# MEAN ATMOSPHERIC PATTERNS ASSOCIATED WITH HEAVY RAIN AND FREEZING RAIN AT BISMARCK, NORTH DAKOTA: AN INITIAL STUDY USING HISTORICAL NMC DATA ON CD-ROM

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***Abstract***

*Historical gridded data from the National Weather Service's (NWS) National Meteorological Center (NMC) on a single CD-ROM disk can now be efficiently accessed and processed using an inexpensive personal computer (PC). This provides the operational meteorologist with a powerful new tool to conduct local forecast studies and develop forecast aids.*

*One application of this historical data is the ability to quickly and easily produce composite synoptic scale fields for local significant weather events. These fields can be valuable as training aids for new employees or to assist forecasters in quick pattern recognition of significant events. Recent studies on summertime heavy convective rainfall and cold season freezing rain events in south central North Dakota are presented as examples.*

## 1. Introduction

Personal computer (PC) technology has brought many changes to operational meteorology over the last 5 years. Most notably it has brought high speed computer processing and high resolution graphics capabilities to operational meteorologists that were available only to research meteorologists a few years ago.

A companion technology is CD-ROM (Compact Disc-Read Only Memory) disks and drives for the PC. A single CD-ROM disk is capable of storing in excess of 550 million data characters. This makes it possible to put in the hands of the operational meteorologist large volumes of historical weather data that can be readily accessed and processed by desktop computers.

A variety of data sets are available on CD-ROM including historical data from the National Weather Service (NWS) CO-OP observing network, historical hydrologic data and data from field research projects. Of particular interest to the NWS field forecaster is the NWS/National Meteorological Center (NMC) Grid Point Data Set prepared by the University of Washington (Mass, 1987). This disk contains grid point data on the NMC octagonal grid for a variety of levels and parameters, some dating back to the late 1940's.

In addition to simply viewing historical data on a computer screen, a number of other applications come to mind. One is to find historical analogs to a current weather pattern in real-time as an adjunct to NWP and statistical forecast guidance. Another would be compositing historical weather maps related to a given meteorological problem (e.g., heavy snowfall or dense fog). This second application is illustrated in this paper.

## 2. Approach

Compositing of historical weather maps related to a given synoptic scale forecast problem is not a new technique (Hirt, 1985). Composite maps provide references to alert a forecaster to the possibility of a significant weather event. They also serve as valuable training tools for forecasters new to an area or for new employees.

Unfortunately, up until now, these studies were very time consuming and required the assistance of research meteorologists with access to large data sets and mainframe computers. With a CD-ROM and a PC, these historical composites can be produced and printed in a matter of minutes once an event has been defined and historical dates selected.

The first step in the process is to identify the weather event to be studied (e.g., rainfall). The selected event should be relatively uncommon (e.g., heavy rainfall). The event should be defined so that about 10 to 40 historical dates fit the event definition (e.g., rainfall greater than 2 inches in 24 hours in the summer). This increases the likelihood that a significant meteorological pattern will result from the compositing process.

Once the historical dates have been identified, the second step is to review the maps for each case and sort them into broad synoptic categories (e.g., southwest flow cases and northwest flow cases). Each broad synoptic regime must be composited separately. If different regimes are composited together, a bland pattern may result that is not representative of either regime.

Finally, the compositing software is run and output maps printed. The software simply computes the mathematical average of the fields at each grid point for the selected dates.

Our goal at the NWS Forecast Office (NWSFO) at Bismarck, North Dakota is to produce a local library of composites of significant weather events affecting North Dakota. A few highlights of two of these studies are presented in the following sections.

## 3. Summer Heavy Convective Rainfall

Daily precipitation data at Bismarck, North Dakota was examined for June, July and August for the years 1962 to 1988. A day was selected for consideration if an inch or more of rain was reported. This 27 year period produced only 32 days which met or exceeded the 1 inch criteria. Ten of the 27 years contained no events while only 3 events had rainfall exceeding 2 inches.

Each event day was examined to determine the starting and ending time of the precipitation and to determine the basic synoptic regime. Of the original 32 cases, the gridded data was missing for one event, two northwest flow events were eliminated and one case of prolonged stratiform rain was removed. This left 28 cases to composite. The two northwest flow cases were eliminated so that the meteorological pattern of the pre-dominate southwest flow regime would be kept pure. If enough northwest flow cases could be identified, they would be composited as a separate heavy rain pattern.

