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SYNOPTIC METEOROLOGY DURING THE SNOW-ONE FIELD EXPERIMENT

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The daily atmospheric pressure systems and weather fronts that traversed the northeastern United States during the SNOW-ONE Field Experiment from 11 January through 20 February 1981 are summarized. This experiment is the first in a planned series of measurements to study the influence of atmospheric obscurants on electro-optical system performance. The analysis of the large-scale synoptic patterns that developed during the field test period constitutes a critical component of the research program.

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The weather during the measurement period included nine new daily high temperature records. January was one of the driest and February was one of the wettest ever observed. These conditions were caused in part by two high pressure cells and two major low pressure systems that crossed the region. One of these lows brought warm air and heavy rain to New England, and the other produced significant snowfall in northern Vermont.

PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, Geophysical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was performed under DA Project 4A762730AT42-R-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, 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 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.

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Michael A. Bilello

INTRODUCTION

The SNOW-ONE Field Experiment, held during January and February 1981 at the Camp Ethan Allen Training Center (CEATC) near Underhill, Vermont, was the first of a series of winter exercises in the U.S. Army Corps of Engineers Winter Battlefield Obscuration Program. One of the objectives of the experiment (Aitken and Redfield 1981) was to establish a comprehensive data base for studies on the influence of the characteristics of falling snow on electro-optical system performance. The planned activities to accomplish this objective included describing the snow crystal types and making replicas of snow crystals and snowflakes that fell during Intensive Measurement Phases (IMPs).[1]

Prediction of the length and intensity of the winter storms and of the type of precipitation, including snowflake characteristics such as size, shape, aggregation and riming, is strongly dependent on the synoptic weather patterns and atmospheric conditions that develop prior to each event (Jiusto and Weickmann 1973). An initial investigation of the relationship between observed snow crystal forms and concurrent weather at SNOW-ONE, for example, revealed the attachment of cloud droplets on snow crystals and the frequent formation of snow aggregates within moist and relatively warm winter air masses (O'Brien and Aitken 1981).

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 Field Experiment would provide one of the essential components of the research program. Such information constitutes a part of the chain that links the large-scale weather patterns with the on-site frozen particle characterization measurements and the data obtained concurrently by the electro-optical sensor systems.

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[1] When obscuration conditions prevailed, designated time periods were scheduled during which as many participants as possible were requested to collect data simultaneously.

Although 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 a region surrounding the SNOW-ONE field site at Camp Ethan Allen in northern Vermont will be discussed here. In general this region includes most of the northeastern portion of the United States and sections of southeastern Canada. It extends from the Great Lakes region eastward to the East Coast and for several hundred miles on into the Atlantic Ocean and from Virginia and Kentucky northward to Ontario, Quebec and the Maritime Provinces of Canada (Fig. 1).

The purposes of this report are to 1) provide a description of the synoptic conditions that developed over the area of interest during January and February 1981 and 2) briefly report the local observed surface weather associated with these systems.

Figure 1. Map of the area surrounding the SNOW-ONE field site.

DATA BASE

The daily synoptic summaries presented in this report for the period from 11 January through 20 February 1981 are based principally on weather maps analyzed by National Weather Service (NWS) personnel. These "facsimile-produced" copies of weather maps were obtained from the weather office at the Burlington International Airport, Vermont, which receives them every three hours throughout the day.

In most instances, especially when no precipitation occurred at the field site, the synoptic summaries are brief, so these NWS maps were sufficient for the analysis. However, during the periods of snowfall at the field site (i.e., 16-17, 22-23, 27 and 29 January and 2, 4, and 8-9 February), the surface and atmospheric weather conditions are described in more detail. During these periods, therefore, the Plattsburgh Air Force Base, New York, surface sectional weather maps, the NWS upper-air weather charts, and other relevant large-scale meteorological data were also used.

To provide the additional synoptic meteorological information that may be required later by other SNOW-ONE investigators, arrangements were made with the Burlington and Plattsburg 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).
3. Temperature and height maps at 850-,700- and 500-mb levels (twice daily).
4. Numerically coded radiosonde data transmissions for: a) Buffalo, New York, b) Albany, New York, c) Portland, Maine and d) Maniwaki, Quebec, Canada (twice daily).
5. National weather depiction charts (every three hours).
6. Satellite cloud charts (daily).
7. Satellite weather analysis (four times daily).

Reference to portions of the above information is made throughout this report. All of the listed weather data for the period 11 January to 20 February 1981 have been chronologically archived and stored at CRREL and are available to all SNOW-ONE participants on request.

SYNOPTIC METEOROLOGY SUMMARIES

Significant changes in the synoptic weather patterns for specific regions generally do not occur over short periods of time. An interval of

12 hours, therefore, is used in the summaries. More frequent descriptions are given during periods of inclement weather or when a frontal system moved rapidly across the area of interest.

The following discussions are presented chronologically. Times throughout the report are based on 0000 to 2400 hours and are in Eastern Standard Time. The meteorological terms used in the study are defined in Appendix A.

1300, 11 January

A deep low pressure center (968 mb) located over the Canadian Maritime Provinces extended across most of New England. Northwest winds behind a cold front that extended through this large system produced cold and cloudy weather in northern Vermont.

0100, 12 January

The low center gradually moved off to the north-northeast, and a ridge of high pressure developed over northern Vermont. Brief and very light snow flurries occurred in the area during the previous 12 hours. It was partly cloudy and still cold (below -18°C).

1300, 12 January

The weak ridge of high pressure still influenced the area, and partial cloudiness and cold weather prevailed. A well-developed frontal wave formed off the East Coast, but the system was located too far to the southeast to affect interior New England.

0100, 13 January

The high pressure ridge remained over northern Vermont. The weather was still quite cold (-26° to -28°C), with nearly clear skies. The storm off the East Coast moved northward and brought significant amounts of precipitation to the Canadian Maritime region. A weak frontal wave located just south of the Great Lakes produced considerable cloudiness and snow as far east as Ohio and West Virginia.

1900, 13 January

Northern Vermont was situated between the deep coastal storm to the northeast over the Canadian Maritimes and the weak wave over Ohio and western Pennsylvania. Snowfall occurred throughout western Pennsylvania and just east of the Great Lakes, but locally the weather remained cold (near -18°C), with high thin cloudiness.

1000, 14 January

The maritime low moved farther to the northeast, and the wave over Ohio and Pennsylvania weakened and stalled. The local weather remained cold but the skies became more cloudy.

2200, 14 January

The weak wave drifted slightly southward to West Virginia, and a trough that developed from a low pressure zone along the wave extended northwestward to the Great Lakes. These systems produced overcast skies and light snow over a large area west of New England. However, a residual small high center (1024 mb) over northern Vermont kept the local area only partly cloudy, with colder than normal temperatures.

1000, 15 January

The wave over West Virginia separated from the trough, which remained as a depression over the Great Lakes region, and moved eastward to the coastal area of Virginia. The center of the weak high remained over northern Vermont, and the skies continued to be clear or partly cloudy. The air temperatures at Burlington Airport ranged from a high of -12° to a low of -22°C during the previous 24 hours.

2200, 15 January

The depression over the Great Lakes merged with a shallow region of low pressure (1016 mb) that moved southeastward from Lake Superior and produced continuous snow and snow showers over most of the Great Lakes region. This precipitation shield had not yet reached northern Vermont.

0700, 16 January

The region of low pressure located over Lake Erie filled slightly (to 1018 mb) but continued to cause light snow to fall in most of the surrounding area. Two fronts extended from the center of this low cell. One was a cold front that stretched southward through Ohio and West Virginia; the other was a warm front that stretched eastward through central New York (Fig. 2).[2]

The principal trough on the 500-mb chart (Fig. 3) extended southwestward from Lake Huron to the central United States, and maximum winds aloft were over Ohio and western Pennsylvania.

[2] The daily NWS weather maps shown in this report are the 0700 maps that are published by the National Oceanic and Atmospheric Administration (NOAA). Although 0700 does not always coincide exactly with the times referred to in the text, the maps still adequately depict the synoptic weather conditions being described.

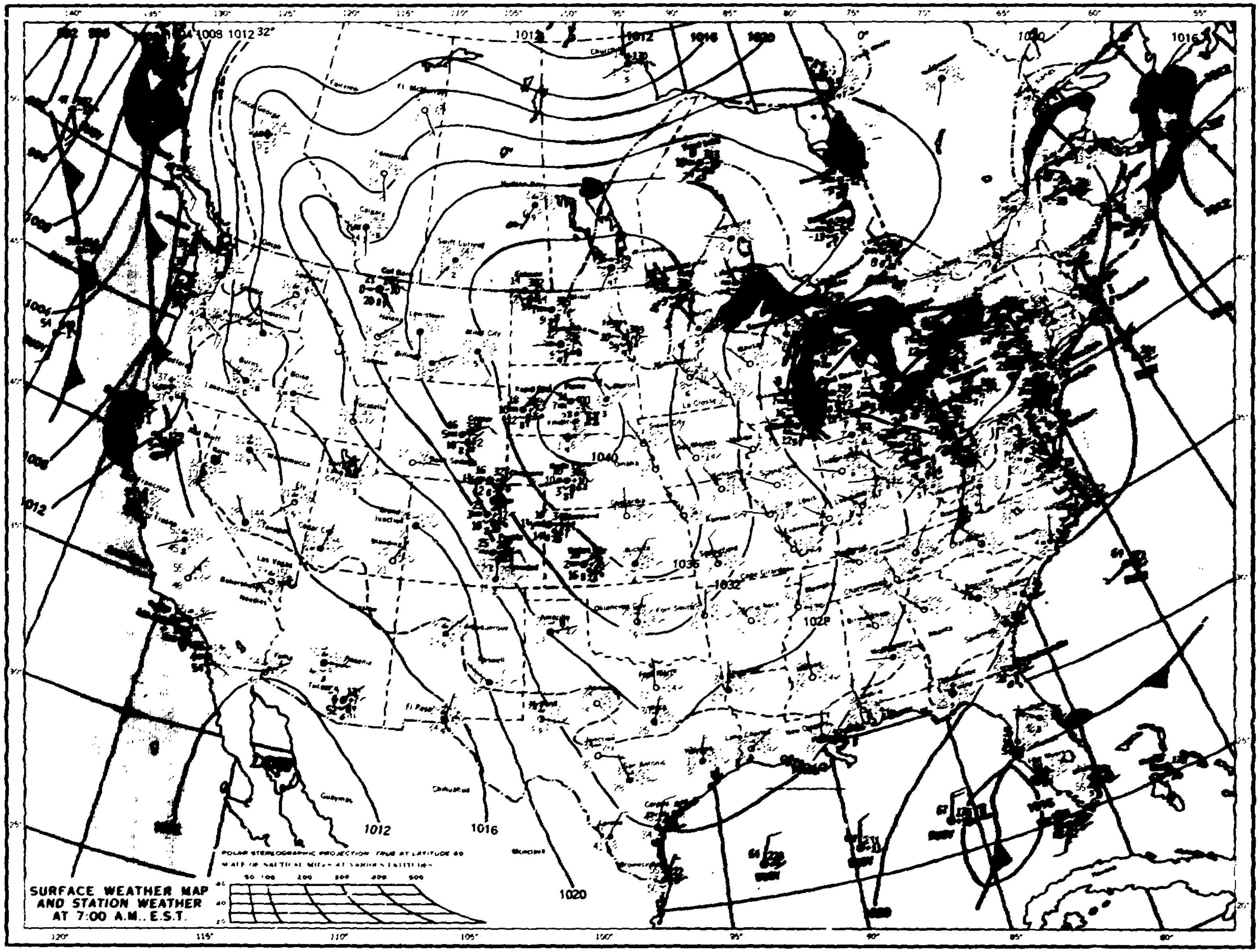

Figure 2. Surface weather map and station weather, 0700, 16 January.

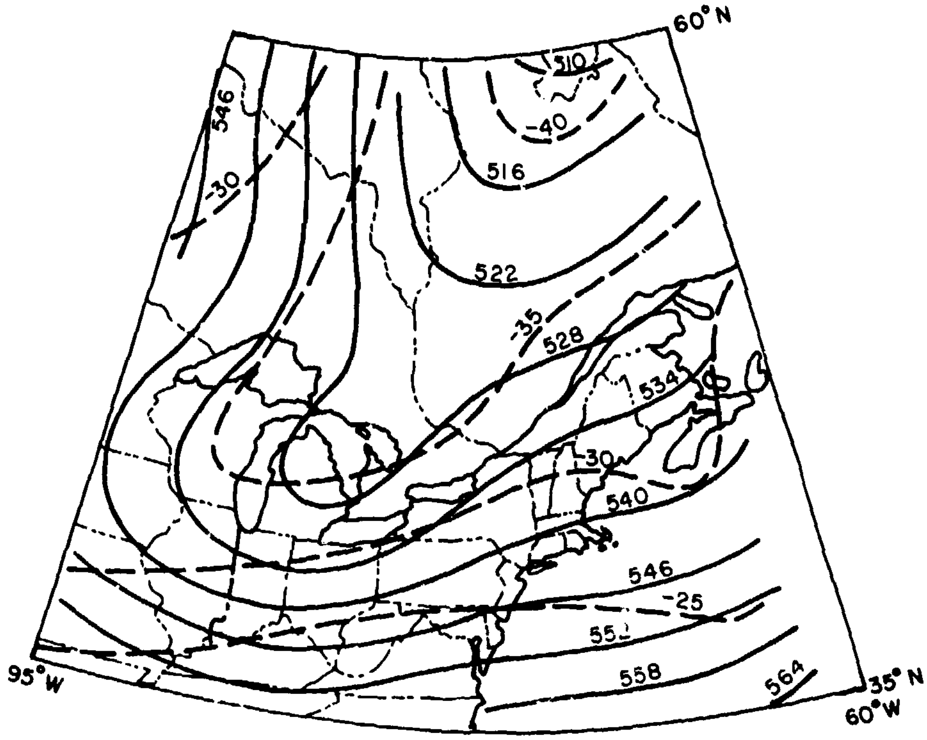

Figure 3. Weather chart for 500-mb level, 0700, 16 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

<u>1000, 16 January</u>

The Plattsburgh Air Force Base sectional surface map showed more precisely the position of the low pressure cell (which had drifted to the south of Lake Erie) and the associated cold and warm fronts (Fig. 4). The area of snowfall had spread eastward into Vermont and western Massachusetts. The snow at CEATC and Burlington Airport began at about 1015, and the ceiling and visibility at both stations decreased rapidly.

The satellite image taken at 0800 shows a vorticity maximum over northwestern Ohio moving east-southeast at about 15.5 m/s. A trough, which extended from a region of maximum vorticity through southern New England, was moving southward. The clouds over western New York and southwestern Ontario had cooled during the previous six hours and were taking on a comma configuration, suggesting a weak impulse centered over western Lake Ontario that was moving east at 10-14 m/s.

<u>1900, 16 January</u>

The USAF sectional map (Fig. 5) showed the center of the low to be over southeastern New York. Three troughs extended from it. One trough

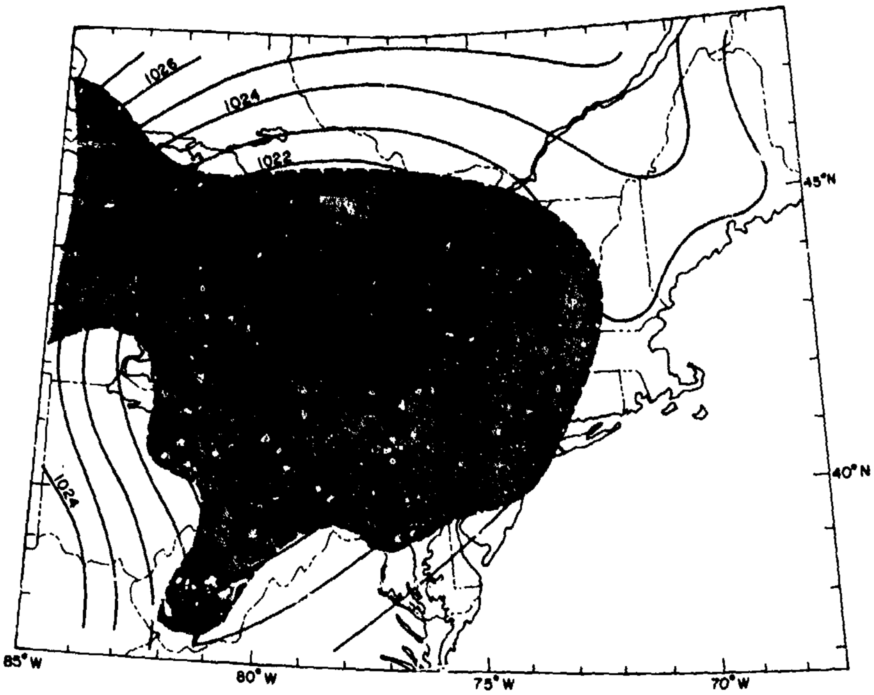

Figure 4. Surface weather map, 1000, 16 January. The precipitation zone is shaded.

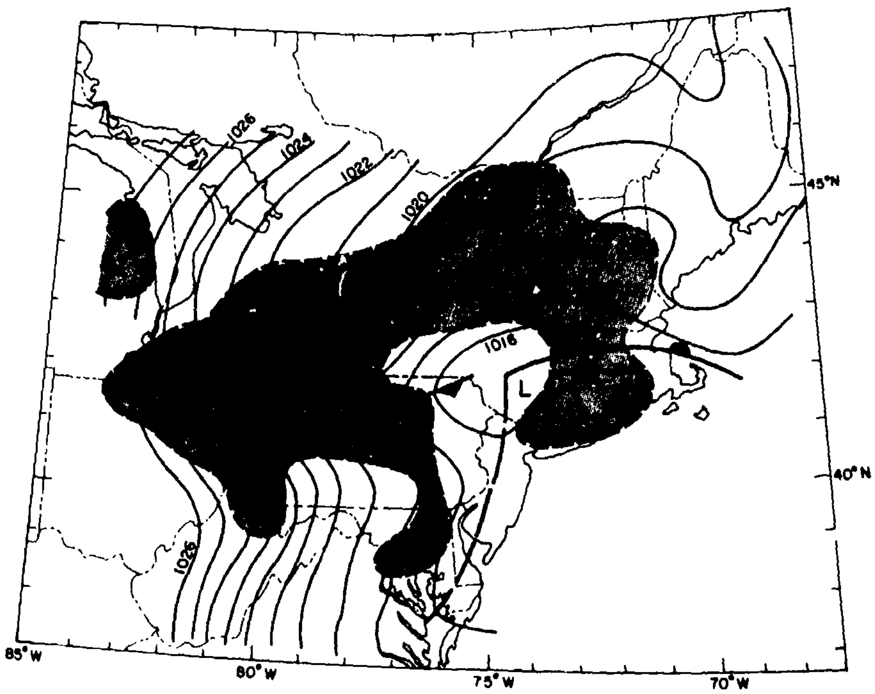

Figure 5. Surface weather map, 1900, 16 January. The precipitation zone is shaded.

contained remnants of the cold front that stretched to the south, the second showed the warm front that was aligned east-west through central Massachusetts, and the third contained a weak cold front that extended westward through Pennsylvania. Snowfall continued over most of New York and western New England, including northern Vermont. During the IMP from 1200 to 1600 hours about 0.6 mm of snow (in water equivalent) was recorded at CEATC. Visibility during the snowfall period between 1100 and 1300 hours decreased to 0.8 km at CEATC. The upper level trough at 500-mb had moved only slightly eastward; it curved southwestward from central Quebec through Illinois and Indiana (Fig. 6).

