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OAA TECHNICAL MEMORANDUM NWS CR-73

THE BLIZZARD OF FEBRUARY 4-5, 1984 OVER THE EASTERN DAKOTAS AND WESTERN MINNESOTA

Michael Weiland
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Sioux Falls, SD

October 1984

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
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National Weather Service
Richard E. Hallgren,
Assistant Administrator

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Winds of 40 knots with gusts to 70 knots roared through the northern plains on the afternoon of February 4, continuing into the morning of February 5, 1984. The strong winds and a light snowfall reduced visibilities to zero at times during the afternoon and night over the eastern Dakotas and western Minnesota. Where existing snow cover and new snowfall were the greatest, conditions were worst. This area was roughly southwestern Minnesota, eastern North Dakota, and northeastern South Dakota. Up to one and a half inches of new snow fell over parts of eastern North Dakota. Temperatures dropped sharply during the evening of February 4, falling to below zero over most of the northern plains by the morning of February 5. Wind chills of 50 to 80°F below occurred.

In these adverse weather conditions a score of people lost their lives. It was the strong wind and the speed of the system that made the storm so severe and deserving of a closer look at what happened on those two days.

An Arctic air mass with very cold temperatures extending to above 700 mb was poised over the Northwest Territories of Canada for nearly a week before the blizzard. The jet stream was from the northwest late in the week over the northern United States and Canada.

On February 3 the flow in the upper atmosphere began to change. The ridge at 300 mb over the Pacific coast was building (compare Fig. 1a with Fig. 1b and note the height rises over British Columbia and Alberta in Fig. 1b). The result was more northerly flow over the Northern plains and Canada in the upper atmosphere. A very strong short-wave trough with temperatures of -40°C or lower at 500 mb was entering the Northwest Territories. At the surface, the Arctic high over northern Canada began to move south on the evening of February 3 in response to the upper system. The sea-level pressure in the Arctic high began to increase rapidly on the evening of February 3. Strong cold-air advection was apparent at 850 mb in the vicinity of Great Slave Lake (GSL in Fig. 2) at 1200 GMT Feb. 3 and 0000 GMT Feb. 4. Note the 8°C temperature drop at the station just south of Great Slave Lake.

During the morning of February 4 surface pressure rises of 4 to 8 mb in three hours were occurring in the Arctic high, now centered over northern Manitoba and Saskatchewan. The short-wave trough in the upper atmosphere was beginning to enter those provinces at that time.

Conditions at 300, 500, 700, and 850 mb, and at the surface for the 24-hour period encompassing the bulk of the storm are shown in Figs. 3-5. At 300 mb a jet streak with winds of 150 knots or so entered the northern plains (Fig. 3). With the strong northerly winds aloft over the Arctic air it began to move southward. Note the strong cold-air advection present at 700 and 850 mb over behind the cold front (Fig. 4). The rapid southward movement of the cold air at the surface is shown in Fig. 5. Surface winds over the northern plains increased from 15 to 25 knots early in the afternoon to 30 to 40 knots during the evening on February 4.

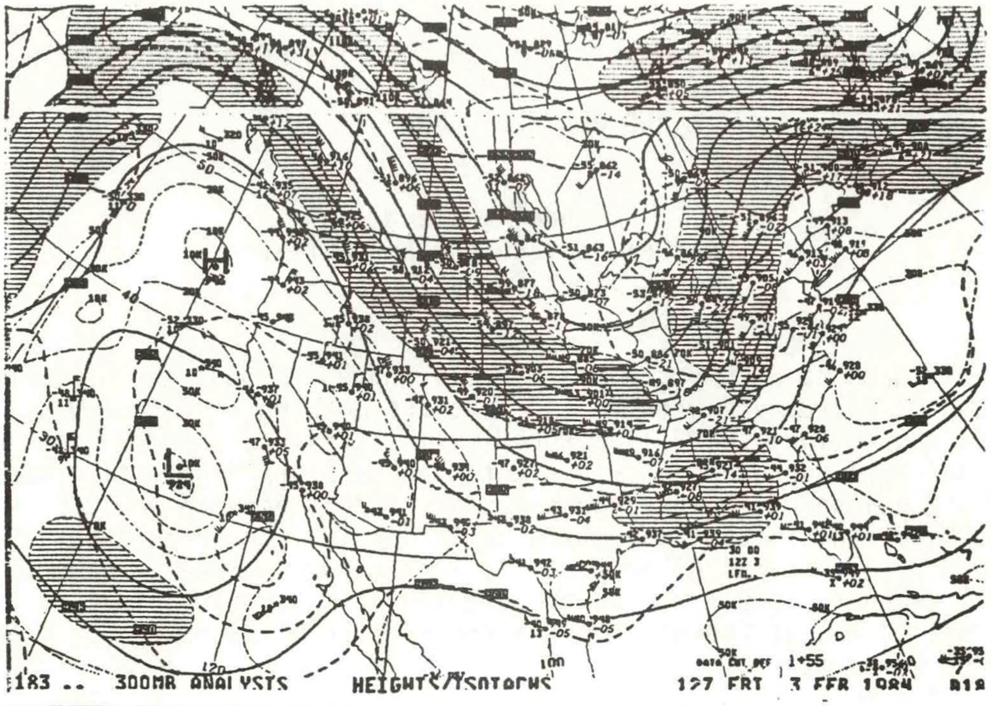


Fig. 1a.