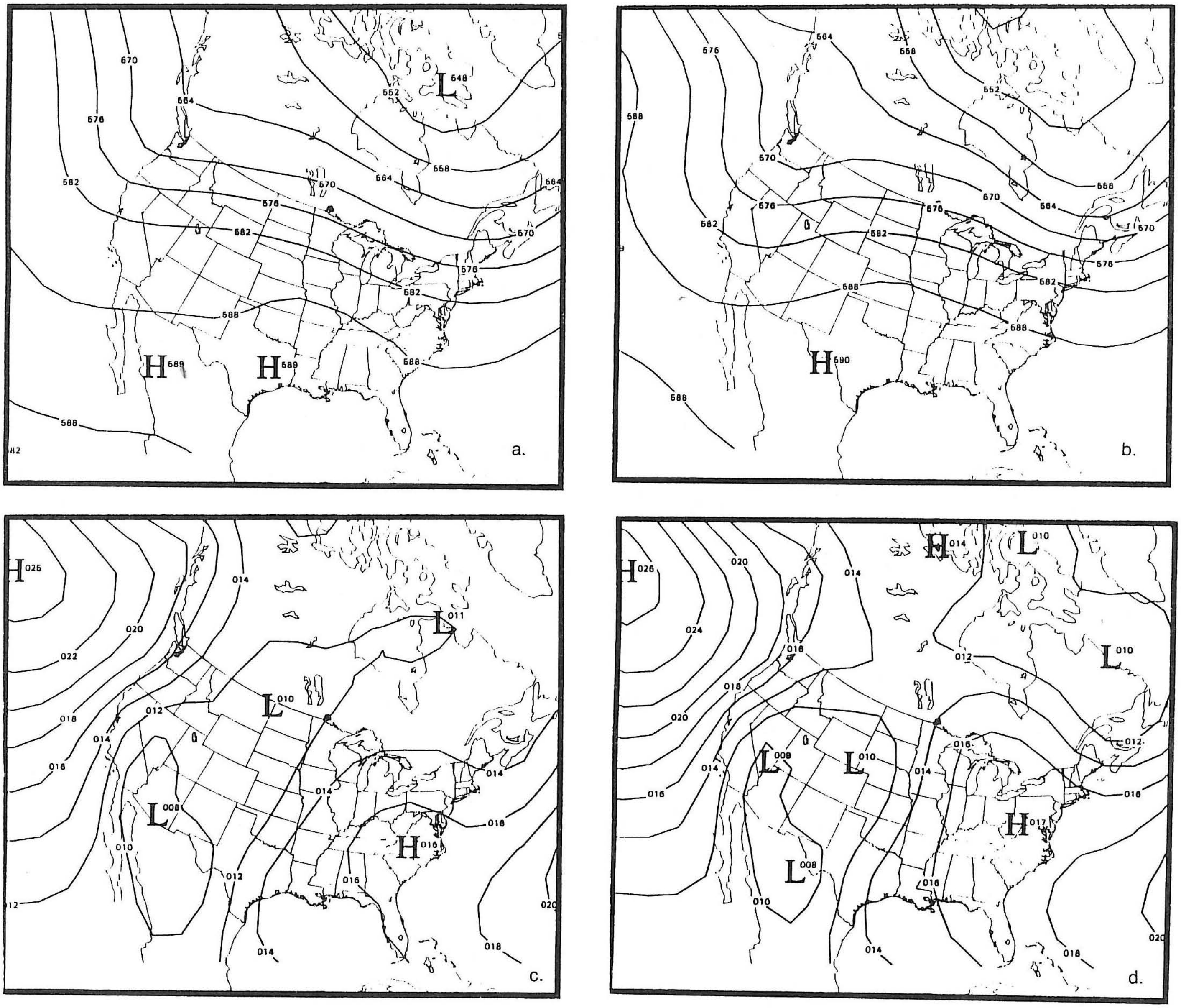


Fig. 1. Composite 500-mb heights (interval 6 dm) for (a) 72-hours and (b) 24-hours, and composite surface isobars (interval 2 mb) for (c) 72-hours and (d) 24-hours prior to the heavy rainfall event.

### a. *Pre-event composite*

Surface and 500-mb composite maps for 72 and 24-hours prior to the precipitation event are shown in Fig. 1. The 500-mb pattern shows a broad and nearly stationary trough along the Pacific Northwest coast for the 72-hour period prior to heavy rain. The surface pattern shows a weak low pressure trough along the Montana/North Dakota border and a strong Bermuda high. This implies southeast flow at the surface which usually brings a layer of Gulf of Mexico moisture into the state. In North Dakota a lack of low level moisture, as opposed to a lack of synoptic forcing, is usually the primary factor limiting summertime convection.

At 850 mb (not shown), a fairly strong east-west thermal boundary is indicated across Montana, the Dakotas and into southern Minnesota. However, there is little temperature advection implied as the composite height gradient is weak across south central North Dakota.