<u>0100, 17 January</u>

The NWS analysis of the surface weather map showed the low pressure zone near eastern Pennsylvania, but it contained no clearly defined fronts. However, the system continued to cause snow to fall over an extensive region to the north and west, including light snow at Burlington Airport. The 0100 satellite image shows a twist in the middle clouds,

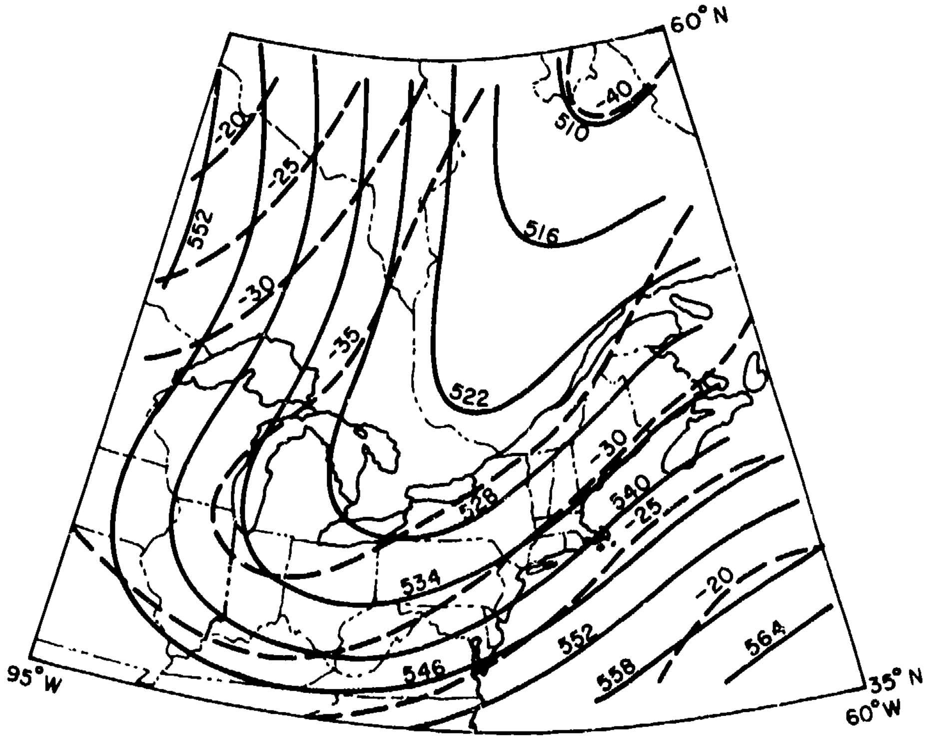

Figure 6. Weather chart for 500-mb level, 1900, 16 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

indicating the vorticity center aloft in southeast Pennsylvania. Variable middle clouds existed above a lower deck in eastern Pennsylvania, eastern New York and New England. Higher clouds along the New England coast continued to move northeastward.

<u>0700, 17 January</u>

The low pressure zone over eastern Pennsylvania regained strength after it moved offshore, then tracked northeastward to the coast east of Nantucket Island, Massachusetts. The continuous light snowfall finally ended between 0500 and 0600 hours at CEATC and at about noon at Burlington Airport. The atmospheric pressure at both stations began to rise slowly from about 0200 to 1000, and some breaks in the overcast were observed by 1400 hours.

<u>1600, 17 January</u>

The low off the coast of New England continued to deepen and move to the northeast. A weak ridge of high pressure influencing northern Vermont extended eastward from Ohio and southern Quebec. The cloudiness started to break up, and the visibility improved to 22 km.

<u>0400, 18 January</u>

The high pressure ridge gradually migrated eastward to western New England, but it was breaking down because the coastal low to the east continued to deepen. Another trough line that stretched northeast to southwest across the Great Lakes moved steadily southeastward. The weather in northern Vermont continued to be mostly cloudy and unseasonably cold (below −18°C).

<u>1300, 18 January</u>

Snow or snow showers developed at various locations in New York, Pennsylvania and northern Vermont, preceding a warm front that moved through southeastern Ontario (Fig. 7). The system extended from a low located in northern Quebec and produced brief and light snow showers in the local region, beginning at 1000 at CEATC. Although 5 mm of snow was recorded during the previous six hours at Burlington, the total water equivalent amounted to traces at the airport and at CEATC.

<u>0100, 19 January</u>

With the passage of the warm front the local air temperatures increased from −23° to −2°C during the previous 24 hours. This influx of warm air from the west was associated with a large high pressure cell that had remained over the central United States for a number of days.

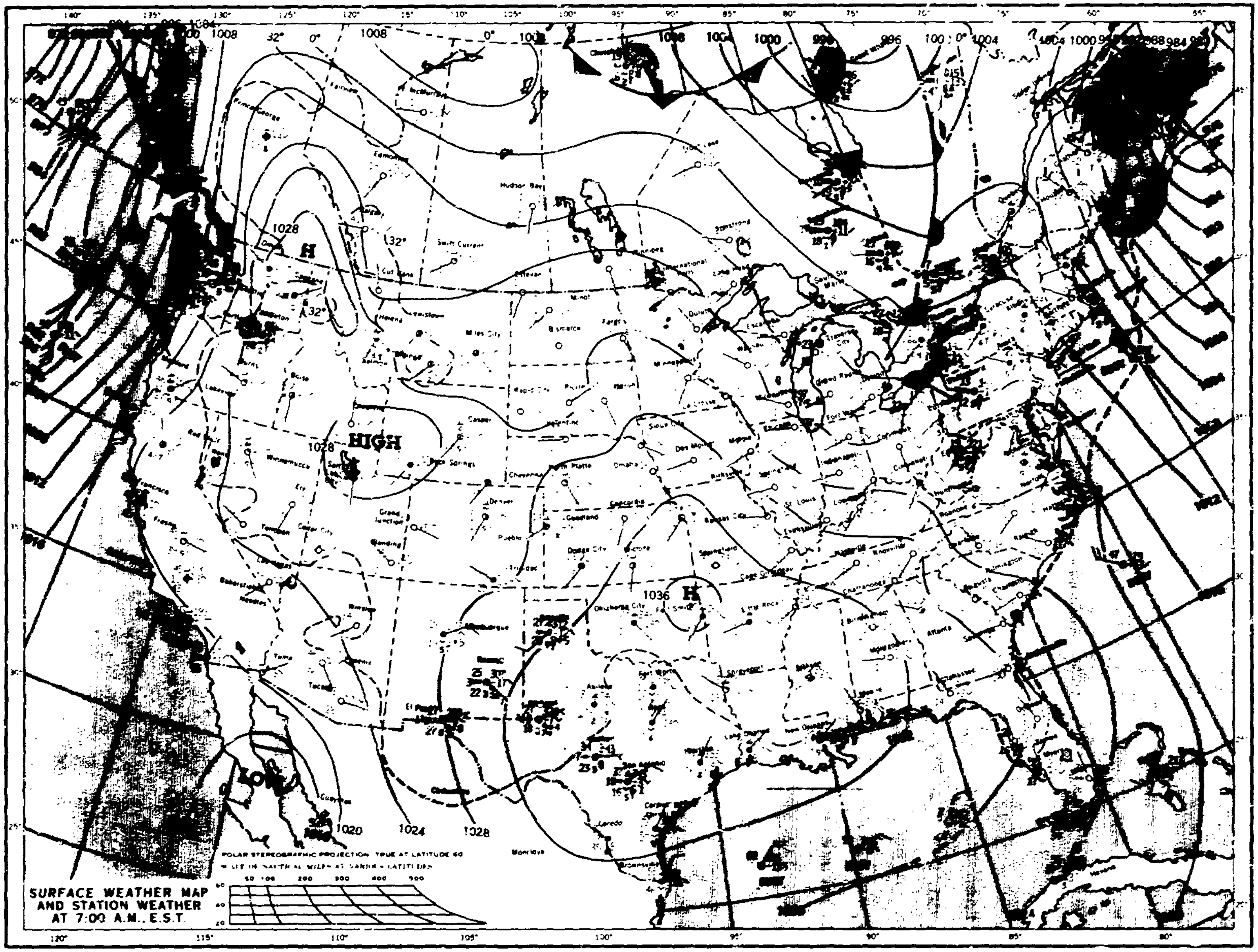

Figure 7. Surface weather map and station weather, 0700, 18 January.

Meanwhile, a weak trough slipped southward from Ontario and caused overcast skies with widely scattered light snow showers in northern Vermont.

1300, 19 January

Some atmospheric instability associated with the passage of the weak trough brought light and scattered snow showers to the local region during the previous 12 hours. The weather was partly cloudy and unseasonably warm (above 0°C).

0400, 20 January

Remnants of a persistent and large low pressure system located over the Labrador Sea kept the immediate area under the influence of a weak and elongated east-west trough. This trough produced a flow of light northerly winds and caused the local air temperatures to decrease gradually. The skies became clear to partly cloudy with the visibility over 32 km.

1300, 20 January

The southern ridge of a weak high pressure cell centered over James Bay, Canada, reached northern Vermont. The system brought cooler air to the area, with clear skies and excellent visibility.

0100, 21 January

The weak high pressure cell (1023 mb) had moved slowly southward and was centered just northwest of Vermont. The weather throughout much of the surrounding area remained clear and considerably colder (below -18°C).

1900, 21 January

The high pressure cell centered over the region was breaking down rapidly due to two major storms located southeast and northwest of the region. One storm was a new frontal wave that developed off the southeast Atlantic coastline and was centered off Cape Hatteras. A second low pressure cell centered over Hudson Bay covered a large area and was associated with an occluded front and trailing warm and cold fronts. Neither of these low pressure systems had yet influenced the local weather.

0700, 22 January

The coastal storm deepened somewhat, but instead of tracking north-northeastward toward New England it veered eastward and out to sea. The occluded front in Canada (Fig. 8) moved directly eastward into Quebec; its trailing warm front extended southward across northern Vermont and caused overcast skies and a lowered ceiling. The cold front extended southwestward from the occlusion to Lake Huron and caused snow to fall over an extensive area around the frontal zone.

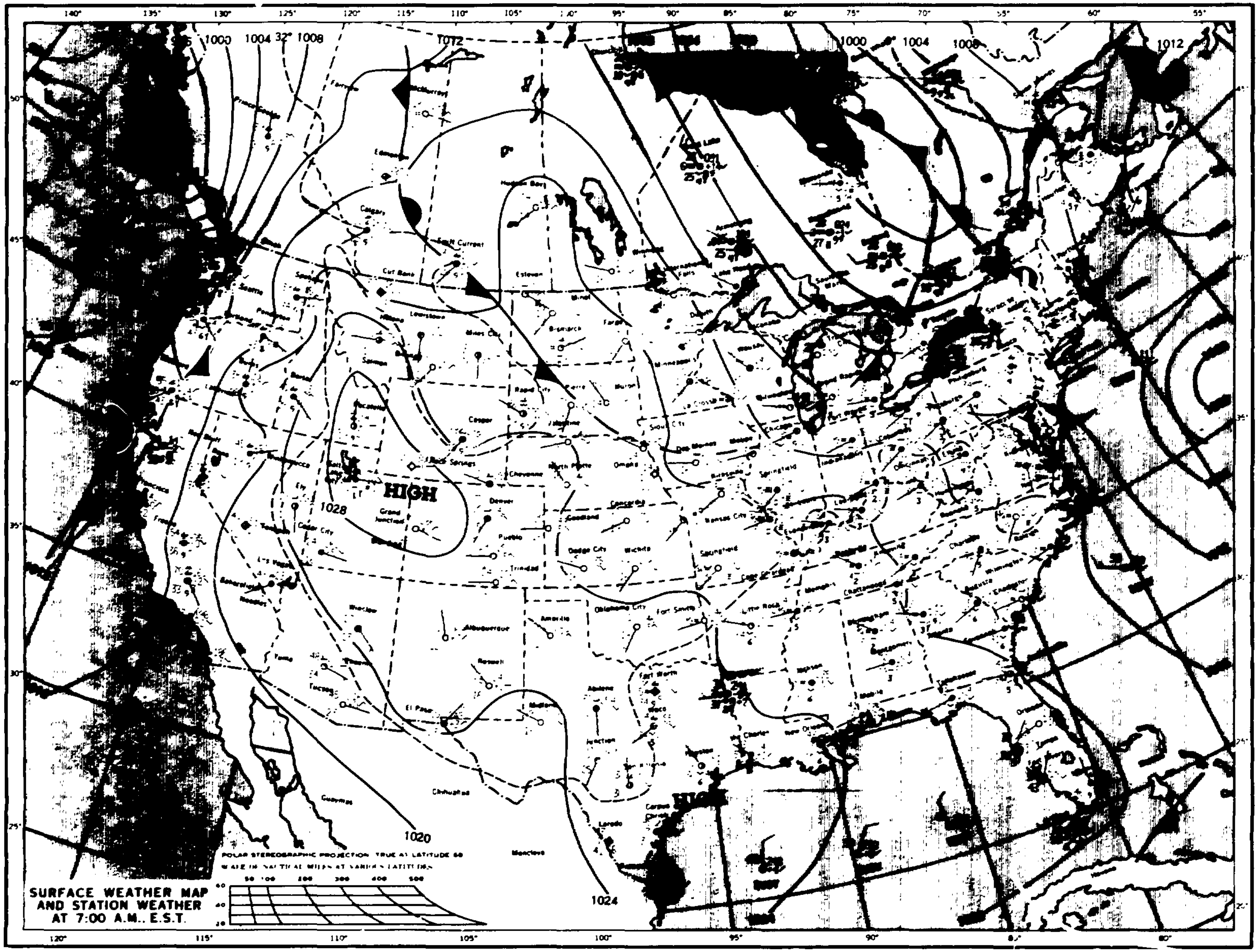

Figure 8. Surface weather map and station weather, 0700, 22 January.

The upper-level (500-mb) low center associated with these systems was over James Bay, and the winds at this level shifted from northwest to west-northwest over northern New England (Fig. 9). The satellite image for 0100 shows a region of maximum vorticity over James Bay and a short wave trough extending southeastward across Quebec. Banded layers of clouds stretched west-southwestward from north of New England and were moving east-southeastward at about 20 m/s.

<u>1300, 22 January</u>

The USAF sectional weather map of the area (Fig. 10) shows the cold front (as analyzed by the NWS in Figure 8) as a trough line that extended from Messina, New York, to just east of Rochester, New York. Snow was observed at all locations about 160 km ahead of this trough zone. Visibility decreased to 1.6-3.2 km in light snow and fog from 1100 to 1700 hours at CEATC. The air temperatures on both sides of the trough were between -2° and +2°C, and the dew points ranged from -8° to -5°C in the vicinity of the trough line.

<u>1600, 22 January</u>

The "cold" front (identified only as a trough on the USAF weather map) approached New England from the northwest and passed over northern Vermont. The surface air temperature at CEATC increased markedly from -28°C at 0700 on the 21st to -3°C at 0400 on the 22nd, but it remained quite uniform (between -1.5° and -5.0°C) during the next 42 hours (i.e., until 2200 on 23 January). Since the dew points during this interval also remained quite high, it appears that the system that passed through the region could not be classified as a typical cold front.

<u>1900, 22 January</u>

The upper level (500-mb) cyclonic flow associated with a closed low centered over southern Quebec covered most of New England (Fig. 11). The major trough line emanating from this low center extended through central New England at all levels of the atmosphere.

<u>0100, 23 January</u>

The USAF sectional weather map shows that the frontal system that had passed through the area moved directly eastward and off the coast of New England (Fig. 12). However, a residual trough remained from southern Quebec to north of Lake Ontario. The resulting surface and upper level cyclonic pattern caused snow to continue to fall over parts of northern Vermont and New York.

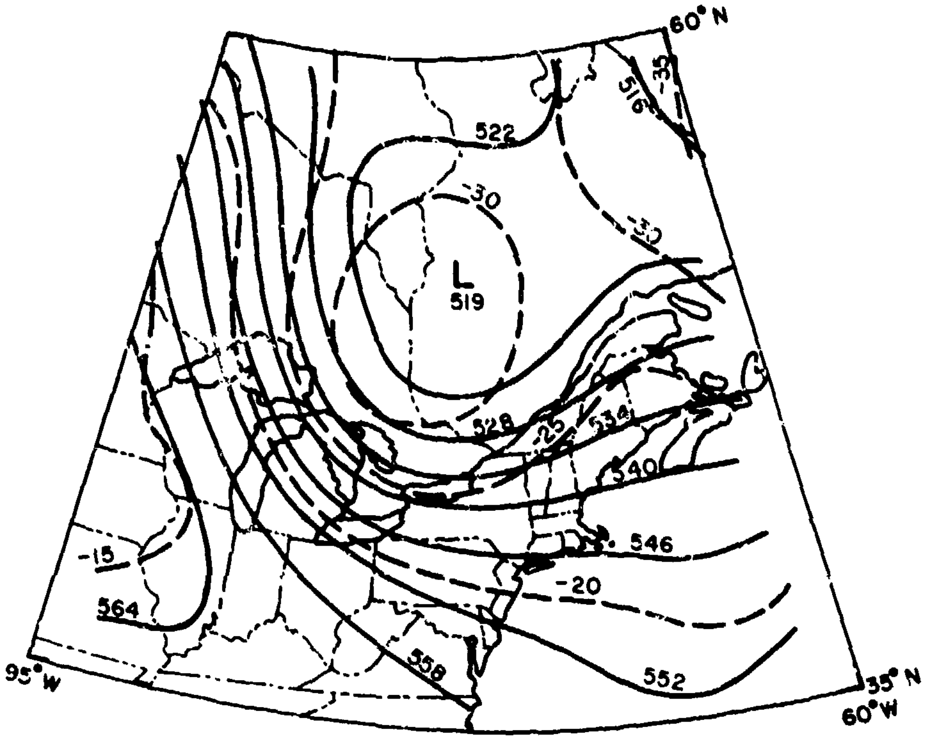

Figure 9. Weather chart for 500-mb level, 0700, 22 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (^{o}C).