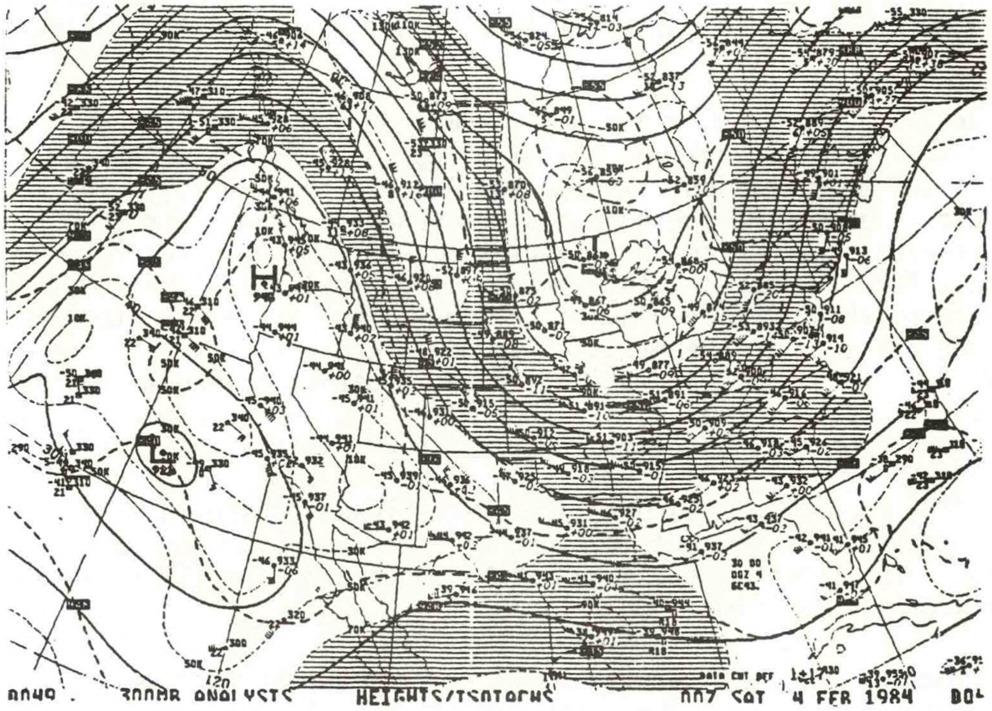


Fig. 1b.

Fig. 1. 300 mb Analyses at a) 1200 GMT Feb. 3, 1984 and
b) 0000 GMT Feb. 4, 1984.

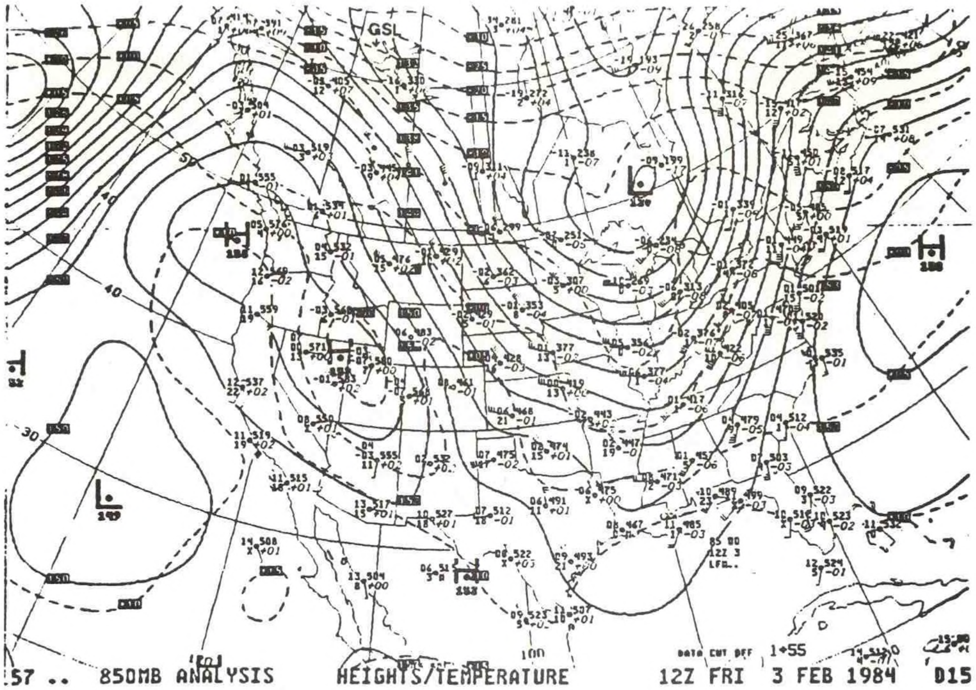


Fig. 2a.