### b. *Event composite*

The data is available for only 1200 and 0000 UTC. In this case, the closest data time preceding the precipitation event was selected to composite. The event composite is representative of conditions roughly 6-hours prior to the onset of the heavy convective rainfall. Figure 2a shows the composite surface map. A well defined surface low is evident over extreme northwest South Dakota. This implies a continuation of strong southeast flow of Gulf moisture into south central North Dakota.

Figure 2b shows 850-mb height and temperature composites. A well defined 850-mb low is indicated in southeast

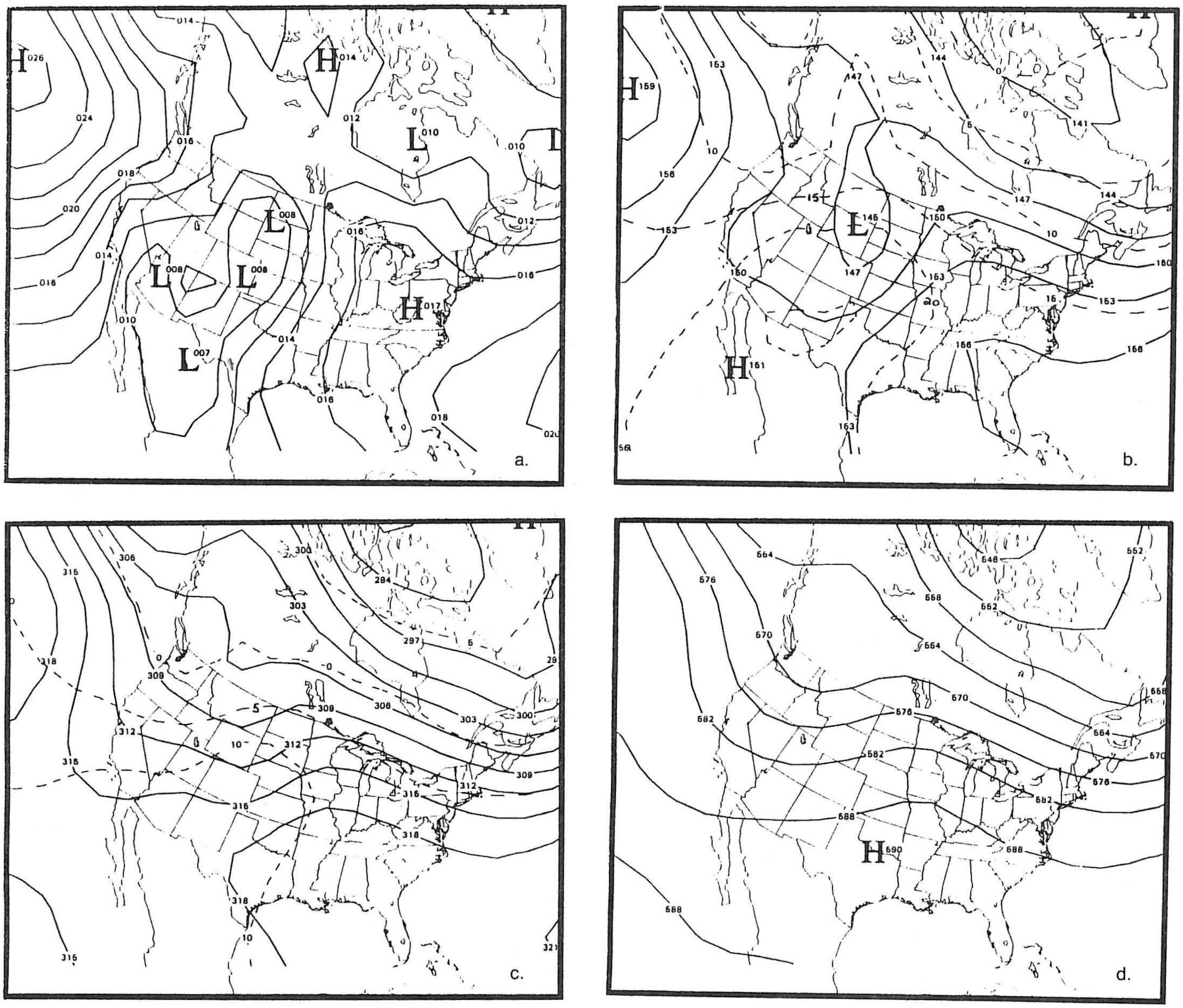


Fig. 2. Composite (a) surface isobars (interval 2 mb), (b) 850-mb heights (interval 3 dm) and temperatures (interval 5°C), (c) 700-mb heights (interval 3 dm) and temperatures (interval 5°C), and (d) 500-mb heights (interval 6 dm) just prior to the onset of the heavy rain event.