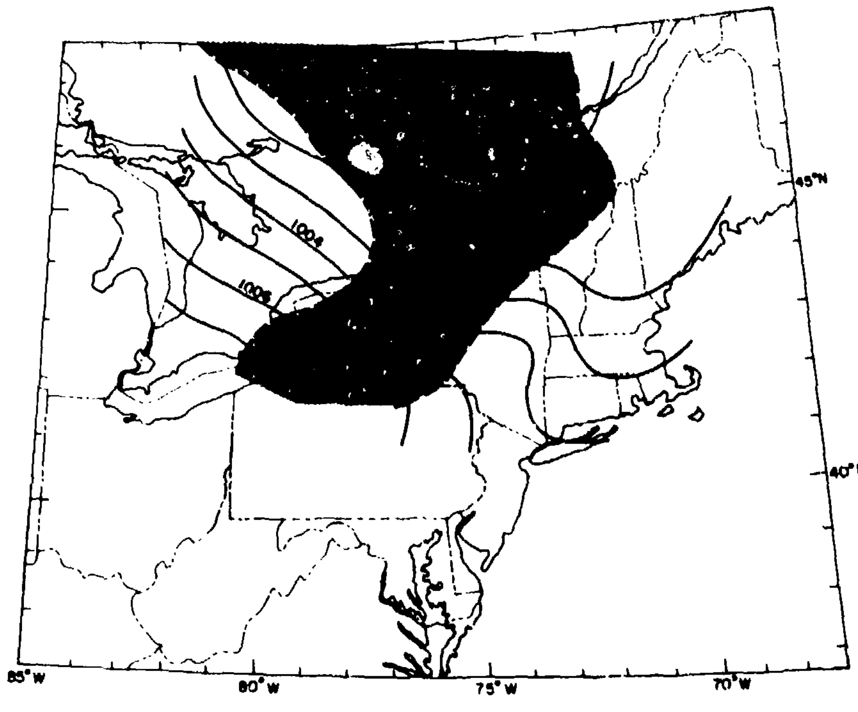

Figure 10. Surface weather map, 1300, 22 January. The precipitation zone is shaded.

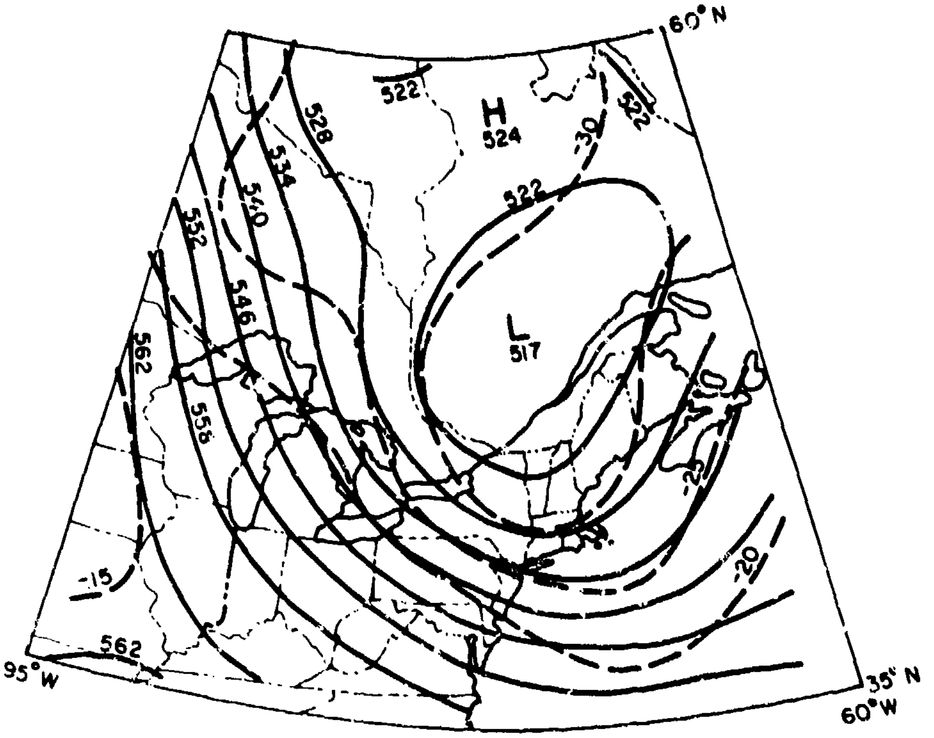

Figure 11. Weather chart for 500-mb level, 1900, 22 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

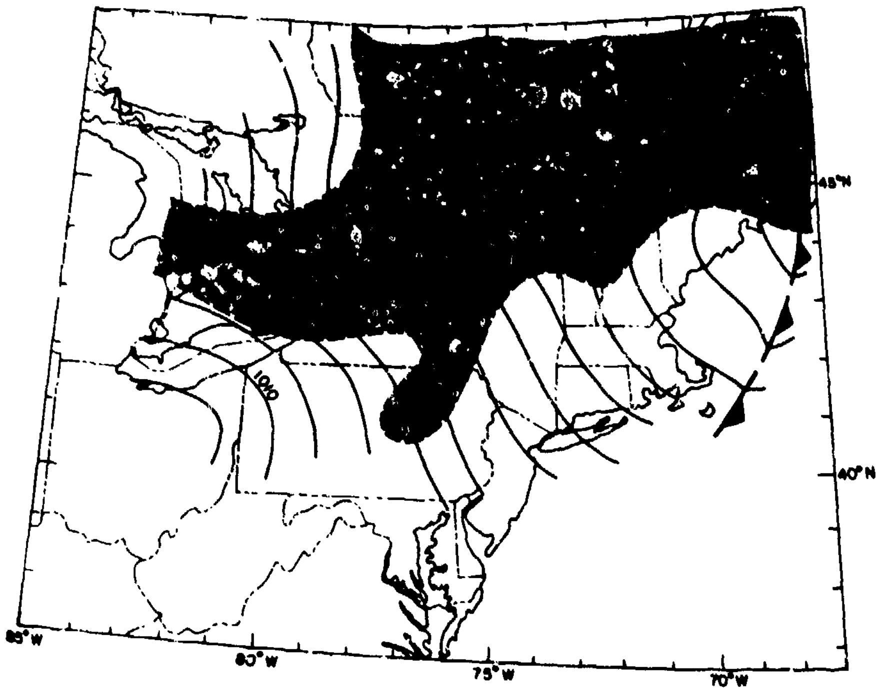

Figure 12. Surface weather map, 0100, 23 January.

0700, 23 January

Although the principal upper level (500-mb) low center in southern Quebec had moved slightly eastward, a minor trough protruded southwestward from the center to Lake Ontario and Lake Erie (Fig. 13). On the surface map (Fig. 14) the low center was over the southern tip of Nova Scotia and significant troughs existed to the northwest and west of the center. The isotherm analysis on the 500-mb chart shows that colder air still existed behind the trough over the eastern region of the Great Lakes (Fig. 13).

1500, 23 January

The satellite image shows that a split in the upper level cyclonic flow had developed. One region, identified as the northern branch, curved across the Great Lakes, and the other extended over New England. The hourly trace of the atmospheric station pressure at CRATC showed that a definite minimum point occurred at 1400 on the 23rd, indicating the passage of another weak frontal zone through the area. The USAF sectional weather

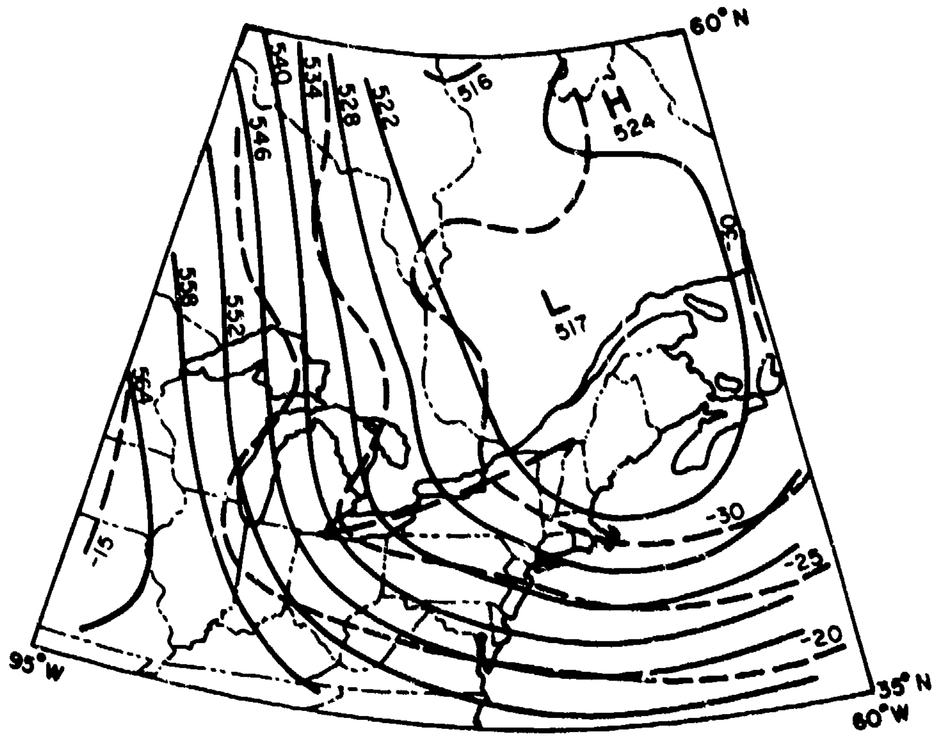

Figure 13. Weather chart for 500-mb level, 0700, 23 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature controus (°C).

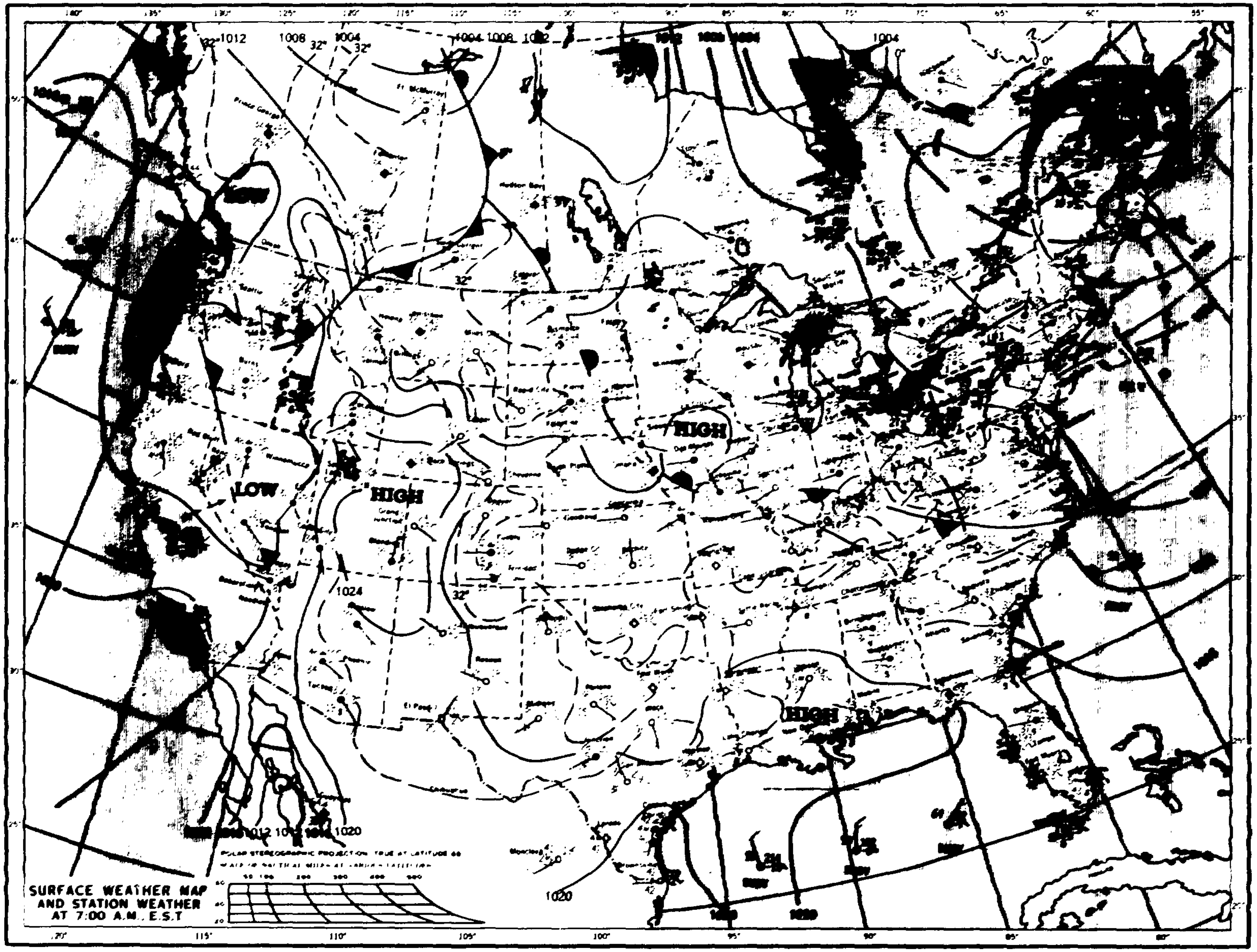

Figure 14. Surface weather map and station weather, 0700, 23 January.

map for 1000 hours on this date shows that a series of minor surface troughs traversed the region. These surface depressions were reflections of the lingering upper-level trough from southern Quebec to north of Lake Ontario.

1900, 23 January

The leading upper level (500-mb) trough that extended from the low in southeastern Canada had moved farther east (Fig. 15). However, the secondary trough that extended southwestward had deepened somewhat and caused light snow to continue to fall in many sections of northern New England.

0700, 24 January

Although the surface troughs that extended southwestward from the Canadian low (centered over the Labrador Sea) had moved southeastward and out to sea, unstable conditions within the cyclonic flow behind the system continued to cause light snow or snow showers over a wide area of northern New England and southern Quebec (Fig. 16).

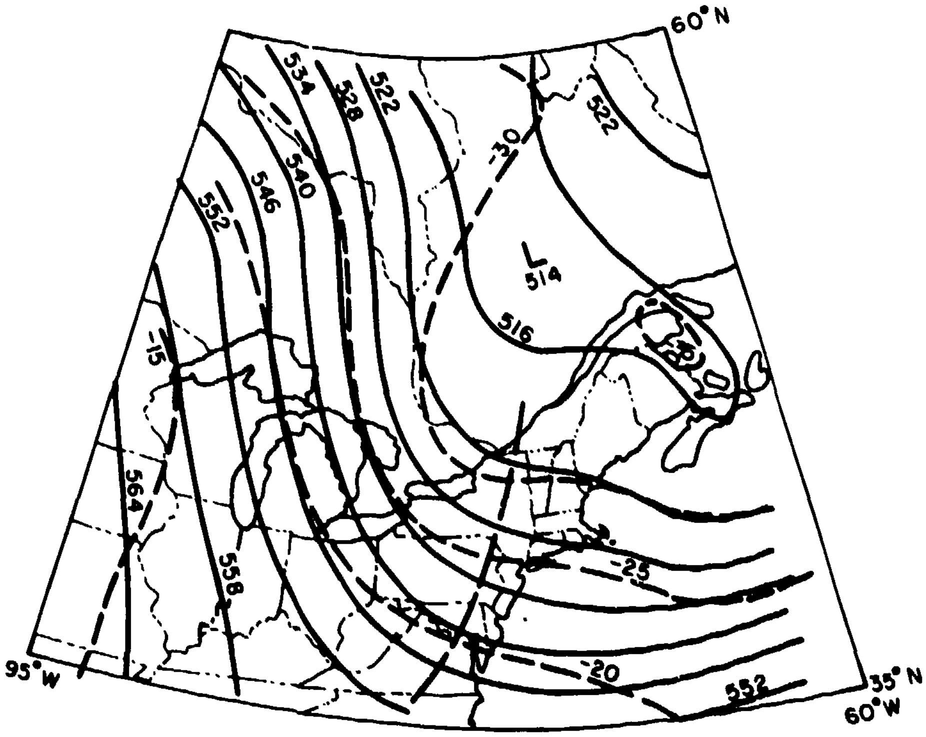

Figure 15. Weather chart for 500-mb level, 1900, 23 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

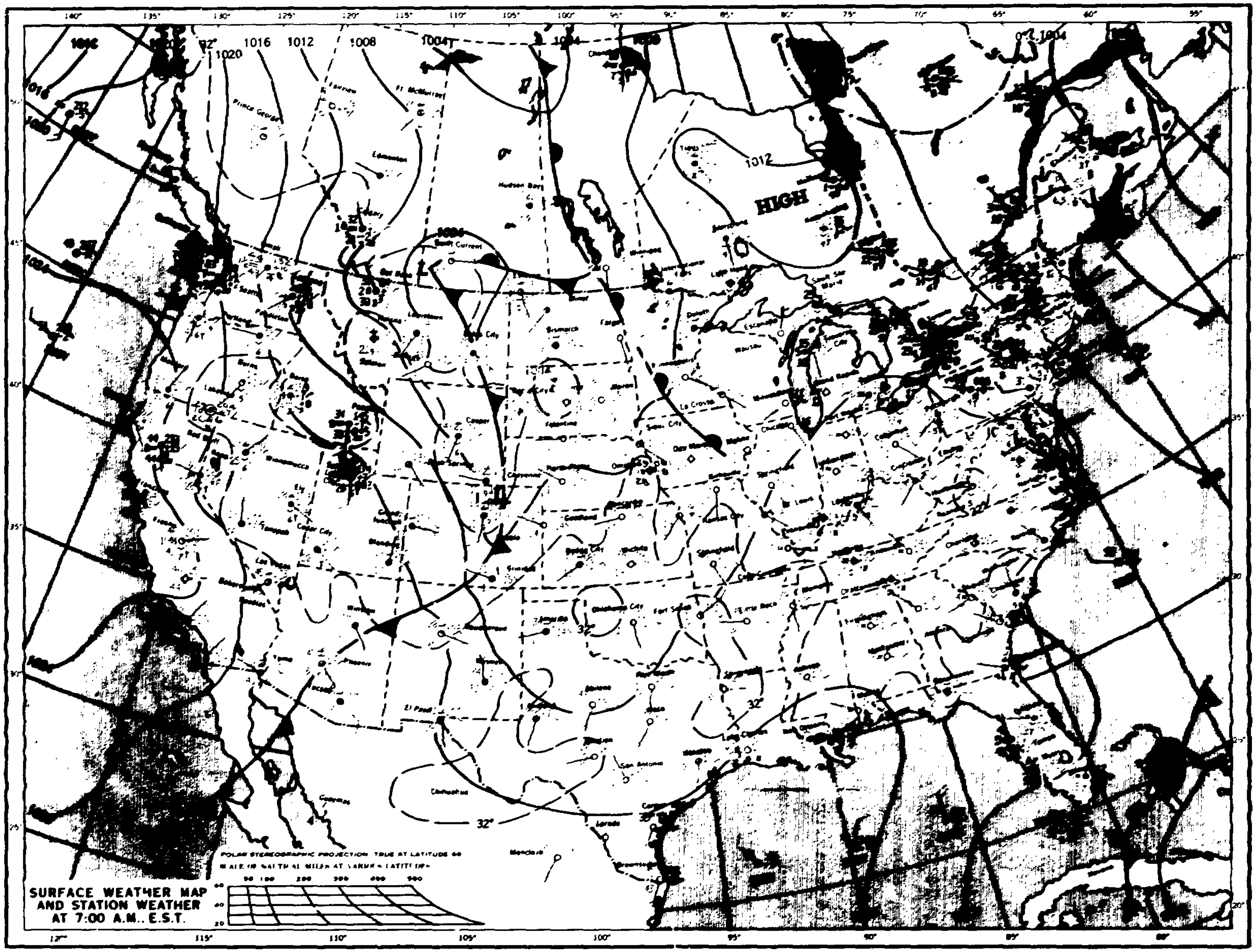

Figure 16. Surface weather map and station weather, 0700, 24 January.