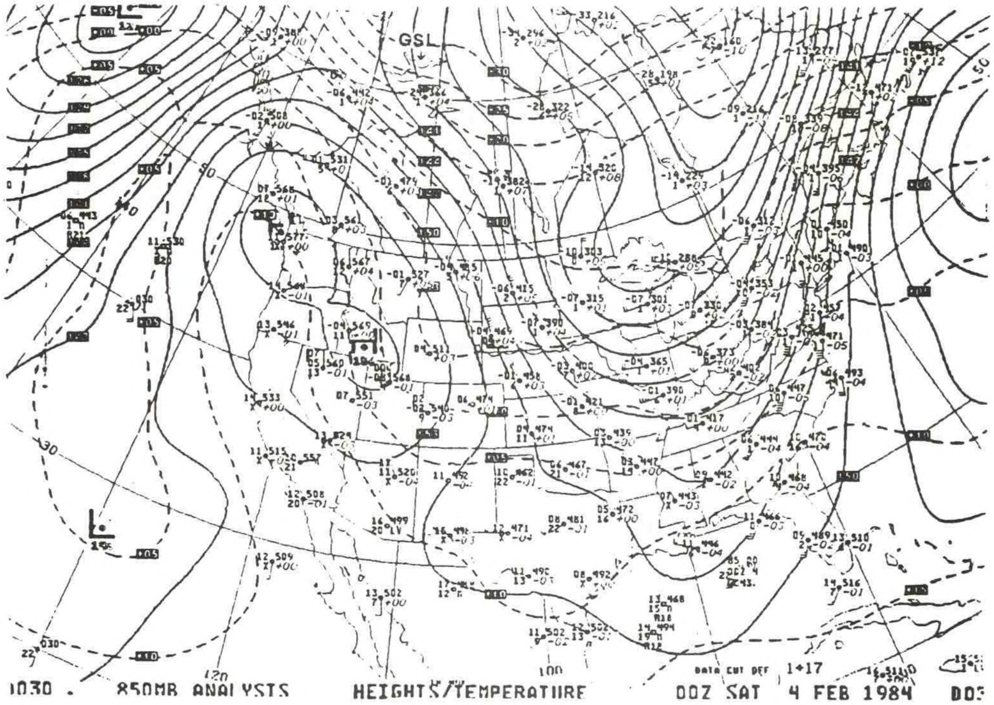
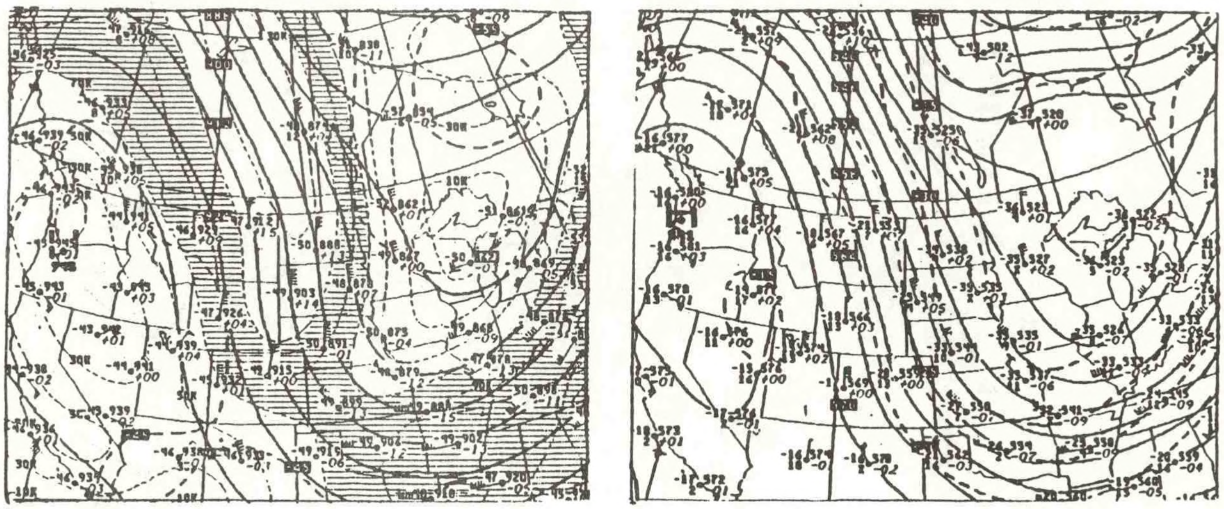