Montana with warm advection into southern North Dakota. Note the east-west thermal boundary across Montana and the Dakotas. The 700-mb pattern is similar (Fig. 2c). Note a distinct short wave trough, strong warm advection and an east-west thermal boundary across the Dakotas.

At 500 mb (Fig. 2d) the trough is indicated to be over western Idaho. However, a weak ridge is indicated across North Dakota. This implies that positive vorticity advection (PVA) at 500 mb was not a primary contributor to vertical motion in these heavy rainfall events but rather strong low level warm advection was a key factor. This pattern is similar to a "typical" severe weather regime across North Dakota (Hirt, 1985).

### *c. Post-event composite*

Composite surface and 500-mb charts for 24-hours after the initial time are shown in Fig. 3. At 500 mb (Fig. 3a) a weak short wave trough is shown across North Dakota. This is apparently a remnant of the earlier Idaho trough (Fig. 2d). The surface composite (Fig. 3b) shows the passage of a cold front through central North Dakota with a dry west or northwest flow behind it. At 850 mb (not shown) an east-west thermal boundary still exists; however, weak cold advection is indicated across south central North Dakota.

In summary, the composites imply that heavy summer convective rainfall in south central North Dakota occurs roughly 12-hours prior to the passage of a cold front after a prolonged period of low level southeast flow. Secondly, low level warm advection appears to be a significant forcing mechanism.

## 4. Cold Season Freezing Rain

Freezing rain is not a common event at Bismarck. It occurs on average, 2 to 3 times each winter. When it does occur,

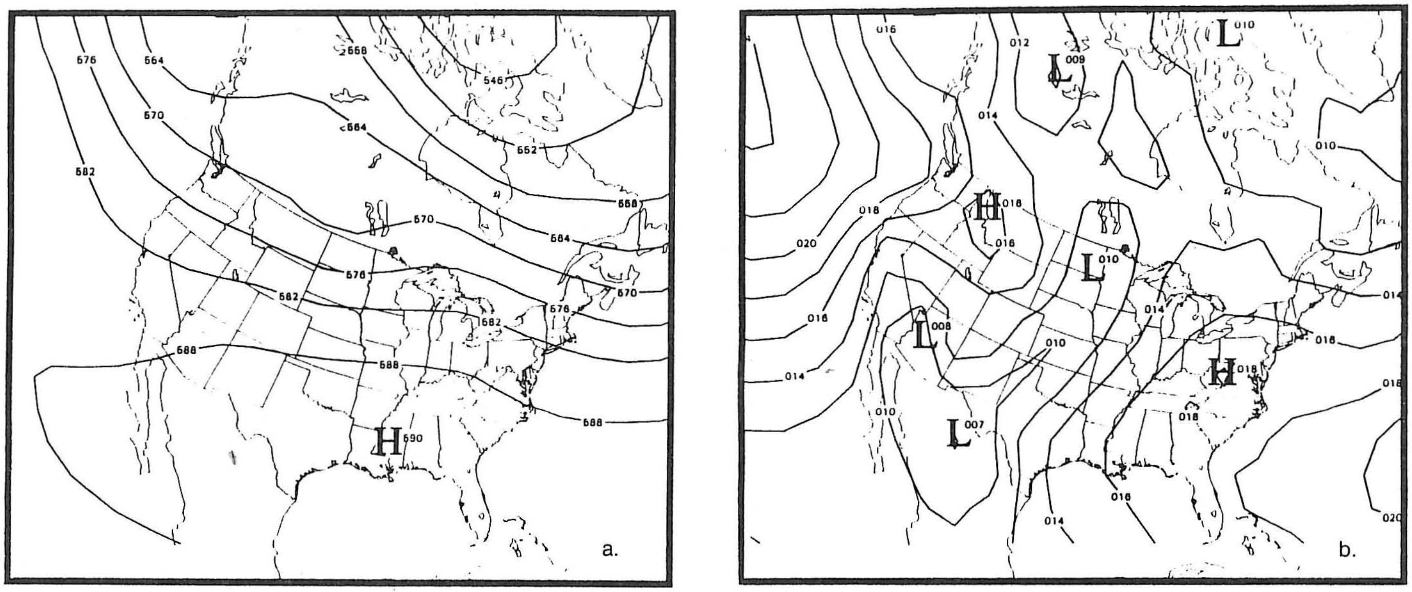


Fig. 3. Composite (a) 500-mb heights (interval 6 dm) and (b) surface isobars (interval 2 mb) for 24-hours after the heavy rain event.

precipitation is 0.01 inch or less two-thirds of the time. Yet even a small amount of freezing rain has a significant impact on travel and outdoor activities.