1600, 24 January

Snow showers ended locally at about noon after almost two days of either continuous or intermittent light snowfall throughout the region. A small high pressure cell centered over southeastern Ontario resulted in vastly improved visibility and breaks in the overcast.

0400, 25 January

A ridge of high pressure extended over the region from the southwest. Good visibility and partly cloudy conditions continued over northern Vermont.

1600, 25 January

The ridge moved gradually eastward, and a warm front, which was associated with a low pressure cell located at the western end of the Great Lakes, stretched east-southeastward across Lake Superior and Lake Huron. This warm front produced considerable cloudiness, with snow north of the system and rain to the south. This precipitation shield had not yet reached western New York and Pennsylvania, and the local weather remained partly cloudy with good visibility.

0400, 26 January

The warm front moved rapidly eastward and grazed northern Vermont. The low pressure center moved over northern Lake Michigan, and a cold front extending southward from the center was located between Lake Michigan and Lake Huron. Air temperatures at CEATC were 2°C, an increase of 19°C in 22 hours. The skies over northern Vermont remained overcast, and a trace of snow was observed at Burlington during the previous two hours.

2200, 26 January

A weak cold front was located just west of northern Vermont, and the southerly flow of air before the front raised the local temperatures to 6°C. Skies remained overcast, but no precipitation had occurred locally during the previous 18 hours. A secondary cold front formed in a trough that extended southwestward across the Great Lakes from the low pressure center located over southern Quebec.

0100, 27 January

The weak cold front (Fig. 17) had passed through northern Vermont during the previous few hours. No precipitation was observed at CEATC, and only a trace of light rain was recorded at Burlington Airport during the passage of this front. However, the secondary cold front located just

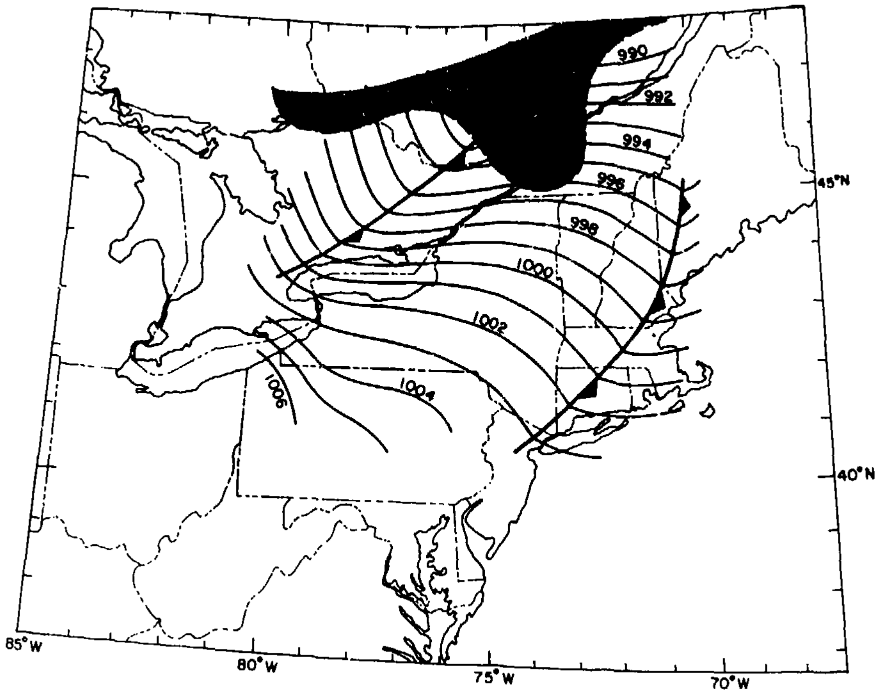

Figure 17. Surface weather map, 0100, 27 January. The precipitation zone is shaded.

north of the St. Lawrence River Valley approached New England from the northwest and appeared to be stronger than the one preceding it.

<u>0700, 27 January</u>

The leading cold front moved rapidly eastward and passed the New England coastline. The secondary cold front moved more slowly to the southeast and was over the cities of Quebec, Montreal and Toronto (Fig. 18). This front produced scattered light rain or snow showers along the St. Lawrence River and at Burlington Airport. The surface air temperatures throughout New England at this time were above freezing; although overcast skies existed at most locations, precipitation at many stations (including CEATC) had not yet begun.

The upper level (500-mb) chart showed a minor trough to the east of New England and a more definite one over the western Great Lakes. Between these troughs the flow pattern was mostly uniform from southwest to northeast (Fig. 19).

<u>1600, 27 January</u>

The second cold front crossed northern New England and produced scattered light-to-moderate snow squalls and snow showers throughout the

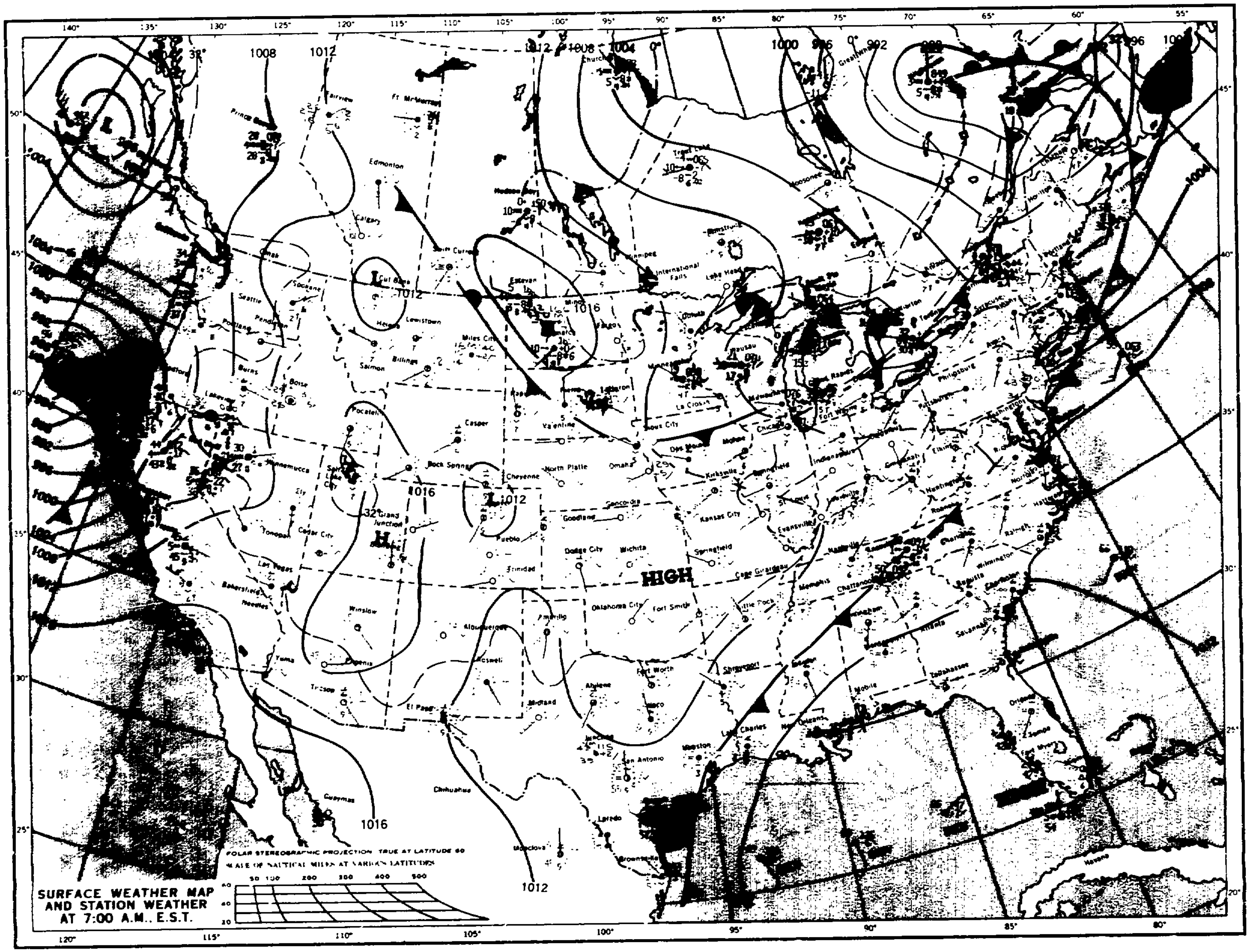

Figure 18. Surface weather map and station weather, 0700, 27 January.

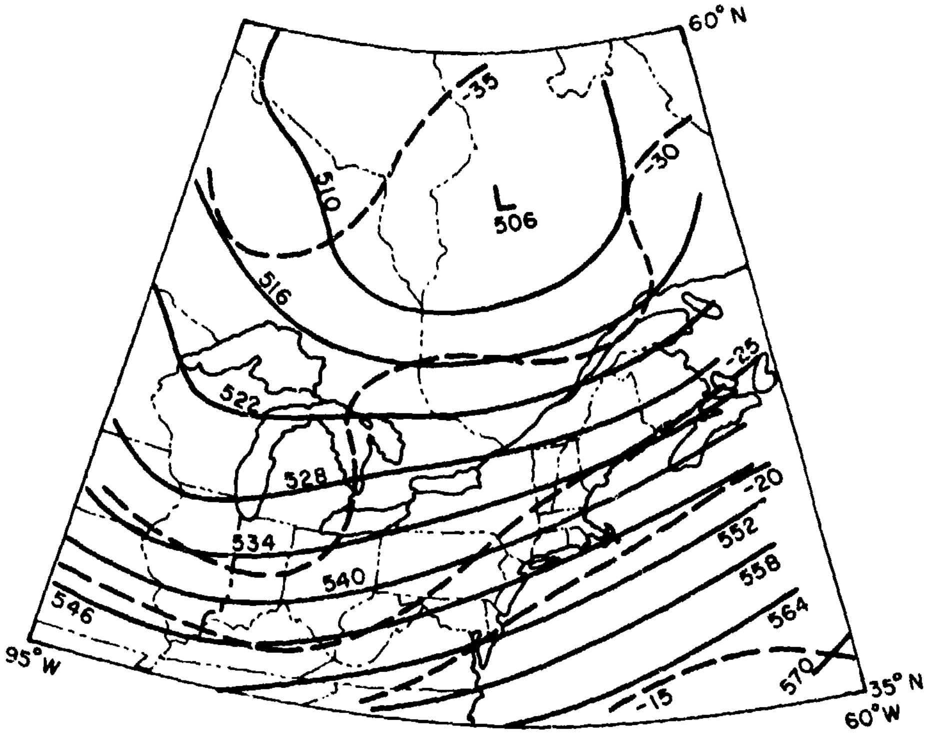

Figure 19. Weather chart for 500-mb level, 0700, 27 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

region. The snow amounts before noon were light (traces) at CEATC but totaled over 3.1 mm (in water equivalent) between 1200 and 1630. The visibility during this period occasionally decreased to 0.8 km or less in fog and moderate snow.

0100, 28 January

The second cold front suddenly stalled in a general east-west position across northern New England, and a frontal wave developed over Lake Erie (Fig. 20). Cooler air moved into the local region, bringing scattered, brief snow showers with only trace amounts of precipitation.

1800, 28 January

The stalled front became essentially stationary in an east-west alignment across central New England, with a standing wave centered approximately over northeast Pennsylvania. Although snow and snow showers persisted in western New York and Pennsylvania, the skies over northern Vermont were mostly clear and the air temperature at CEATC decreased to -15°C.

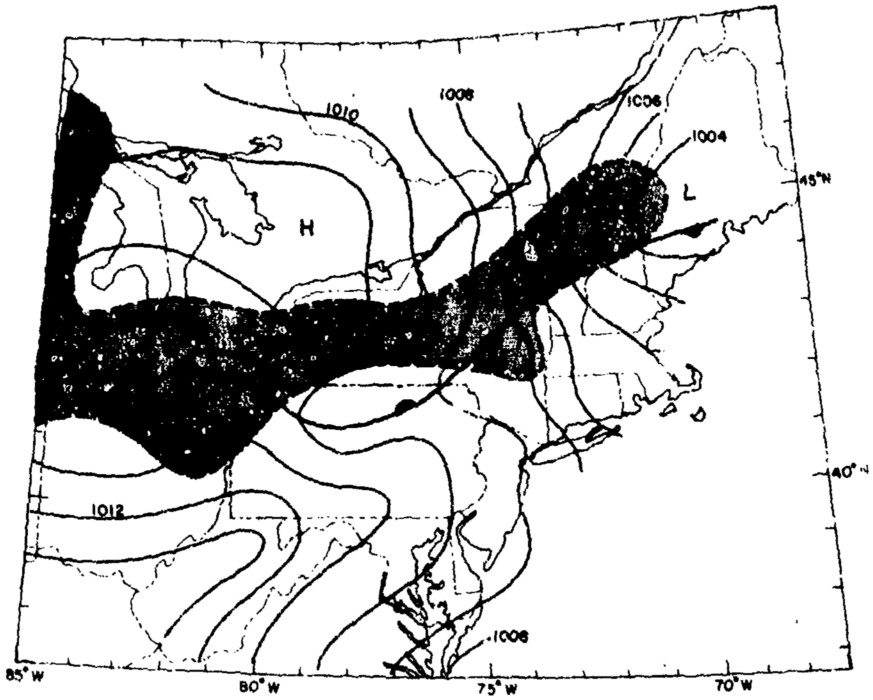

Figure 20. Surface weather map, 0100, 28 January. The precipitation zone is shaded.

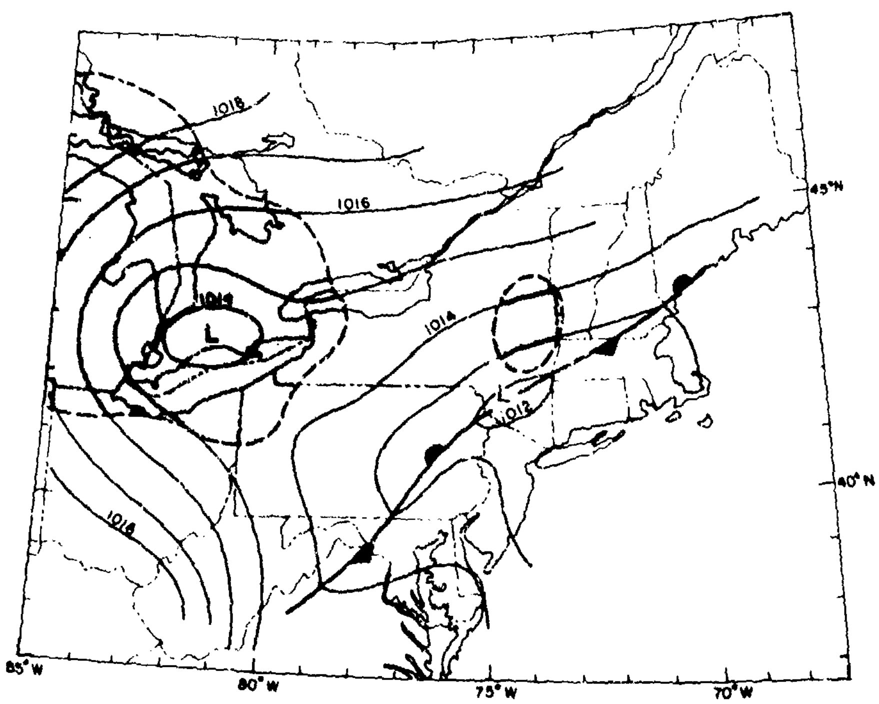

Figure 21. Surface weather map, 0100, 29 January. The precipitation zone is shaded.

0100, 29 January

The lowest pressure point along the stationary front was situated over the southeast corner of New York (Fig. 21), and except for isolated pockets of light or moderate snow showers in New York the system did not produce much precipitation. A residual low pressure center lingered over Lake Erie and caused additional snow to fall throughout much of the central Great Lakes region. The skies over northern Vermont became overcast and the ceiling decreased rapidly.

0700, 29 January

The quasi-stationary wave became more clearly defined; its lowest pressure zone was located over central Connecticut (Fig. 22). Light snow fell over much of western and southwestern New England. Occasional light snow showers were recorded at Burlington Airport between 0545 and 0910, but they only amounted to traces. An IMP was conducted between 0900 and 0930 hours at CEATC, but the snow that fell during that time was too light to record.

The upper level (500-mb) flow pattern shows a very weak trough that extended southward along the Atlantic coastline and a more well-defined trough that extended southwestward across Lake Huron and Lake Michigan from a low center in Quebec (Fig. 23). The satellite image obtained at 0800 shows that the maximum vorticity was in the vicinity of Detroit and was moving southeastward at 13 m/s. The associated clouds ahead of this system had split into two sections; one area was over southern New England and the other over the Appalachian Mountain ridge.

1900, 29 January

The almost stationary wave suddenly picked up speed and moved out to the Atlantic Ocean east of Cape Cod, Massachusetts. The atmospheric pressure over northern New England increased rapidly, and some breaks in the overcast were observed at Burlington Airport.

0400, 30 January

A massive high pressure cell (1038 mb) centered over Minnesota and Wisconsin dominated all of the Great Lakes area and northeastern United States. The skies over most of New England were mostly clear, and the visibility was excellent.

1600, 30 January

The synoptic conditions were similar to those given in the preceding description.