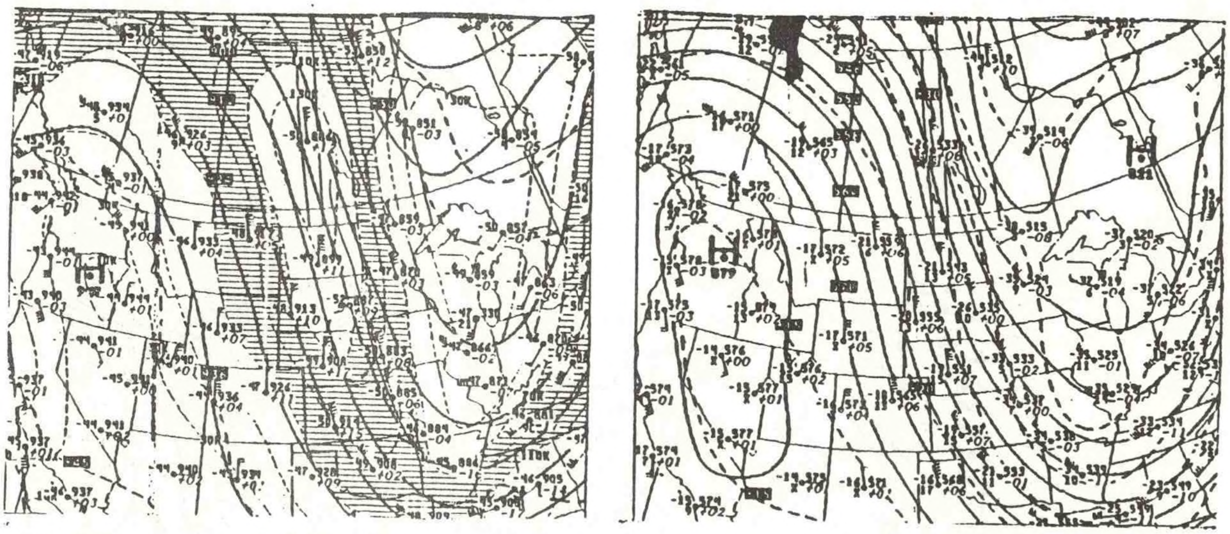
Fig. 2b.

Fig. 2. 850 mb Analyses at a) 1200 GMT Feb. 3, 1984 and
b) 0000 GMT Feb. 4, 1984.
Great Slave Lake is just south of "GSL" on map.