Freezing rain events at Bismarck occurring between November and March from 1980 to 1989 were tallied and then grouped by surface synoptic pattern. Of the 28 events identified, 15 were associated with the west to east passage of a warm front across North Dakota. The remainder of the events were evenly divided among 3 other synoptic patterns: a central plains low, an east-west stationary front across South Dakota, and a Canadian cold front. This section of the paper focuses on the two synoptic patterns that produced the heaviest freezing rain episodes: the warm front and the central plains low.

### *a. The warm front*

With this pattern, freezing rain at Bismarck occurs as a maritime Pacific airmass, warmed by its passage over the Rockies, overruns and replaces a cold arctic airmass over the state. Typically, a mid-level short wave trough provides additional dynamic lift.

Figure 4a is a composite surface pressure map of the 15 freezing rain events associated with the approach of a warm front from the west. A trough lies 200 miles west of Bismarck, in the lee of the Rockies, at the onset of freezing rain. The trough is the dividing line between mild northwest chinook winds and cold southeast winds near the western perimeter of an arctic airmass. The warm front lies at the boundary of these two wind fields. A comparison with the composite surface map for 12-hours preceding the event (not shown) indicates the composite front is moving east at about 30 mph.

Composite 850-mb heights and temperatures are shown in Fig. 4b. The zero degree isotherm is over Bismarck and warm advection is taking place over the cold arctic boundary layer.

The 500-mb height composite (Fig. 4c) is characterized by a long wave trough along the east coast and a ridge over the Rockies. The northern portion of the ridge appears to be flattened; likely in response to the passage of a short wave trough. The short wave is more apparent as a dip in the departure from climatology contours (Fig. 4d). The application of the Student t test to the departure from normal of the composite 500-mb height field, and all the other fields of this paper, indicate that they are significant to the 5% and many times to the 1% level.

To determine how characteristics of heavier freezing rain episodes differ from all freezing rain events, the original set of 15 events was narrowed down to those associated with precipitation totals of 0.03 inches or more. Three events met this criteria (0.08 in. being reported for the heaviest event). To develop a more representative climatology 2 additional events from 1979 were added to the group. Composite maps of the 5 events were then produced.

The composite surface map for heavy freezing rain (Fig. 5a) is very similar to the map produced from all freezing rain. The one difference of note is that the lee side surface trough does not have a negative tilt. The difference between heavy and all events is more pronounced on the 850-mb temperature map (Fig. 5b). Here a noticeably warmer layer of air has overrun the arctic boundary layer. This suggests stronger dynamics and the potential for more available moisture than in the general case. Stronger dynamics are evident on the 500-mb composite map of heavier events (Fig. 5c), where a short wave trough crossing the Rocky Mountain ridge is clearly stronger than the overall composite short wave.

### *b. The central plains low*

Another synoptic pattern associated with freezing rain at Bismarck features a deep central plains surface low. Warm moist air from the Gulf of Mexico is pulled north and then northwest to the northern plains. Here it overrides a cold arctic boundary layer. Although this type of freezing rain pattern only occurs on average every 3 years, it generated the heaviest event (0.11 in.) in the study.

Composite maps for the 4 events of this type that occurred between 1977 and 1989 are shown in Figs. 6a-c. The surface map (Fig. 6a) shows a low pressure system centered in north-