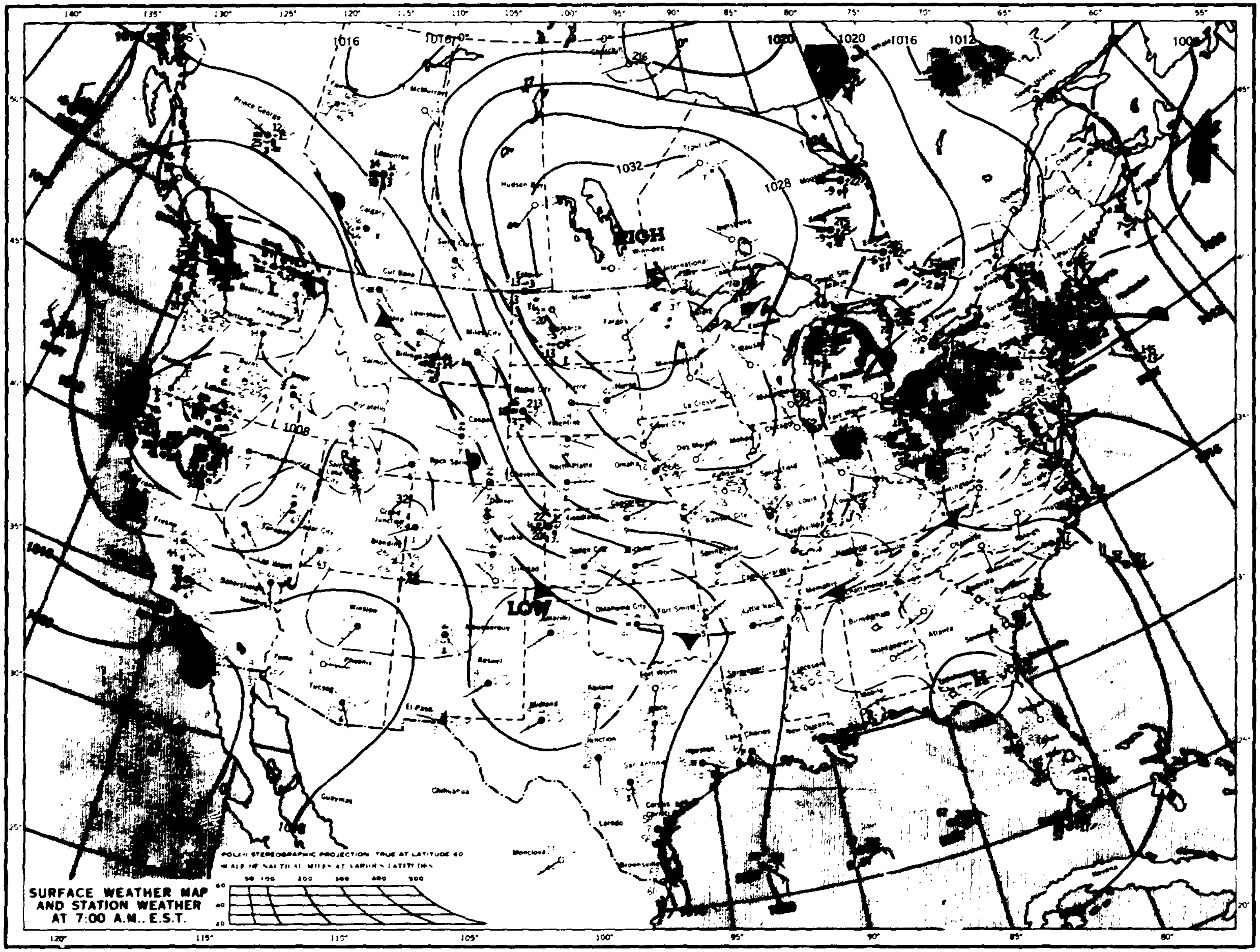

Figure 22. Surface weather map and station weather, 0700, 29 January.

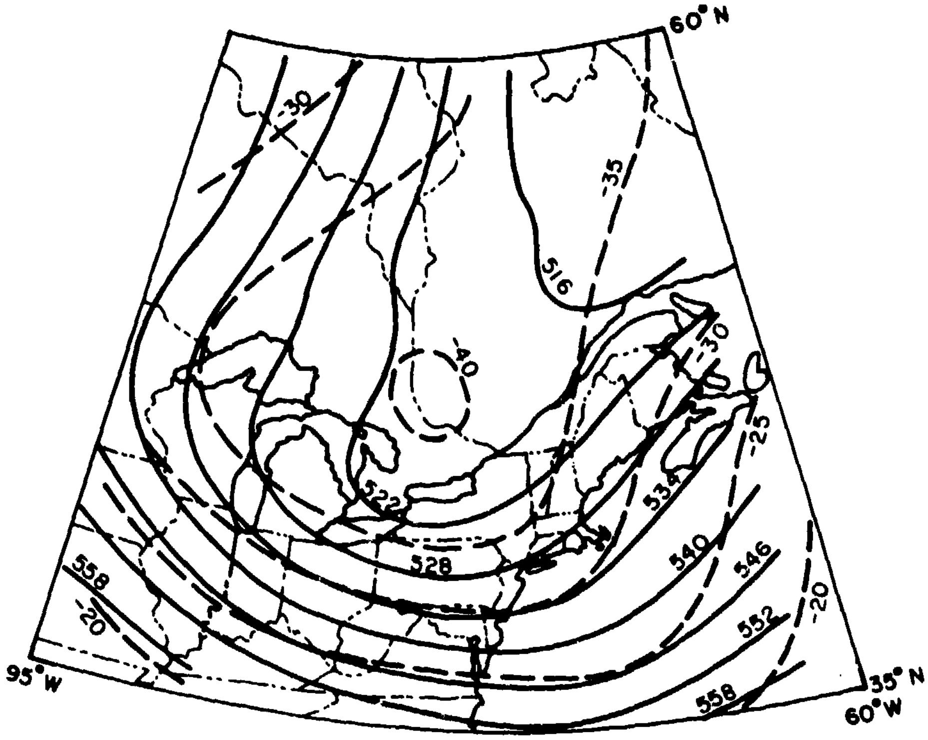

Figure 23. Weather chart for 500-mb level, 0700, 29 January. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

<u>0700, 31 January</u>

The high pressure cell centered over Ohio, Indiana and Michigan dominated a large region that included all of New England (Fig. 24). The skies remained mostly clear, and the night-time temperatures had fallen to −18°C or lower across northern Vermont.

<u>1600, 31 January</u>

The synoptic conditions were similar to those given in the preceding description. Daytime temperatures at CEATC reached a maximum of 0°C.

<u>0400, 1 February</u>

The massive high pressure cell moved directly eastward and was centered off the coast of New Jersey and Maryland. This system produced new record high pressures at many locations and covered the entire east coast of the United States. The sky was still cloudless and visibility remained excellent in Vermont.

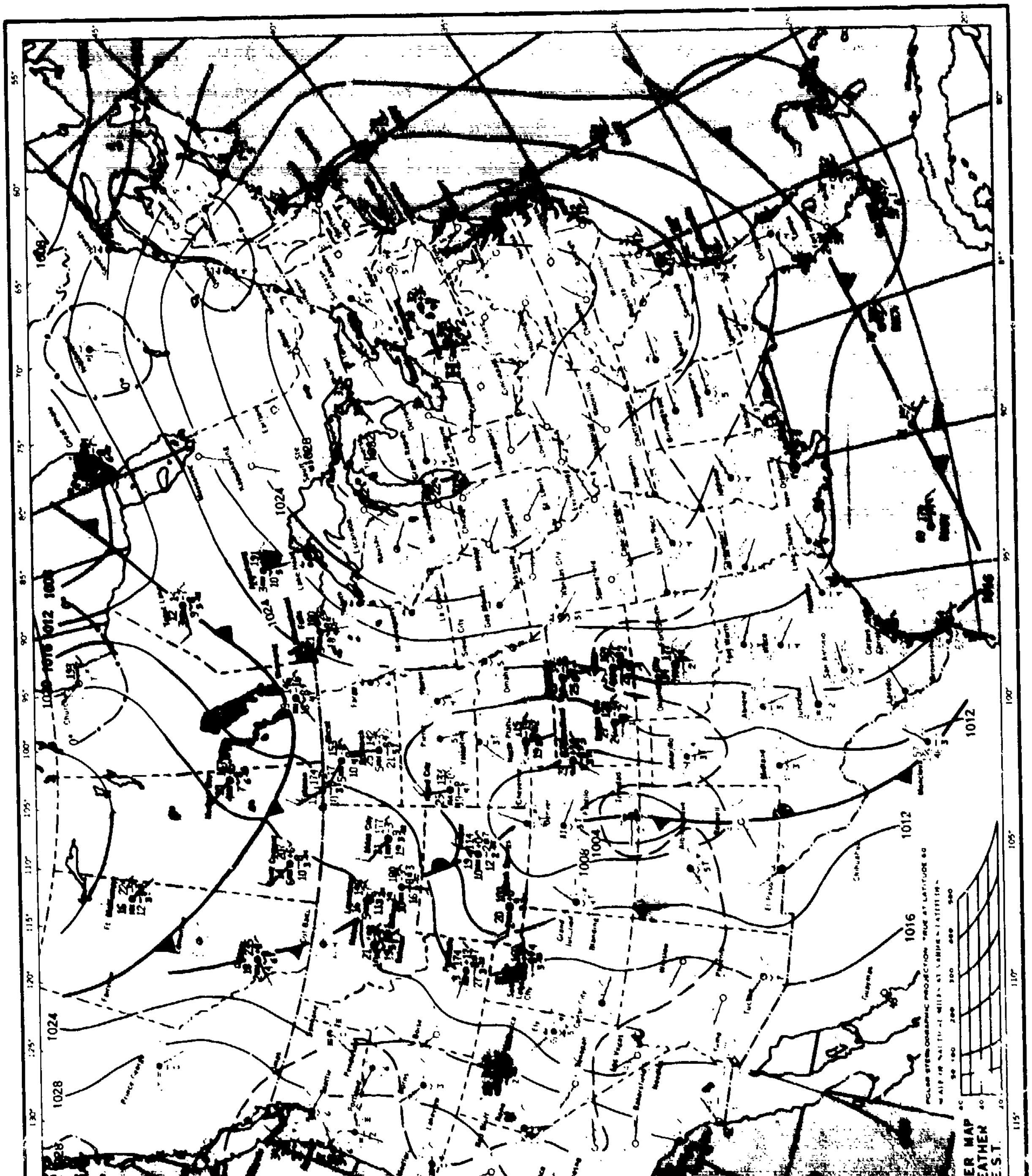

Figure 24. Surface weather map and station weather, 0700, 31 January.

1000, 1 February

A deep low pressure system centered over the Great Lakes caused snow to fall in most of the states and Canadian provinces surrounding the Great Lakes (Fig. 25). The same storm caused rain to fall from central Indiana to Louisiana. A number of fronts, including an elongated occlusion that extended to the south and a stationary front that extended northeastward, were associated with this depression. Middle and high clouds moved rapidly into the local region. Air temperatures at CEATC rose from -20° to 6°C during the previous 12 hours.

1900, 1 February

The center of the deep low moved eastward across the Great Lakes to southeastern Ontario. The occlusion associated with this low stretched far to the south to eastern Tennessee. A warm front extended mostly east or northeastward from Tennessee through North Carolina and Virginia.

Warm southerly winds were observed throughout New England, and rain or snow was observed over much of the northeastern United States. Although light snow was observed within the previous hour at Burlington Airport, precipitation had not yet begun at CEATC. Air temperatures at both locations were above freezing, and wind gusts of over 25 m/s were recorded at 1845 at Burlington Airport.

0700, 2 February

The low center in Canada merged with a secondary low center that developed at the juncture of the warm front and the occlusion. This secondary low center was located over central Pennsylvania, and the warm front extended northeastward across Pennsylvania and into southern New England (Fig. 26). The upper air pattern (500 mb) shows an extremely deep trough that was centered over Hudson Bay and affected the eastern two-thirds of the North American continent (Fig. 27). Strong southerly winds continued across New England. Locally the surface temperature was over 8.0°C, and rainfall was light but steady. These are unusual mid-winter conditions for northern New England. The depth of the snow on the ground at CEATC decreased from 36 cm on 24 January to 7.5 cm on this date.

1900, 2 February

The central part of the storm passed over northern Vermont at about 1430, and at that time, light snow mixed with rain was observed. Prior to

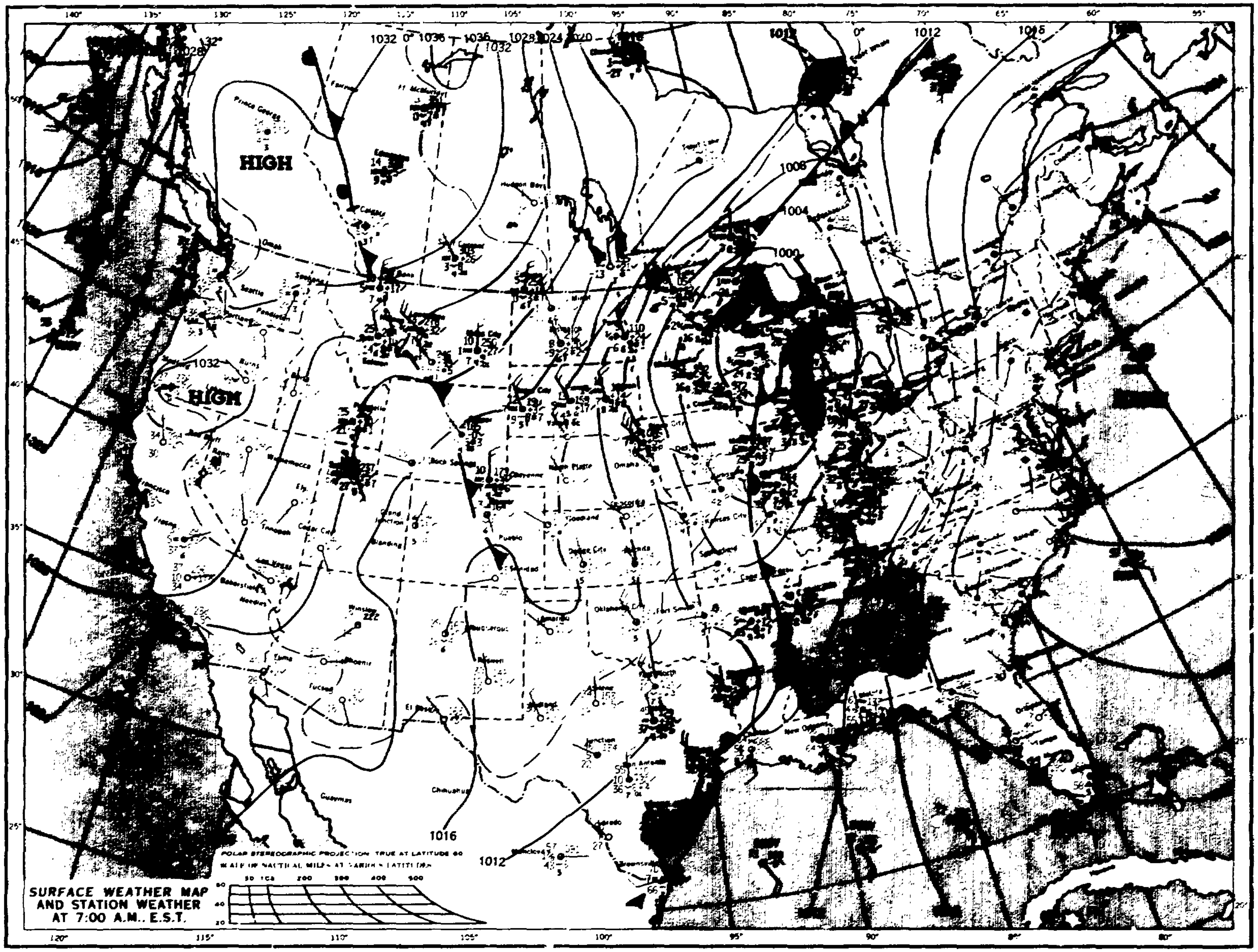

Figure 25. Surface weather map and station weather, 0700, 1 February.

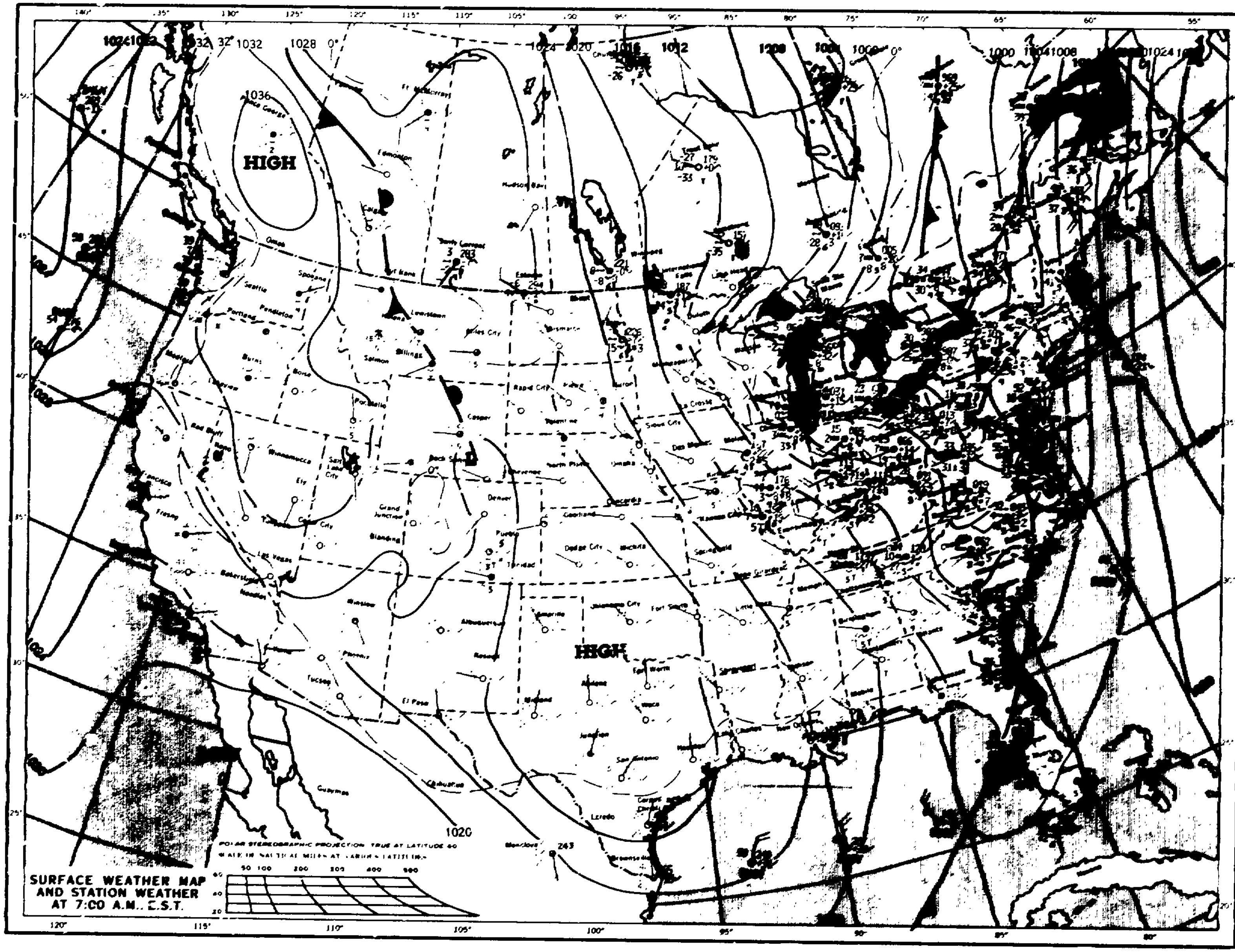

Figure 26. Surface weather map and station weather, 0700, 2 February.