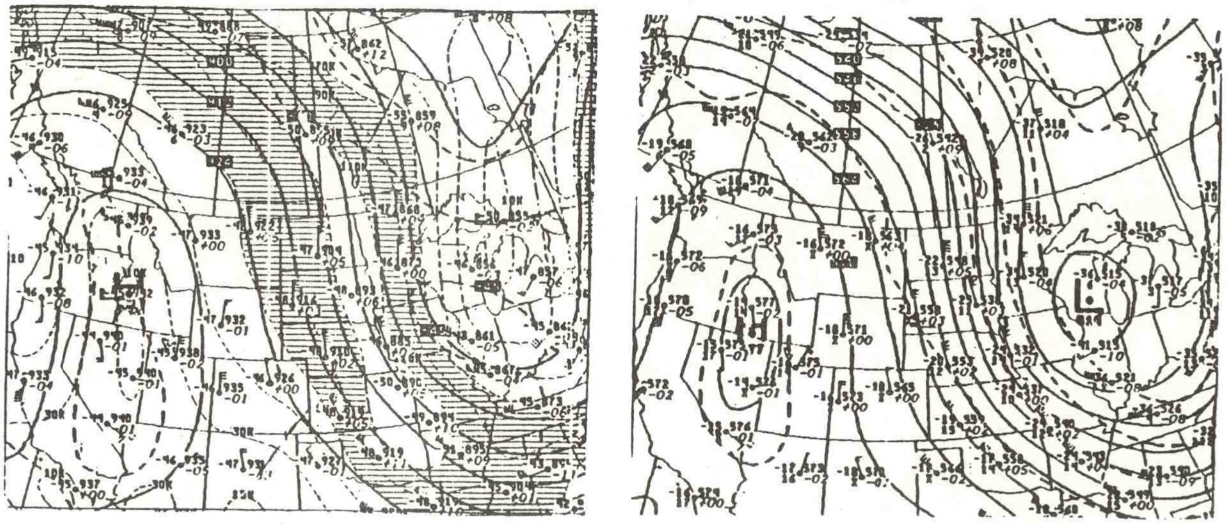
300 MB 500 MB



1200 GMT 4 Feb. 84 a. 1200 GMT 4 Feb. 84 b.



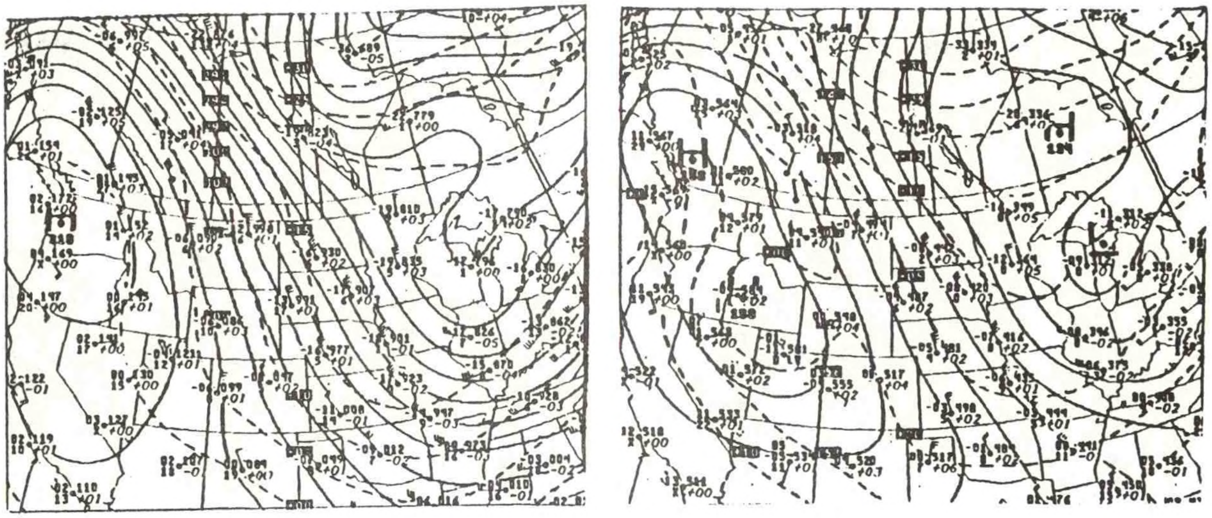
0000 GMT 5 Feb. 84 c. 0000 GMT 5 Feb. 84 d.



1200 GMT 5 Feb. 84 e. 1200 GMT 5 Feb. 84 f.

Fig. 3. 300 mb. and 500 mb. charts for 1200 GMT Feb. 4, 0000 GMT Feb. 5, and 1200 GMT Feb. 5, 1984.

700 MB 850 MB



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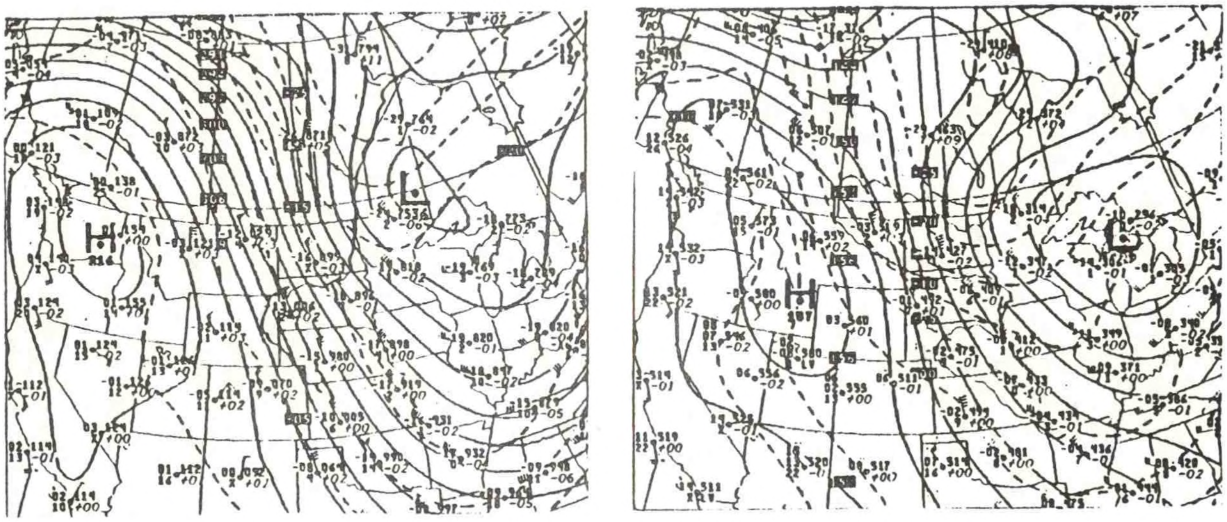