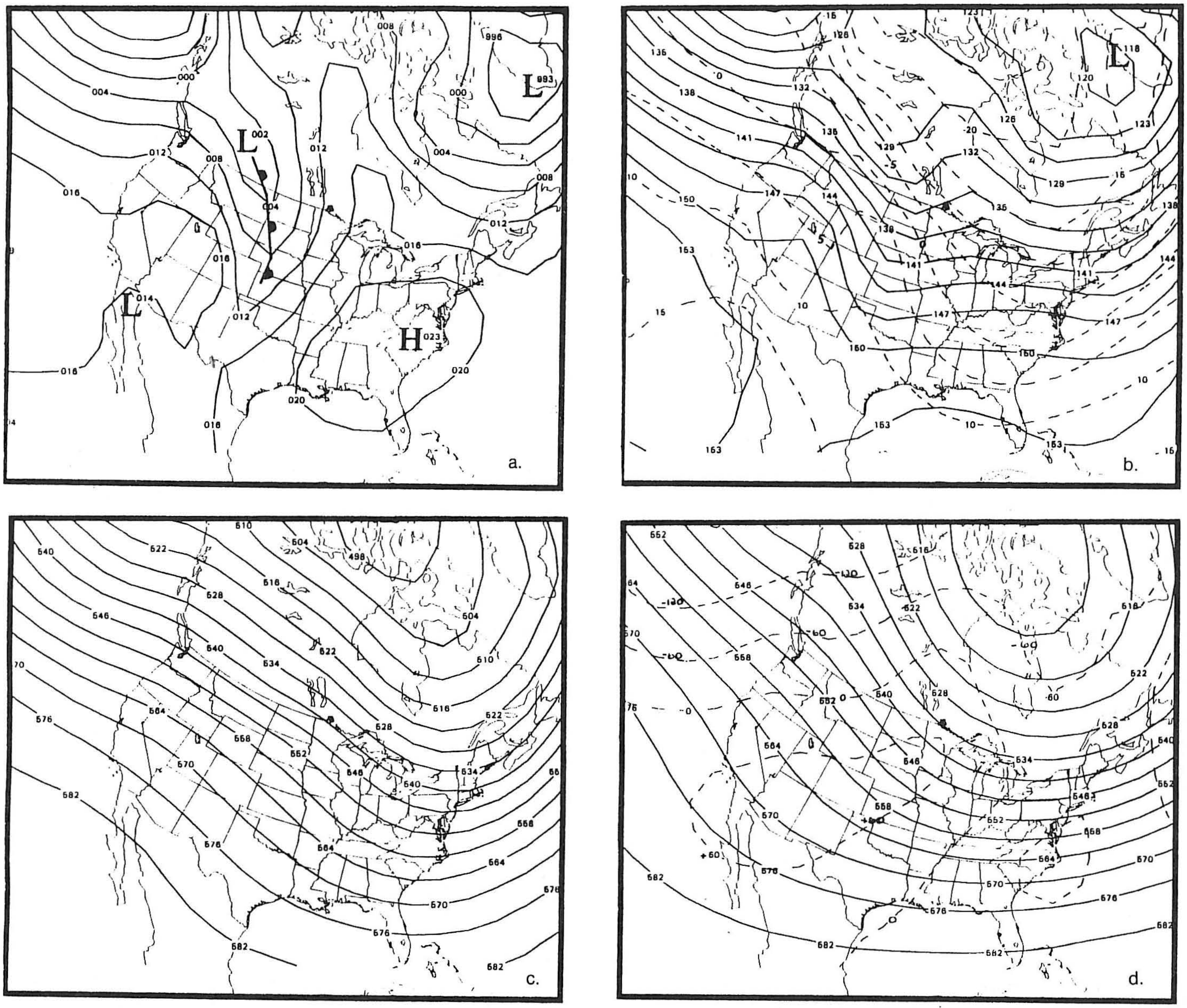


Fig. 4. Composite (a) surface isobars (interval 4 mb), (b) 850-mb heights (interval 3 dm) and temperatures (interval $5^{0}$C), (c) 500-mb heights (interval 6 dm), and (d) 500-mb climatology (interval 6 dm) and composite departure (interval 60 m) for the 15 freezing rain episodes between 1980 and 1989 associated with an approaching warm front.

ern Oklahoma and a cold high over James Bay. At 850 mb (Fig. 6b), the zero degree isotherm is over Bismarck with the height field indicating weak warm advection. At 500 mb (Fig. 6c), a low is over southeastern Colorado with strong ridging from the southeast to the western Great Lakes. The northern branch of the split flow is just north of the Canadian border. When the 2 heaviest events are composited, their 850-mb thermal pattern (Fig. 7) indicates a more extensive north-northwest penetration of warm air. This parallels the finding from the warm front case. Clearly, stronger dynamics and warmer air aloft are associated with more severe freezing rain episodes at Bismarck.

## 5. Conclusions

This paper has shown two examples using NMC gridded data on CD-ROM with desktop computer graphics and printing capability to study south central North Dakota weather events. Once an event is defined and historical maps selected, production of composite charts requires only a few minutes. Most NWS offices now have access to a dedicated training computer called the Professional Development Workstation (PDW). These computers have internal CD-ROM drives as part of the standard configuration and therefore, the capability to perform similar studies.

The two example studies shown here are only the beginning of many being planned at NWSFO Bismarck. Composite maps of historical events provide a valuable station reference for experienced, as well as new employees. The authors predict that gridded data on CD-ROM will be a valuable tool for operational weather offices in this age of modernization of weather services and would appreciate hearing from other users.