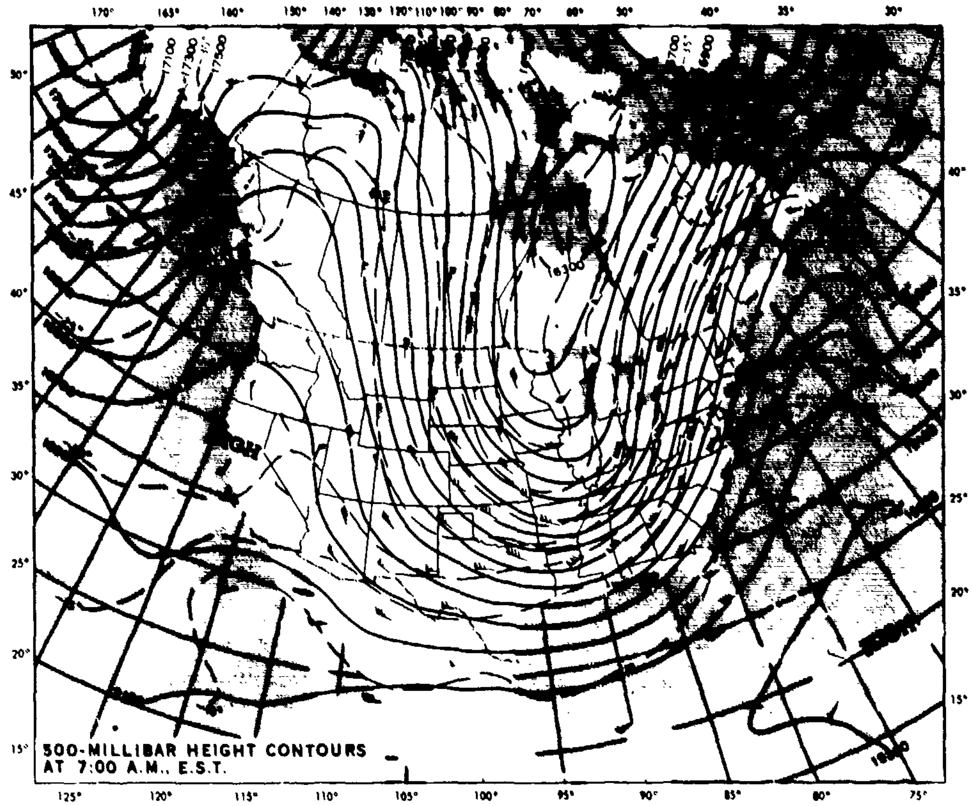

Figure 27. Weather chart for 500-mb level, 0700, 2 February. The solid lines are height contours (feet above sea level). The dashed lines are temperature contours (°C).

the passage of the front, then identified as a cold front instead of an occlusion (Fig. 28), the rainfall became moderate in intensity from about 0800 to 1400. During that period over 22 mm of water was recorded at CEATC. The snowfall, which started at 1504 and ended at 1955, amounted to approximately 8.1 mm in water equivalent. The IMP at CEATC on 2 February lasted from about 0700 to 2030. Visibility during the periods of snowfall and fog decreased to 800 m or less in some quadrants.

The satellite image taken during the afternoon shows that the back edge of several layered frontal clouds were moving eastward at 13-16 m/s along a line from New England to just off the Georgia coast. Weak impulses continued to move rapidly (in excess of 36 m/s) north-northeastward along the back edge of the cloud band. Strong gusts were enhancing cloud formation over eastern New York.

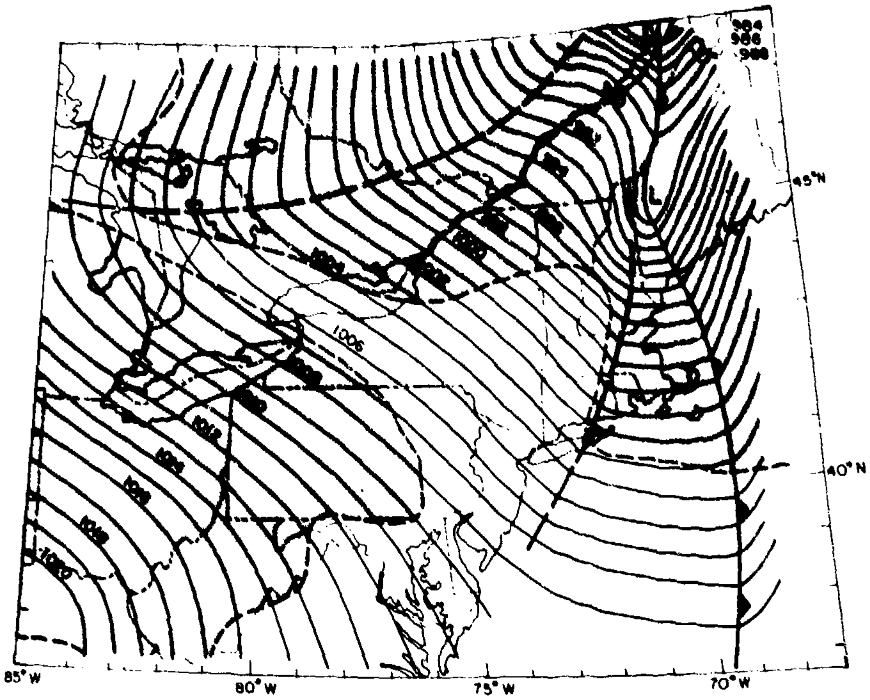

Figure 28. Surface weather map, 1900, 2 February. The precipitation zone is shaded.

0700, 3 February

The primary low center in Canada and the secondary center that passed over the region had merged, deepened rapidly, and moved off to the north-northeast into central Quebec. The air temperature decreased steadily (-13°C at CEATC) after the front passed, and the air became quite dry (55-60% relative humidity) across northern Vermont.

1900, 3 February

A ridge of high pressure, which extended northwestward from a high center located over the southeastern United States, covered most of New England. The skies over northern Vermont remained partly cloudy to overcast, and the lower atmosphere remained dry (near 50% relative humidity), with excellent visibility.

0700, 4 February

A trough curved southwestward across the Great Lakes and extended from a shallow (1016-mb) low pressure center over the southeastern corner of Ontario (Fig. 29). The cyclonic flow around this system caused snow to

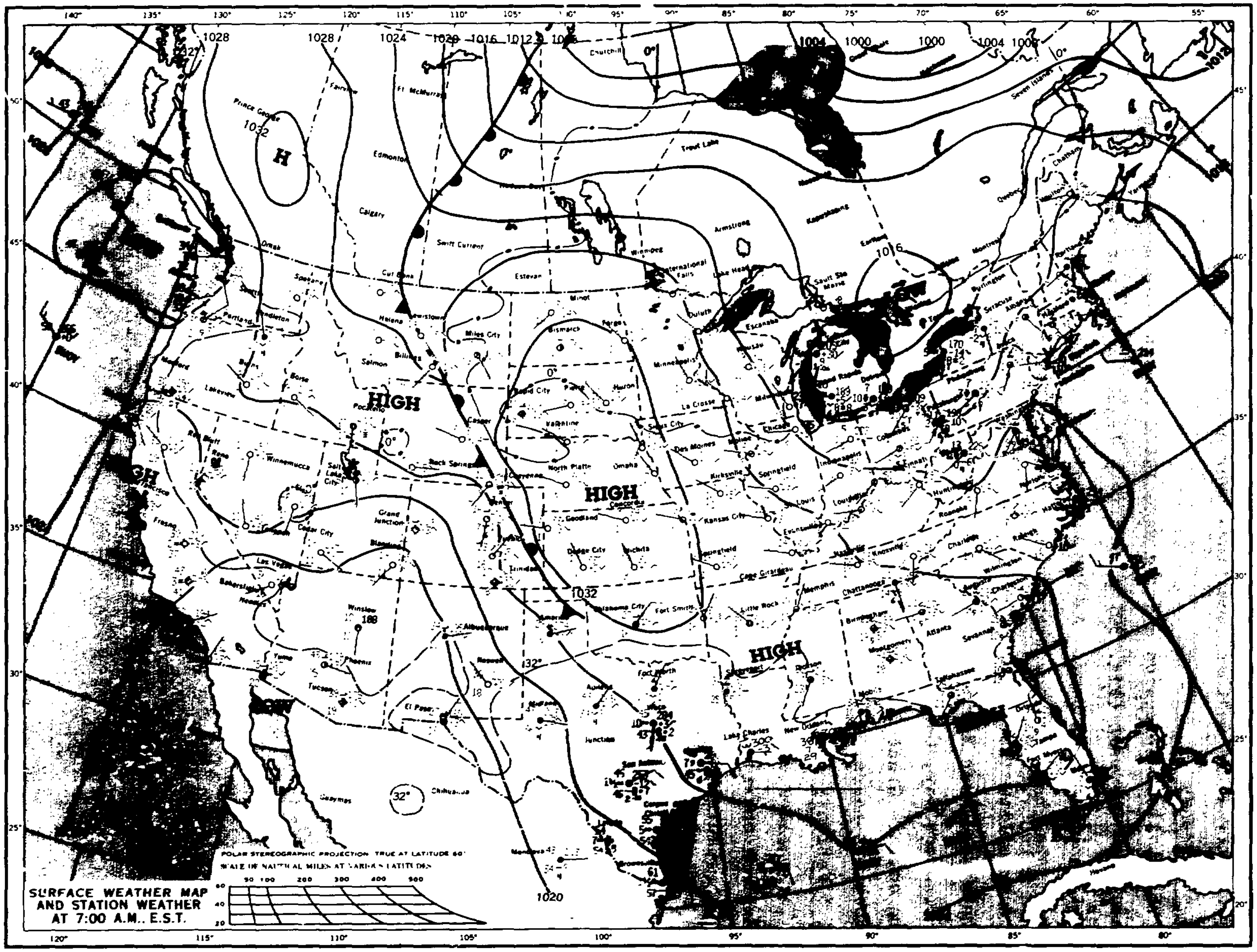

Figure 29. Surface weather map and station weather, 0700, 4 February.

fall over much of the Great Lakes region. The eastern end of the precipitation shield reached central New York and Pennsylvania. The system had not yet altered the weather conditions over northern Vermont.

1600, 4 February

The shallow depression and the associated trough that approached New England from the west (Fig. 30) caused very light snowfall between 1100 and 1300 at Burlington Airport. An IMP was held at CEATC between 1300 and 1445 on this date, but the snow that fell at the site was too light to record.

A satellite image ending at 1300 shows a few weak impulses moving northeastward over New York and New England and around an upper low located east of James Bay, Canada. Low clouds extended from southern New England to the eastern Great Lakes, with some thickening of these clouds during the previous six hours.

1900, 5 February

The shallow depression that moved through northern Vermont passed the New England coastline, followed by a ridge that extended northwestward from a high pressure cell over the southeastern United States. After a few very

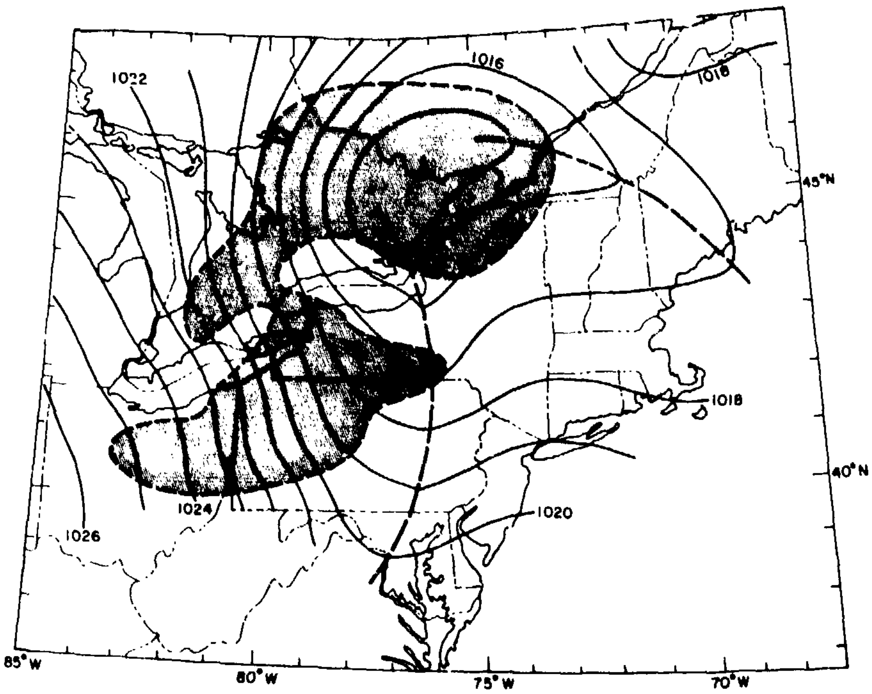

Figure 30. Surface weather map, 1600, 4 February.
The precipitation zone is shaded.

light and brief snow showers, the skies over northern Vermont became partly cloudy with good visibility.

0700, 6 February

The ridge had moved off to the east and was being replaced by a well-developed trough extending southward over the Great Lakes from a low pressure cell centered over Ontario. The system caused snow to fall over an extensive area surrounding the trough, including parts of western New York and Pennsylvania. The cold front associated with the system stretched southward between Lake Michigan and Lake Huron. The effects of this system had not yet reached New England, and local weather conditions remained unchanged.

1900, 6 February

The trough over the Great Lakes weakened and passed quickly through New England. Although some lingering snow and snow showers continued in parts of New York, the cold front lost its intensity and did not produce any precipitation in the local area. The surface winds also increased in speed, and the air became warmer.

0700, 7 February

A secondary trough, or perhaps an instability associated with the primary trough that passed through New England, produced periods of light snow between 2300 on the 6th and 0400 on the 7th in parts of northern New England. Snowfall at the Burlington Airport amounted to a trace and reduced the visibility to 10 km with very low clouds.

1900, 7 February

The northern fringe of a weak ridge that had influenced Vermont during the previous 12 hours moved eastward off the coast of New England, and two major low pressure systems approached the region. One rather deep low (998 mb) was centered over northern Lake Michigan, and an occlusion extended outward across Lake Huron and southward through Ohio. This low caused snow to fall over almost all of the Great Lakes region and southern Ontario. Another small low pressure center located over the coast of South Carolina was associated with a wave that had developed in the Gulf Coast region a few days before. This coastal storm caused rain to fall over much of the Southeast. Locally these systems maintained surface winds from the south, kept the air temperature unseasonably high (near 0°C), and produced increased amounts of cloudiness. The visibility remained good to excellent.

0200, 8 February

Two major low pressure systems approached New England. One rather deep low (996 mb), centered over northern Lake Michigan, caused snow to fall over most of the Great Lakes region and southern Ontario. Another low pressure center, located over the coast of South Carolina, was associated with the frontal wave that developed in the Gulf Coast region. These systems brought southerly surface winds and unseasonably high air temperatures (above freezing) to northern Vermont.

0600, 8 February

The low center over northern Lake Michigan moved only slightly to the northeast, but an occlusion associated with the low proceeded eastward to central New York and Pennsylvania. The low off the Carolina coast continued to move northeastward and was located about 240 km east of the Maryland coastline (Fig. 31). Together these systems caused rain or snow to fall over almost all of New England. Light snow started at CEATC at 0315 but up to this time had amounted to less than 0.2 mm in water equivalent. The ceiling decreased rapidly, visibility during snowfall

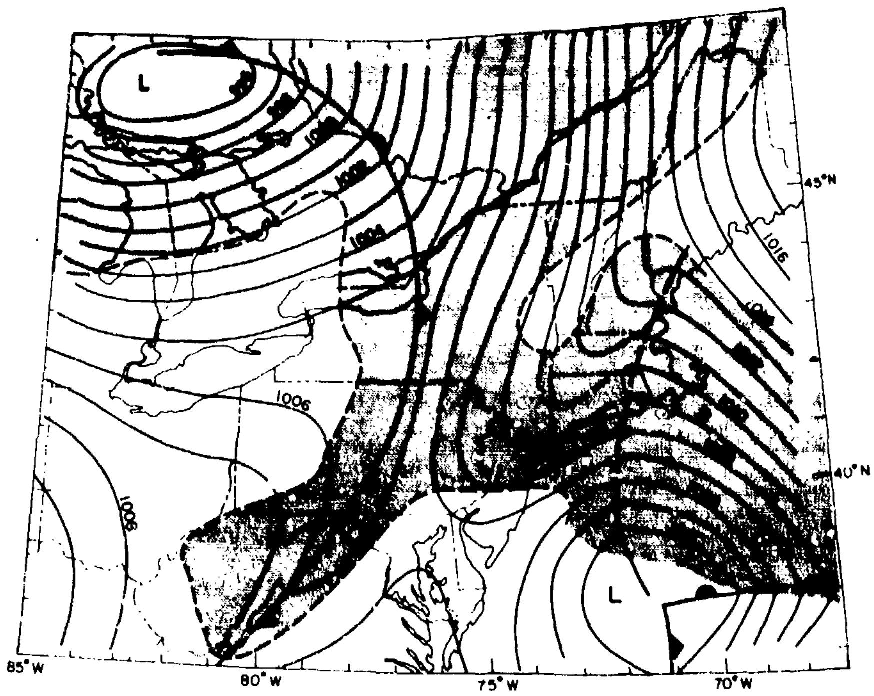

Figure 31. Surface weather map, 0600, 8 February. The precipitation zone is shaded.

decreased to less than 1.6 km, and the air temperature at CEATC was slightly above freezing.

An upper air trough across the central United States became more pronounced and moved slowly eastward. Winds at the 500-mb level over New England started to shift from west to southwest as the trough approached (Fig. 32). The satellite image taken at 0800 shows multilayered thick clouds covering all of New England, eastern New York, northeastern Pennsylvania and northern New Jersey. The cloud tops at Utica, New York, and Concord, New Hampshire, were estimated to be at 9100 and 9800 m, with temperatures at -54° and -58°C, respectively.

<u>1300, 8 February</u>

The low center north of the Great Lakes showed little movement, and the occlusion associated with it also slowed down. However, the cyclonic wave off the coast of Maryland deepened considerably, moved rapidly north-northeastward, and was centered off the coast of New England. The surface pressure at CEATC fell rapidly, the ceiling lowered, and the snowfall gradually increased in intensity.

<u>1500, 8 February</u>

The Plattsburgh AFB sectional weather map of the area showed a juncture of several fronts and three low pressure centers over or adjacent to New England (Fig. 33). The map shows 1) a bent-back occluded front that extended from the junction point over northern Vermont northwestward into one low center that had moved from north of the Great Lakes to a location over west-central Quebec, 2) a quasi-stationary front that stretched mostly eastward from the juncture point across northern Vermont and New Hampshire into a second (coastal) low pressure center located southwest of Nova Scotia, and 3) a frontal wave that extended south-southwestward from the juncture into a third (shallow) low center located over eastern Pennsylvania and southern New Jersey. Rain or snow fell over all of the northeastern states because of this complex weather pattern.