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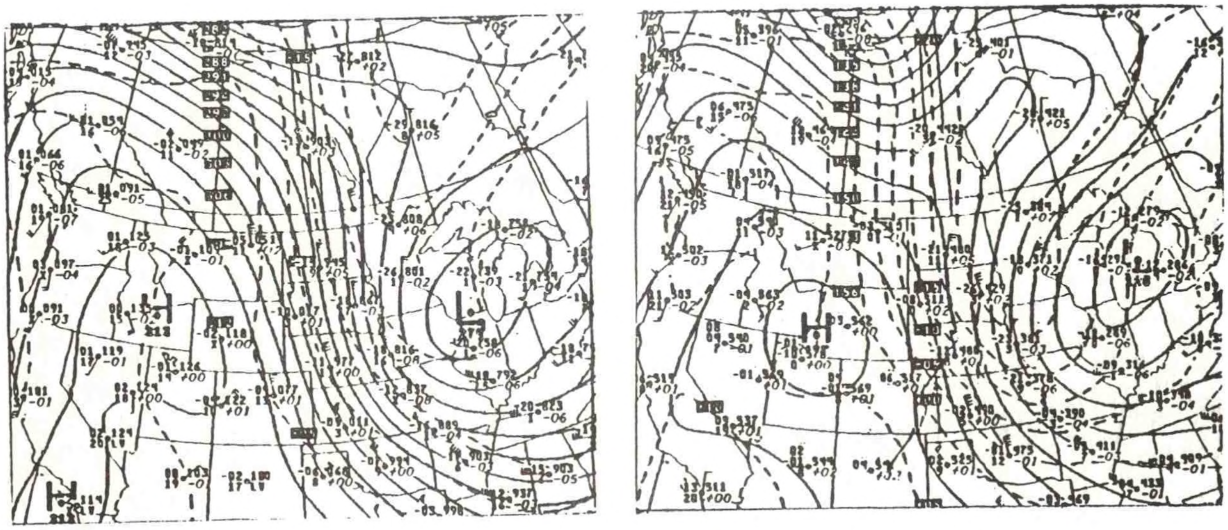
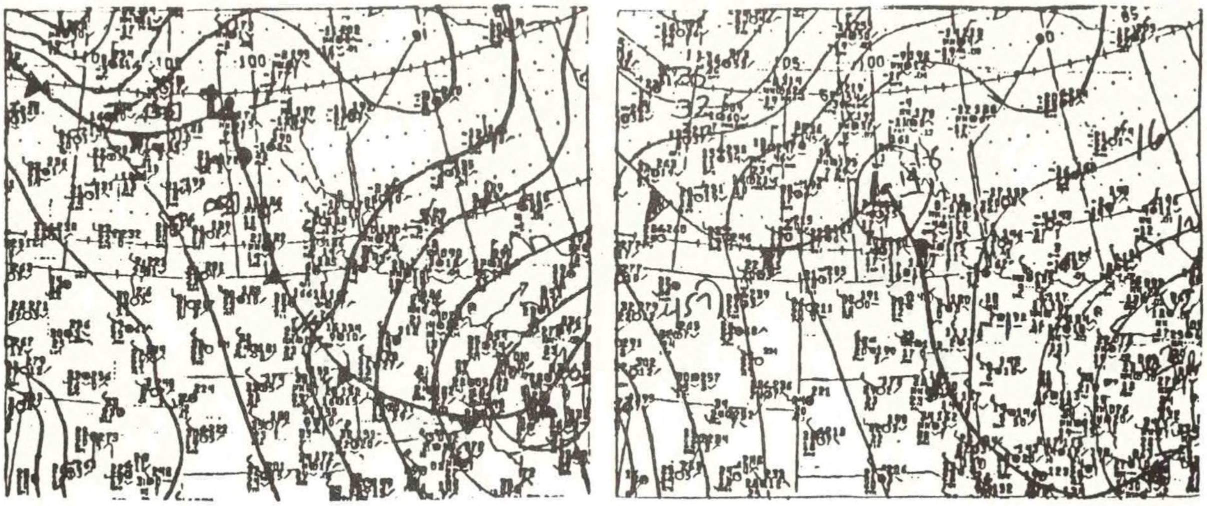


1200 GMT 5 Feb. 84 e. 1200 GMT 5 Feb. 84 f.

Fig. 4. 700 mb. and 850 mb. charts for 1200 GMT Feb. 4, 0000 GMT Feb. 5, and 1200 GMT Feb. 5, 1984.

SURFACE CHARTS



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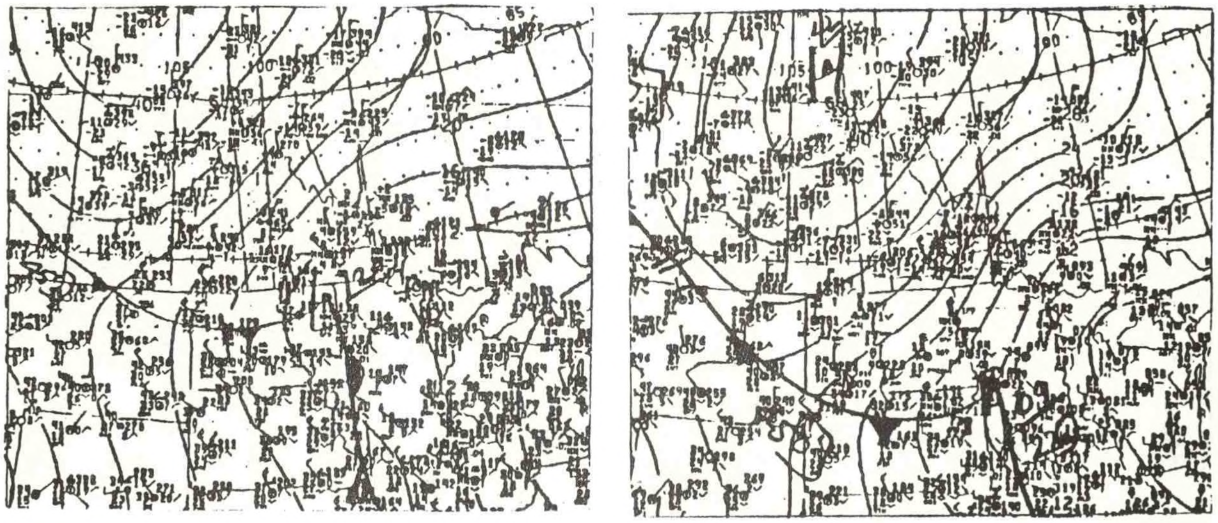
1200 GMT 4 Feb. 84 b.