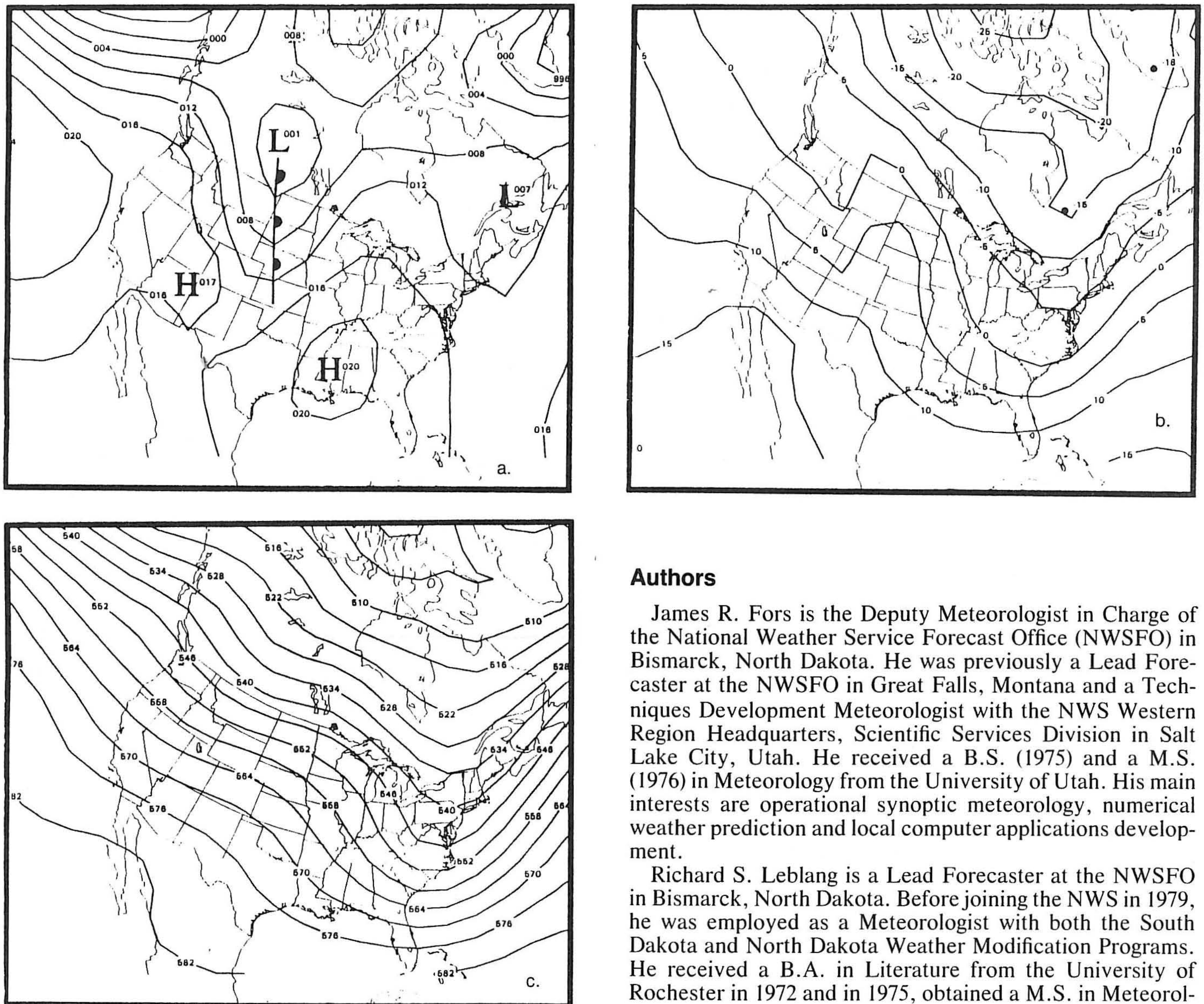


Fig. 5. Composite (a) surface isobars (interval 4 mb), (b) 850-mb temperatures (interval $5^0C$), and (c) 500-mb heights (interval 6 dm) for the 5 heaviest freezing rain episodes between 1979 and 1989 associated with an approaching warm front.

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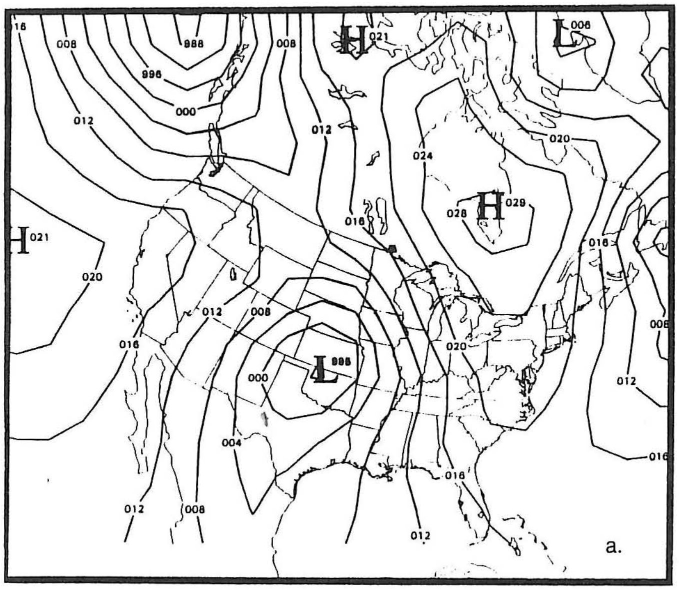