<u>1900, 8 February</u>

The stationary front at the juncture point separated from the occlusion and merged with the deeper coastal low over Nova Scotia. The occlusion and the low pressure region associated with it (in Canada) stalled, and a residual east-west trough remained across south-central Quebec. Meanwhile, the frontal wave over Pennsylvania and New Jersey continued to track toward the Northeast. Snowfall was extensive throughout most of

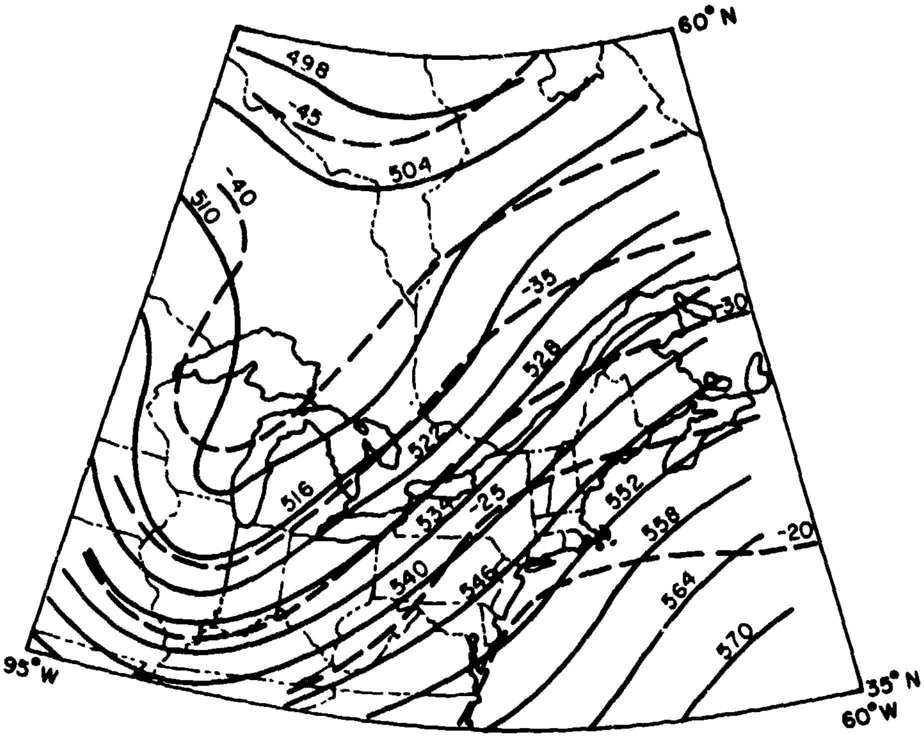

Figure 32. Weather chart for 500-mb level, 0700, 8 February. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

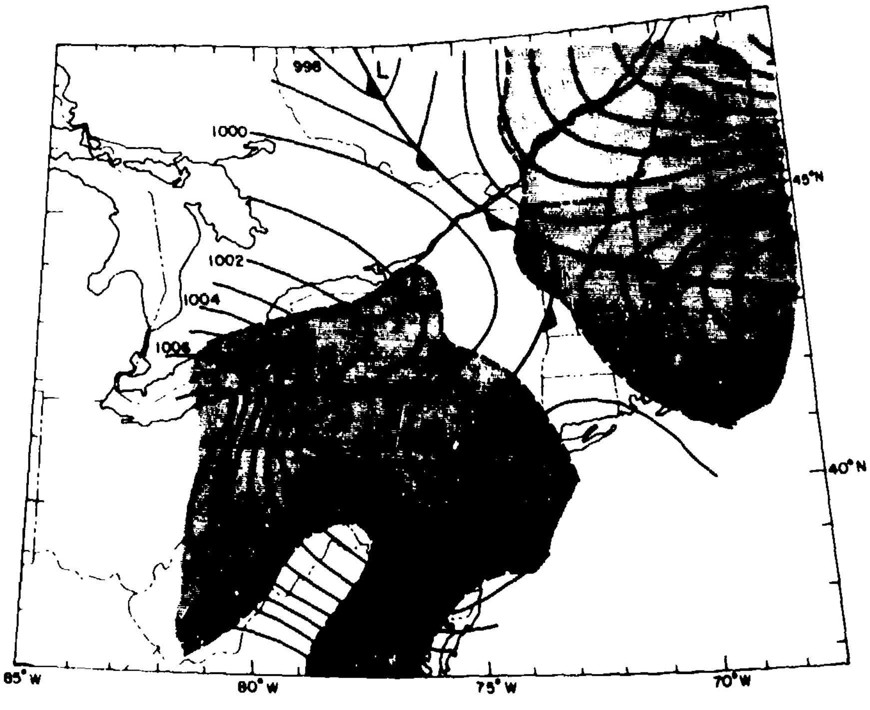

Figure 33. Surface weather map, 1500, 8 February. The precipitation zone is shaded.

northern New England and parts of New York. Visibility decreased to less than 1.6 km in fog and snow, with low and ragged ceilings at both CEATC and Burlington Airport.

The principal upper level trough on the 500-mb chart was located over Lake Ontario and Lake Erie and extended southward to the Appalachian Mountains (Fig. 34). Strong southerly winds and an influx of warm air were also noted over northeastern New England at that level. For example, at Caribou, Maine, the isotherm analysis on the 500-mb chart showed that the temperature had increased from -33° to -25°C during the previous 24 hours.

<u>0100, 9 February</u>

The low center over Nova Scotia moved northeastward, but the trailing low pressure trough remained over New England. It appears that the old occlusion that had stalled in Quebec may have retrograded westward and then southward, because a strong front passed over CEATC and Burlington Airport between 2300 and 2330 on 8 February. The greatest snowfall intensities occurred from about 1800 (8 February) to 0300 (9 February) at CEATC and Burlington Airport. The snowfall rate during this period averaged about 1.3 mm of water equivalent per hour. The ceiling continued to be ragged and low, with visibility down to 0.8 km (probably less in some quadrants). Following the frontal passage, the surface pressure rose quickly and the air temperature started to fall.

<u>0700, 9 February</u>

Indications of the unstable conditions that existed in the residual low pressure region across northern New England and central New York are shown by the series of troughs on the USAF sectional map (Fig. 35). Snow continued to fall at CEATC and Burlington Airport until about 0500. Visibility from midnight to 0300 occasionally reduced to 0.8 km or less during moderate snowfall or blowing snow. The low clouds began to lift by 0500 and the visibility improved. By this time the various low centers had merged, and the entire system was centered over New Brunswick and the Gulf of St. Lawrence (Fig. 36).

<u>1900, 9 February</u>

The northern edge of a high pressure cell centered off the coast of North Carolina controlled the local weather. The skies became partly cloudy, visibility was very good, and the air near the surface was dry.

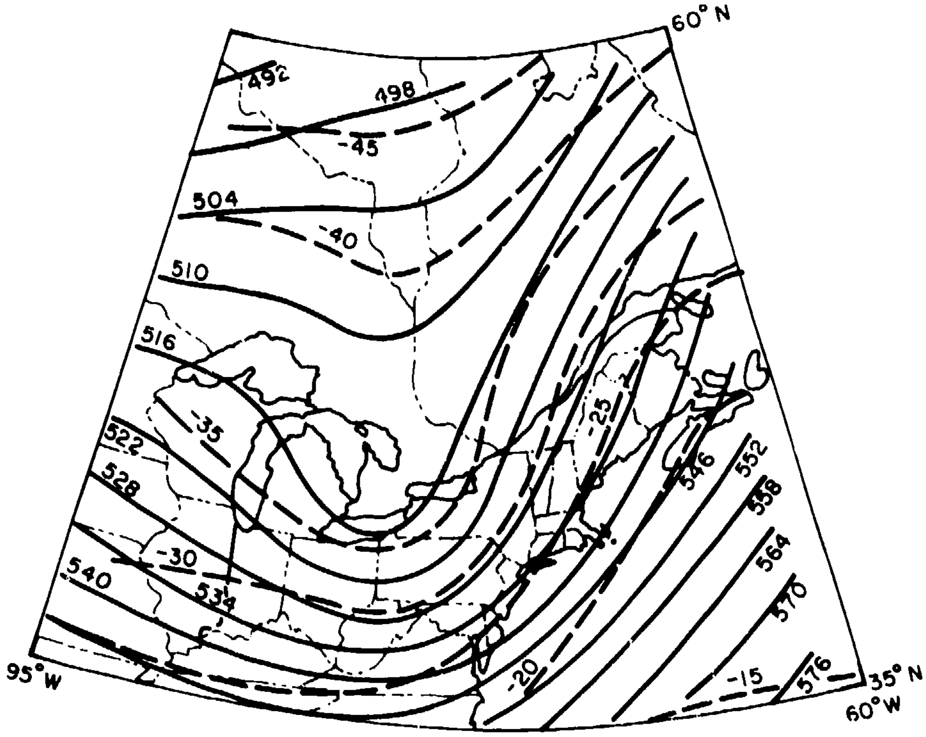

Figure 34. Weather chart for 500-mb level, 1900, 8 February. The solid lines are height contours (10's of meters above sea level). The dashed lines are temperature contours (°C).

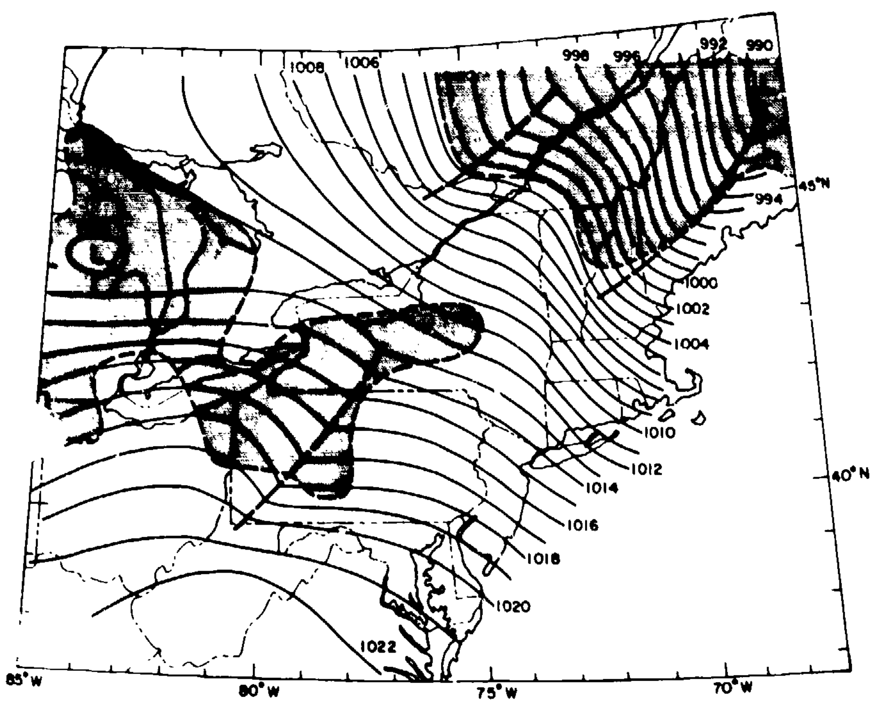

Figure 35. Surface weather map, 0700, 9 February. The precipitation zone is shaded.

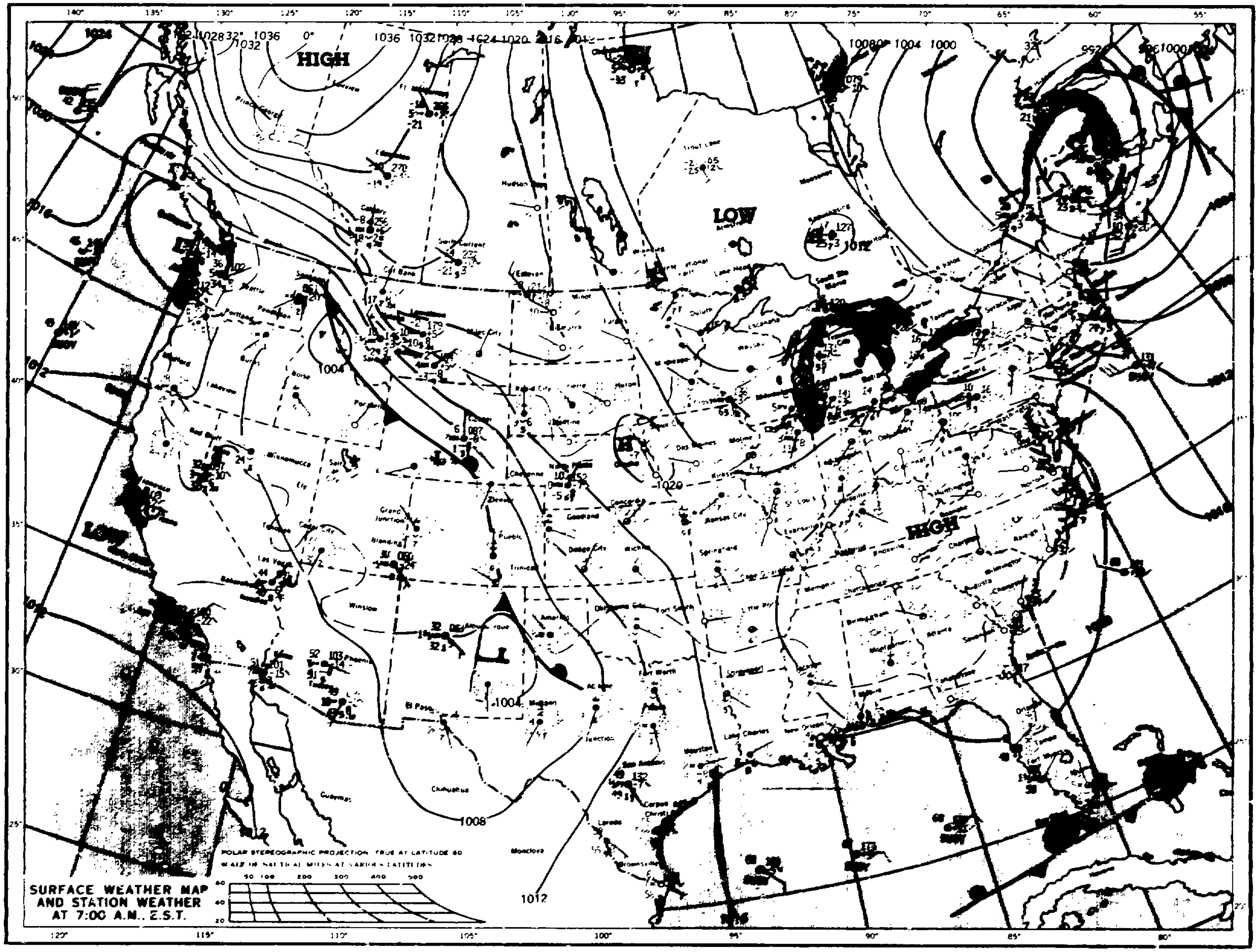

Figure 36. Surface weather map and station weather, 0700, 9 February.

0700, 10 February

The high pressure cell off the central east coast of the United States had drifted northeastward and was centered off the southeast coast of New England. The local weather remained mostly unchanged, with scattered clouds and good visibility.

1900, 10 February

The high pressure cell off the New England coast built rapidly to 1049 mb, and its center moved northeastward to a point off the northeast coast of Nova Scotia. Meanwhile, an intense storm had developed suddenly over the south-central states (Kentucky and Missouri) and was located over Indiana. Its central pressure was less than 996 mb. The elongated trough associated with the storm reached southward to Louisiana. Two waves were identified with the storm: one wave center over Indiana and another over western Tennessee. The dominant warm front associated with the storm appeared to be the one that stretched eastward from the low center in Indiana. Precipitation was heavy in many sections around this storm, with rainfall on the east side of the trough and light-to-heavy snowfall on the north side of the warm front and west of the trough line. Locally, cloudiness increased, and the surface winds became stronger from the southeast. The air temperatures increased rapidly to above freezing at CEATC.

0100, 11 February

The deep low pressure system crossed the central Great Lakes region and dominated most the northeastern United States. A strong flow of south-to-southeast winds developed over all of New England as this large depression approached the region. A cold front starting at the center of the low extended directly southward through an elongated trough to Alabama, and a warm front stretched mostly eastward from the center through Lake Huron and across northern New England. Rain or snow covered large regions around this depression, but precipitation had not yet started in northern Vermont. The skies were overcast, strong southeast winds continued, and the air temperature was still increasing. A peak wind gust of 21 m/s from the southeast was recorded at Burlington Airport at 2230 on the 10th.

0700, 11 February

The center of the large depression moved northeastward and was just north of Lake Huron. The entire system formed a nearly north-south configuration, possibly due to a "blocking high" that developed because the massive high pressure cell over Newfoundland remained nearly stationary and continued to build (to near 1056 mb at its center). The cold front in the elongated trough moved slowly eastward, cutting through Ohio, northeastern Tennessee and Georgia. The warm front that extended from the center of the low lay mainly across the southwestern corner of Quebec, northern Vermont, and New York (Fig. 37). South-to-southeast winds continued on the east side of the depression, accompanied by significant amounts of rain in some areas. Locally, the mixed light rain and snow that had started at about 0300 changed to light rain. Southeast winds increased in strength, with gusts reaching 14.3 m/s. (The mid-point trailer at CEATC tipped over between the hours of 2200 on the 10th and 0600 on the 11th.) Gusts at both meteorological towers at the site reached 45 knots at about 1930 on the 10th. An electric power failure prevented further wind measurements until after 0800 on the 11th. The air temperature at CEATC reached 5.5°C, and the atmospheric pressure started to fall rapidly.

1900, 11 February

The large depression and its associated cold front and trough moved directly eastward and reached the western edge of New England, including northern Vermont. Rainfall at CEATC had been was steady since about 1000, averaging between 0.5 and 2.0 mm of water per hour during each of the previous nine hours. The surface winds veered to the south and south-southeast and were very strong all day. The average hourly surface wind speeds at CEATC reached 10.5 m/s, with peak gusts up to 19 m/s. At Burlington Airport a new daily high temperature record of 14.4°C was reached at 1800, and the depth of snow on the ground decreased from 17.8 cm at 0100 to a trace at 1900. These are phenomenal weather conditions for Vermont during mid-winter!

0100, 12 February

The cold front went through the area at about 1930. The classic weather changes that occur with such a passage followed: the pressure rose rapidly, the light rain changed to rain showers and then to snow showers, the temperature fell quickly from over 10° to -4°C, and the winds shifted sharply from southerly to westerly.