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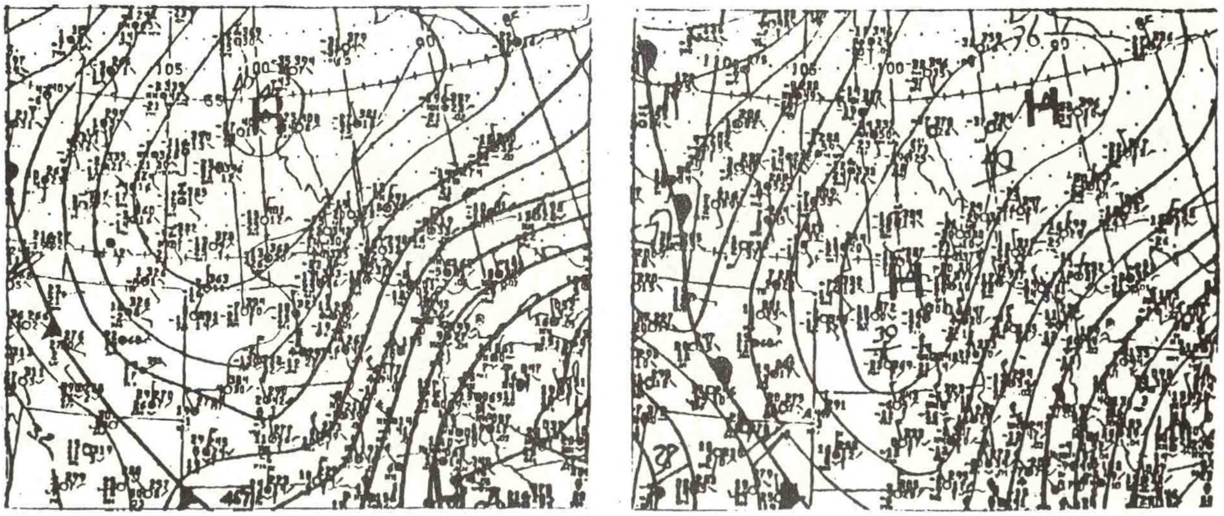
0000 GMT 5 Feb. 84 d.



0600 GMT 5 Feb. 84 e.

1200 GMT 5 Feb. 84 f.

Fig. 5. Surface charts with sea-level isobars. 0600 GMT Feb. 4 to 1200 GMT Feb. 5, 1984.

By 0000 GMT on February 6 the long wave trough had shifted to the east, upper winds diminished, and 500 mb heights had risen 7 to 18 dm over the northern plains. The center of the Arctic air mass was over the central plains with diminishing winds.

The synoptic situation described was similar in several ways to a "typical" blizzard over the northern plains. It also had several differences. According to a paper by Black (1971), the majority of blizzards are associated with an intense surface cyclone which originates in either Alberta or Colorado. With the surface cyclone is a deep, digging trough at 500 mb which moves east out of the Rockies onto the plains. In the blizzard under discussion there was only a weak surface low over the plains, the trough at 500 mb deepened over the plains and did not move east from the Rockies. High pressure plunging into the northern plains was the main surface feature.

The most dangerous aspect of this storm was the occurrence of very strong winds at and near the surface. What process was responsible for converting the potential energy to the kinetic energy evidenced by the strong winds? In looking at the upper air analyses during the storm it is apparent that strong subsidence of the cold air was occurring. At 500 mb temperatures warmed over North and South Dakota between 1200 GMT Feb. 4, and 0000 GMT Feb. 5, apparently due to adiabatic subsidence. (BIS warmed from -34 to -21°C and at HON the warming was from -35 to -26°C.) Upper level convergence may have been a factor, since the northern plains was an exit region at 300 mb (Fig. 3).

The subsidence can be observed on soundings (not shown) from the storm area at 1200 GMT Feb. 4 and 0000 GMT Feb. 5. The sounding at BIS at 1200 GMT already indicated warming temperatures and winds of over 100 knots down to 400 mb. By 0000 GMT the sinking at BIS was nearly complete with warmer temperatures down to 800 mb and winds of 70 knots down to 7000 ft above MSL. This process continued from north to south over the northern plains as the 300 mb jet and Arctic high moved south. The strong winds began at HON about 0000 GMT Feb. 5 and the sounding from HON at that time shows a sinking up to 600 mb. At that time wind speeds were 90 knots at 600 mb and 55 knots at 700 mb.