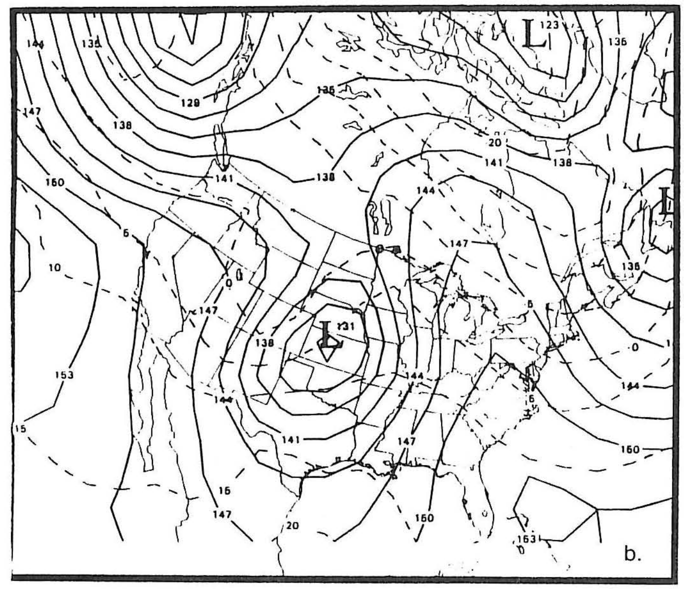


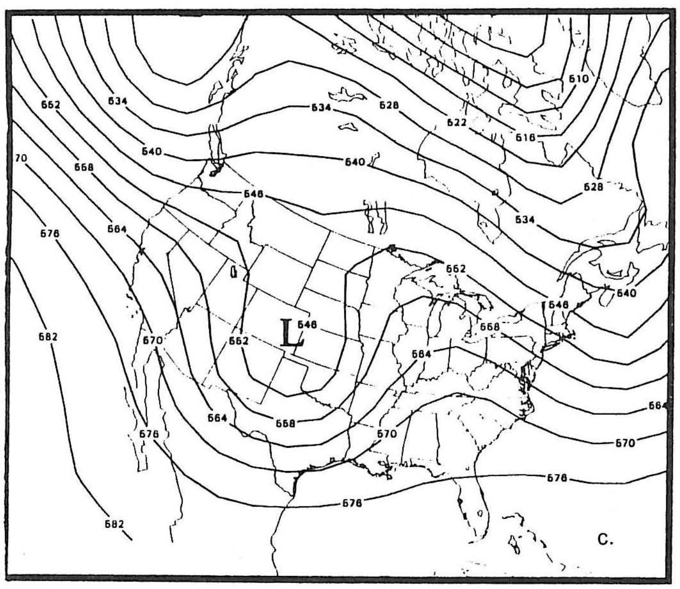


Fig. 6. Composite (a) surface isobars (interval 4 mb), (b) 850-mb heights (interval 3 dm) and temperatures (interval $5^0C$), and (c) 500-mb heights (interval 6 dm) for the 4 freezing rain episodes between 1977 and 1989 associated with a central plains low.

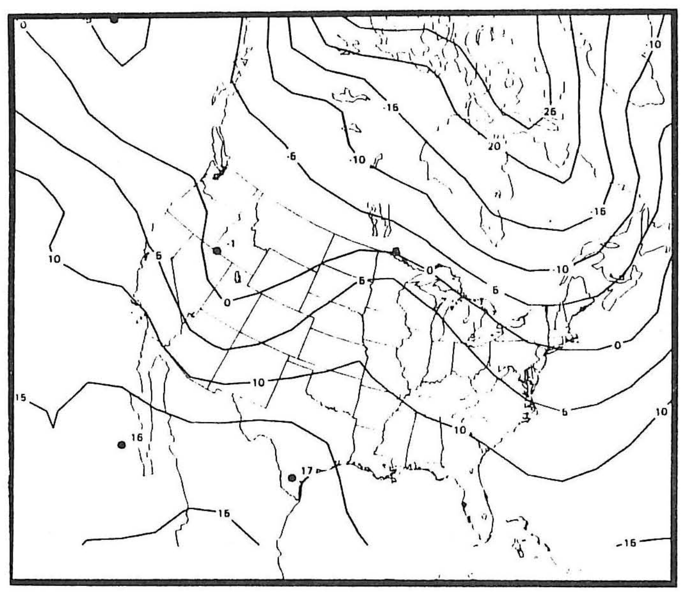

Fig. 7. Composite 850-mb temperatures (interval $5^0C$) for the 2 heaviest freezing rain episodes between 1977 and 1989 associated with a central plains low.