0700, 12 February

The low pressure center moved rapidly to the northeast, and the cold front moved eastward and off the New England coast. The pressure continued to rise rapidly, and the local area quickly came under the influence of a

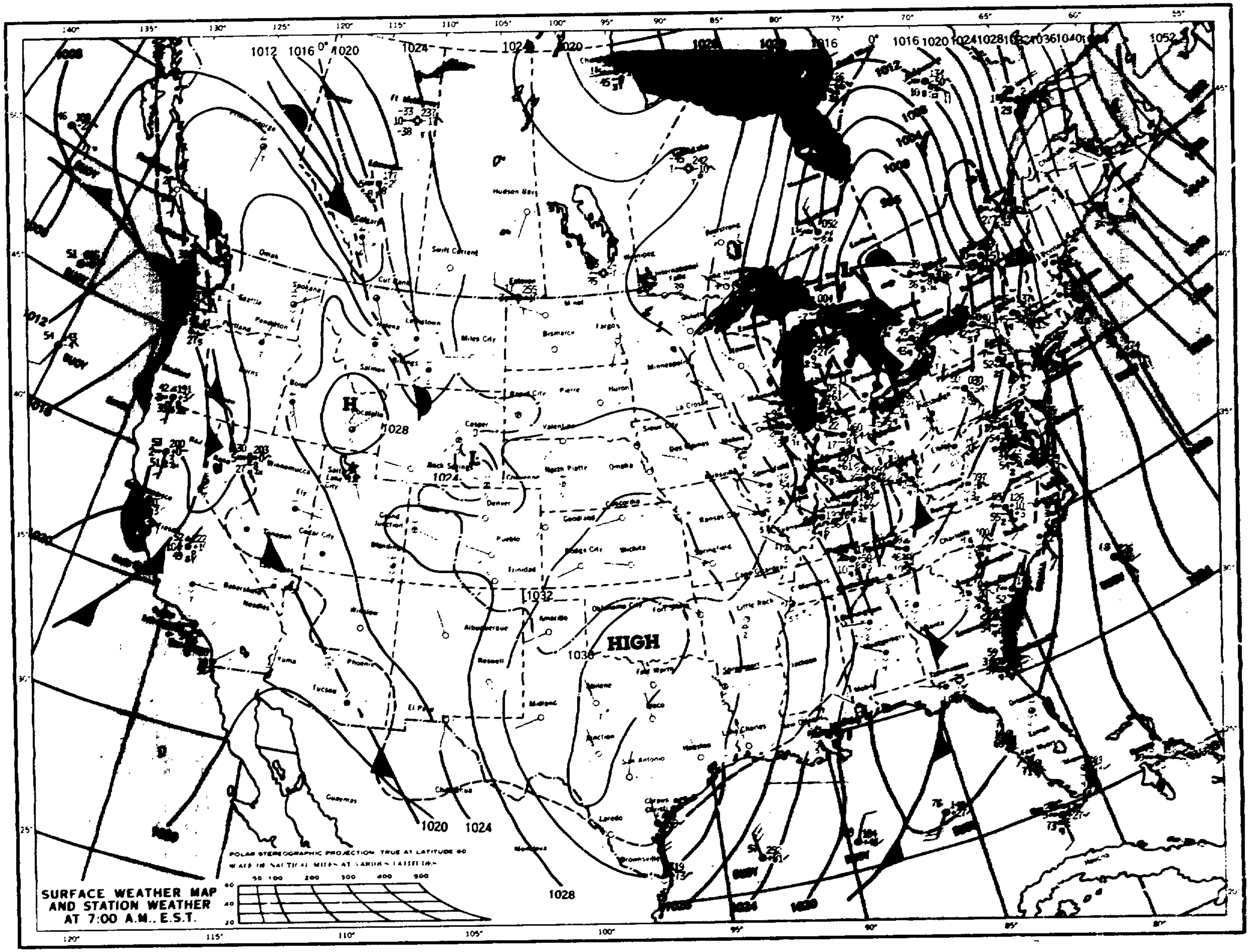

Figure 37. Surface weather map and station weather, 0700, 11 February.

high pressure cell centered over Ohio, Kentucky, Indiana and parts of Tennessee (Fig. 38). The local weather improved quickly, with only scattered clouds and excellent visibility. However, westerly winds were still strong, gusting to 16.5 m/s from the northwest at 0530, and there were periods of drifting snow at Burlington Airport. The air temperature at CEATC dropped to -13.5°C and the air was much drier.

1900, 12 February

The high pressure cell moved eastward and covered most of the northeastern United States. The skies became clear and the visibility was excellent over New England.

1900, 13 February

The synoptic weather pattern changed very little during the previous 24 hours. The high pressure cell remained essentially centered over New England and continued to provide clear to partly cloudy weather in the region.

0700, 14 February

The high pressure cell weakened slightly and moved off the New England coastline. A trough with a weak front through it extended from Lake Huron northeastward into Quebec and was drifting southeastward toward northern New England. Considerable high cloudiness moved into Vermont, and the visibility remained excellent.

1900, 14 February

The trough and the associated weak cold front in Quebec passed through northern New England, but other than a shift in wind direction, little change in the local weather was observed. The sky remained partly cloudy (middle height), with a high thin overcast and excellent visibility.

0700, 15 February

The weak trough dissipated rapidly as it passed through a high pressure cell that was building over New England. The atmospheric pressure at Burlington Airport reached 1041 mb. The local weather remained essentially unchanged, with high thin cloudiness, good visibility, and daily temperatures ranging from -15° to 5°C.

1900, 15 February

The synoptic pattern over the region showed little change during the previous 12 hours. However, the local surface winds had increased slightly and were from the south. The air temperature stayed above the freezing mark.

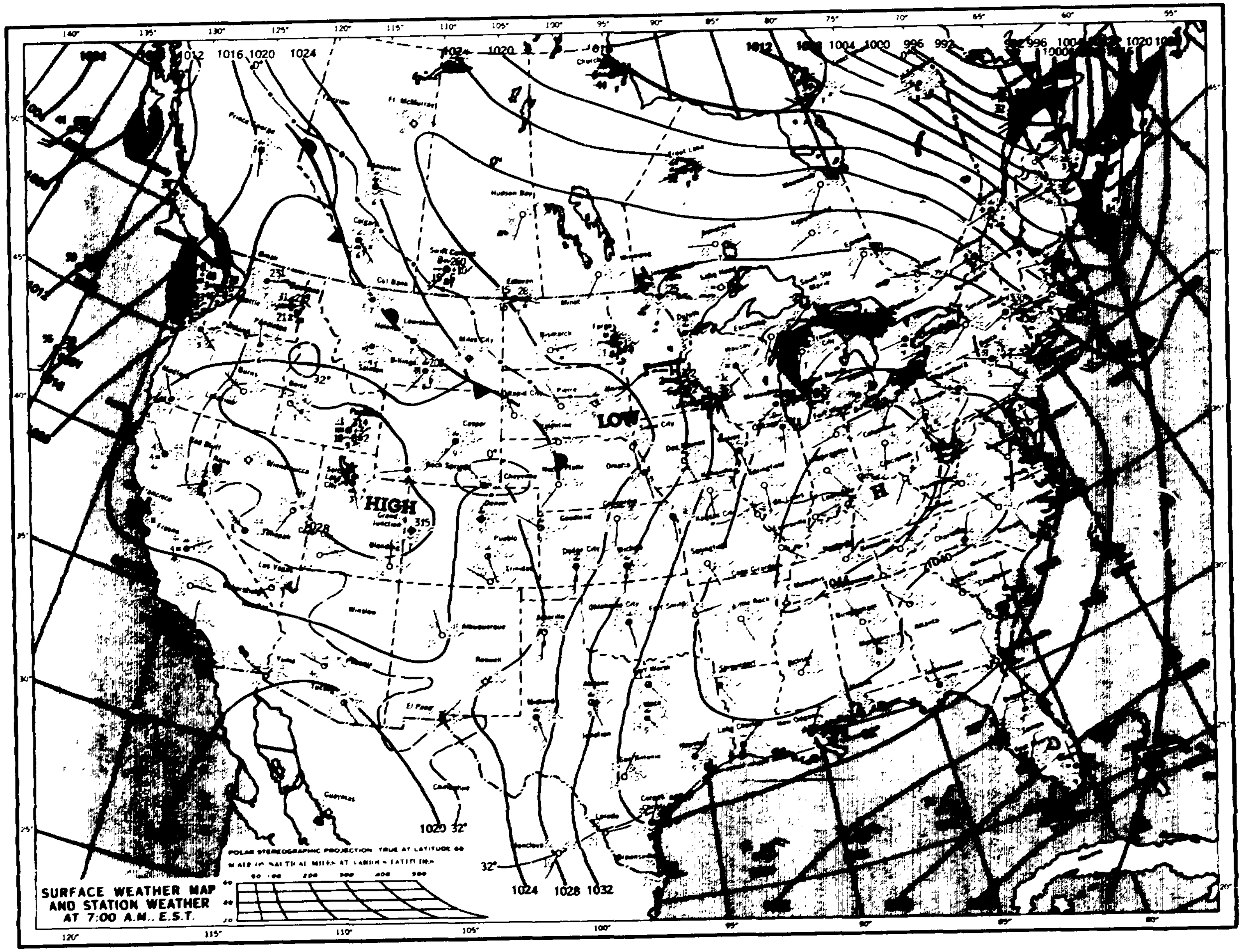

Figure 38. Surface weather map and station weather, 070Ͻ, 12 February.

0700, 16 February

The high pressure cell weakened somewhat, but the center (1038 mb) was still located about 360 km off the New England coast. High broken-to-scattered clouds prevailed over northern Vermont, and the visibility was good. Strong southerly winds persisted in the area, and night air temperatures hovered just above the freezing mark. Only a trace of snow remained on the ground at CEATC and Burlington Airport.

1900, 16 February

The constant flow of warm southerly winds that influenced the northeastern region of the United States resulted from the isobaric patterns established on the back side of the high pressure cell centered off the coast of New England. Middle-to-high cloudiness prevailed locally, with continued strong southerly winds. The air temperatures across the region exceeded 10°C.

0700, 17 February

A very weak frontal system passed quickly through New England from the west and produced only scattered light (trace) and brief rain showers is northern Vermont. Otherwise, the weather remai essentially unchanged throughout the region.

0700, 18 February

The large high pressure system centered well off the coast of New England (to the southeast) continued to provide spring-like weather to most of the region. The weather had remained fairly uniform over the previous 42 hours. Temperatures were unseasonably warm (-2° to 14°C), with scattered-to-broken (mostly high) clouds and good visibility.

1900, 18 February

The southerly flow of air on the back side of the high pressure cell now off the east-central coastline of the United States continued to provide fair weather for New England. Skies became clear with good visibility. A new record high temperature of 14.5°C for this date was recorded at Burlington Airport.

0700, 19 February

The high pressure cell started to weaken, and a frontal system over the Great Lakes moved eastward toward New England. Although clear skies caused the air temperature to drop to the freezing mark in the area in the night (due to radiational cooling), the daytime temperatures increased rapidly (to 11°C). The skies also started to become cloudy.

1900, 19 February

The weak cold front reached almost to the borders of northern New England. Cloudiness increased throughout the day, with stronger winds from the south. Another new record high air temperature for the date (16.7°C) was recorded several times during the afternoon at Burlington Airport. A low pressure center with a wave developed over southern Lake Michigan. The system caused rain to fall over parts of New York, Pennsylvania and southwestern New England.

0700, 20 February

The low south of the Great Lakes moved eastward, and its center was over Pennsylvania and Virginia (Fig. 39). Two frontal systems extended from its center: a cold front that moved off the East Coast and a stationary front that stretched northeastward across northwestern New York to just north of New England. Rain spread over all of New England except for most of Maine. Light rain showers began at Burlington Airport at about 2330 on the 19th and continued intermittently. The air temperature at CEATC had remained above 11°C overnight and was 12°C at this time.

1900, 20 February

The low pressure cell moved only slightly up the East Coast to New Jersey and dominated almost all of New England. The cyclonic flow, with its east-to-east-southeast onshore (moisture-laden) winds, brought light rain and continued warm air temperatures to the area throughout most of the day. Burlington Airport recorded another new record high air temperature (14.4°C); the daily minimum temperature of 10°C observed on this date was the warmest minimum temperature ever recorded during February--another phenomenal occurrence to add to this extremely unusual Vermont winter.

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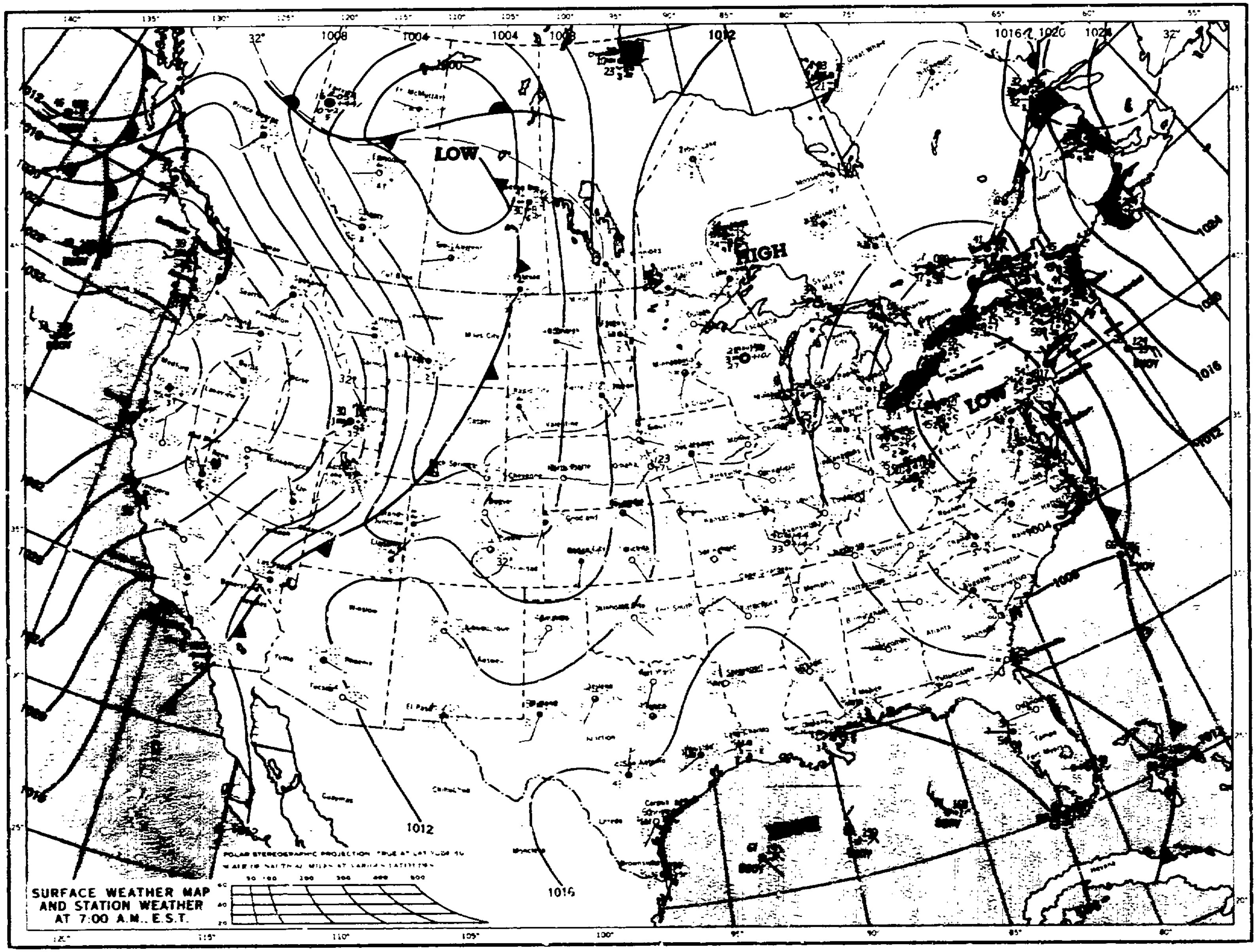

Figure 39. Surface weather map and station weather, 0700, 20 February.

APPENDIX A. DEFINITIONS OF METEOROLOGICAL TERMS.

These definitions are taken from the Glossary of Meteorology, (R.E. Huschke, ed., 1959) with the permission of the publishers, the American Meteorological Society, Boston, Massachusetts.

bent-back occlusion — (Also called back-bent occlusion.) An occluded front that has reversed its direction of motion as a result of the development of a new cyclone (usually near the point of occlusion) or, less frequently, as the result of the displacement of the old cyclone along the front. The resulting movement of the occluded front is westward and/or southward behind its associated cold front.

cold front — Any non-occluded front, or portion thereof, that moves so that the colder air replaces the warmer air; i.e., the "leading edge" of a relatively cold air mass.

cyclonic — Having a sense of rotation about the local vertical the same as that of the earth's rotation: that is, as viewed from above, counter-clockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere, undefined at the equator; the opposite of anti-cyclonic.

deepening — A decrease in the central pressure of a pressure system on a constant-height chart ...; the opposite of filling. The term is usually applied to a low rather than to a high, although technically it is acceptable in either sense.

depression — 1. In general, a point of limited area of locally lower elevation in a particular surface.

2. In meteorology, an area of low pressure; a low or a trough. This is usually applied to a certain stage in the development of a tropical cyclone, to migratory lows and troughs, and to upper-level lows and troughs that are only weakly developed.

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filling — An increase in the central pressure of a pressure system on a constant-height chart ...; the opposite of deepening. The term is commonly applied to a low rather than to a high.

high — In meteorology, elliptical for "area of high pressure," referring to a maximum of atmospheric pressure in two dimensions (closed isobars) in the synoptic surface chart, or a maximum of height (closed contours) in the constant-pressure chart.

Since a high is, on the synoptic chart, always associated with anticyclonic circulation, the term is used interchangeably with anticyclone.

low — (Sometimes called depression.) In meteorology, elliptical for "area of low pressure," referring to a minimum of atmospheric pressure in two dimensions (closed isobars) on a constant-height chart or a minimum of height (closed contours) on a constant-pressure chart.

occluded front — (Commonly called occlusion; also called frontal occlusion.) A composite of two fronts, formed as a cold front overtakes a warm front or quasi-stationary front. This is a common process in the late stages of wave-cyclone development, but is not limited to occurrence within a wave cyclone.

ridge — (Sometimes called wedge.) In meteorology, an elongated area of relatively high atmospheric pressure, almost always associated with and most clearly identified as an area of maximum anticyclonic curvature of wind flow. The locus of this maximum curvature is called the ridge line.

The most common use of this term is to distinguish it from the closed circulation of a high (or anticyclone); but a ridge may include a high (and an upper-air ridge may be associated with a surface high) and a high may have one or more distinct ridges radiating from its center.

secondary front — A front which may form within a baroclinic cold air mass which itself is separated from a warm air mass by a primary frontal system.

The most common type is the secondary cold-front.

stationary wave — (Also called standing wave.) A wave with nodes stationary relative to the given coordinate system. Any permanent wave may be rendered stationary by appropriate chosen coordinates. In meteorology the coordinate system is usually fixed with respect to the earth, so that a stationary wave usually refers to one stationary relative to the earth's surface.

trough — In meteorology, an elongated area of relatively low atmospheric pressure; the opposite of a ridge. The axis of a trough is the trough line.

This term is commonly used to distinguish the above from the closed circulation of a low (or cyclone); but a large-scale trough may include one or more lows, an upper-air trough may be associated with a lower-level low, and a low may have one or more distinct troughs radiating from it.

warm front — Any non-occluded front, or portion thereof, which moves in such a way that warmer air replaces colder air.

water equivalent — The depth of water that would result from the melting of the snow pack or of a snow sample. Thus, the water equivalent of a new snowfall is the same as the amount of precipitation represented by that snowfall.

wave — Very generally, any pattern with some roughly identifiable periodicity in time or space. This applies, in meteorology, to atmospheric waves in the horizontal flow pattern.

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