNOW-ONE field experiment. USA Cold Regions Research and Engineering Laboratory, Special Report 81-27.

Bilello, M.A. (1982) Meteorology and observed snow crystal types during the SNOW-ONE experiment. In Snow Symposium I: Hanover, New Hampshire, August 1981. USA Cold Regions Research and Engineering Laboratory, Special Report 82-17.

Bilello, M.A. and H. O'Brien (1983) Atmospheric conditions and concurrent snow crystal observations during SNOW-ONE-A. In Snow Symposium II: Hanover, New Hampshire, August 1982. USA Cold Regions Research and Engineering Laboratory, Special Report 83-4.

Cornillon, P. (1982) A guide to environmental satellite data. University of Rhode Island, School of Oceanography, Marine Technical Report 79.

Jiusto, J.E. and H.K. Weickmann (1973) Types of snowfall. Bulletin of the American Meteorological Society 54(11), 1148-1162.

U.S. Army CRREL (1983) Snow Symposium II: Hanover, New Hampshire, August 1982. USA Cold Regions Research and Engineering Laboratory, Special Report 83-4.

U.S. Department of Commerce (1981-82) Surface weather observations, WSO Burlington, Vermont: Hourly records from 27 November 1981 to 10 February 1982. National Weather Service, NOAA, Washington, D.C.

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