Cross sections were made from RAP to GRB for 1200 GMT Feb. 4 and 0000 GMT Feb. 5. At 1200 GMT the jet core was to the east of RAP with maximum winds of 130 knots at 280 mb. The sinking of the atmosphere below that part of the cross section can be seen by the close spacing and sloping of the isentropes between RAP and HON. (Fig. 6).

By 0000 GMT the jet was over HON with winds in excess of 50 knots just above the surface at RAP, very near the surface at HON and at 8000 ft above MSL at STC. The 300°K isentrope descended in the twelve hours between RAP and STC, indicative of the subsidence. At the same time the 100 knot wind area increased toward the surface.

In addition to the strong geostrophic winds present, there was a strong isallobaric wind due to the gradient of the pressure tendencies. The total wind including the contribution of the isallobaric wind is given by Haltiner and Martin (1957) as:

$$\mathbb{V} = \mathbb{V}_g - \frac{\alpha}{f^2} \nabla_H \left(\frac{\partial p}{\partial t} \right) \qquad (1)$$

Thus there is an additional component to the wind which is directed from pressure rises to pressure falls.

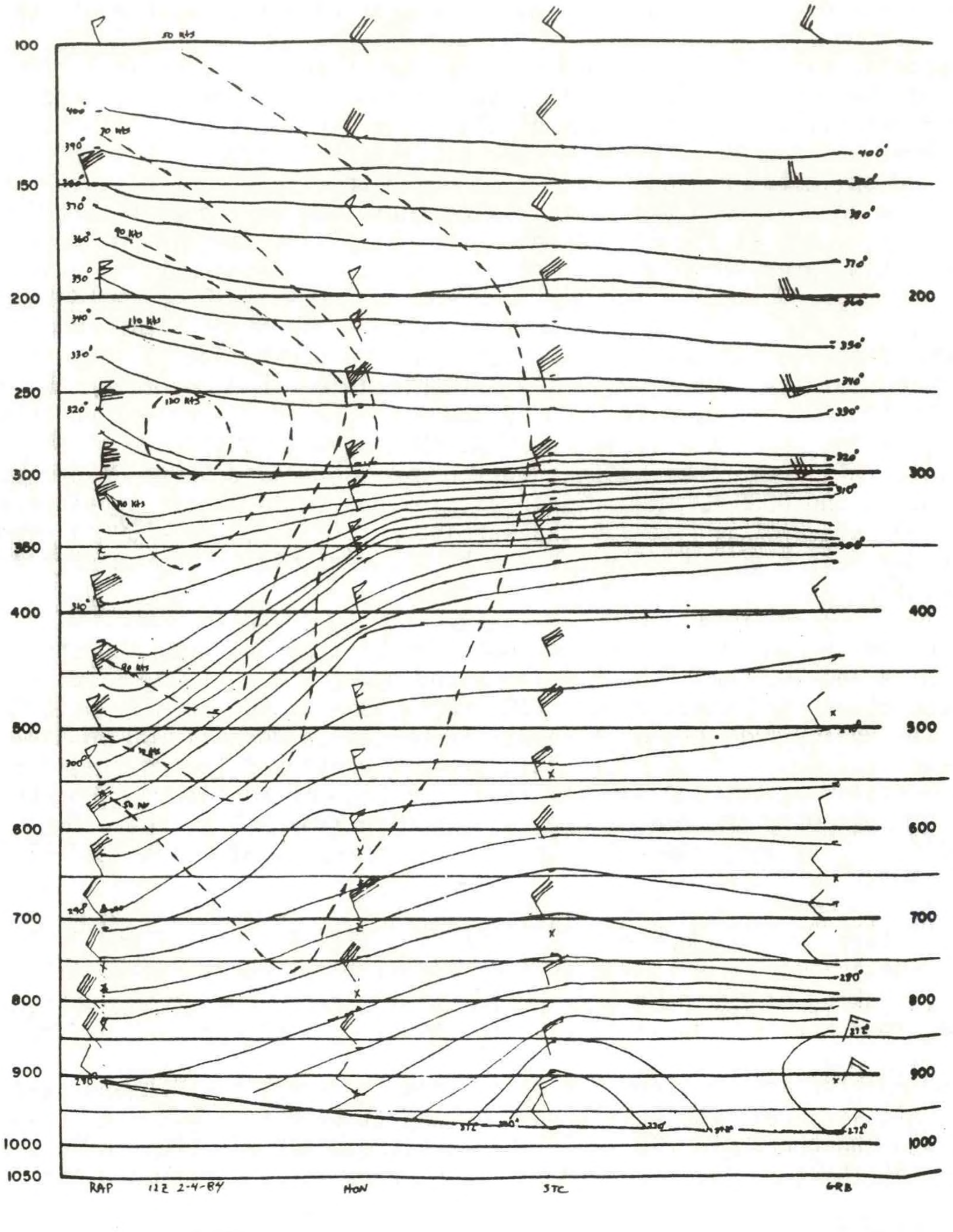


Fig. 6a. Cross section from RAP to GRB at 1200 GMT 4 Feb, 1984.

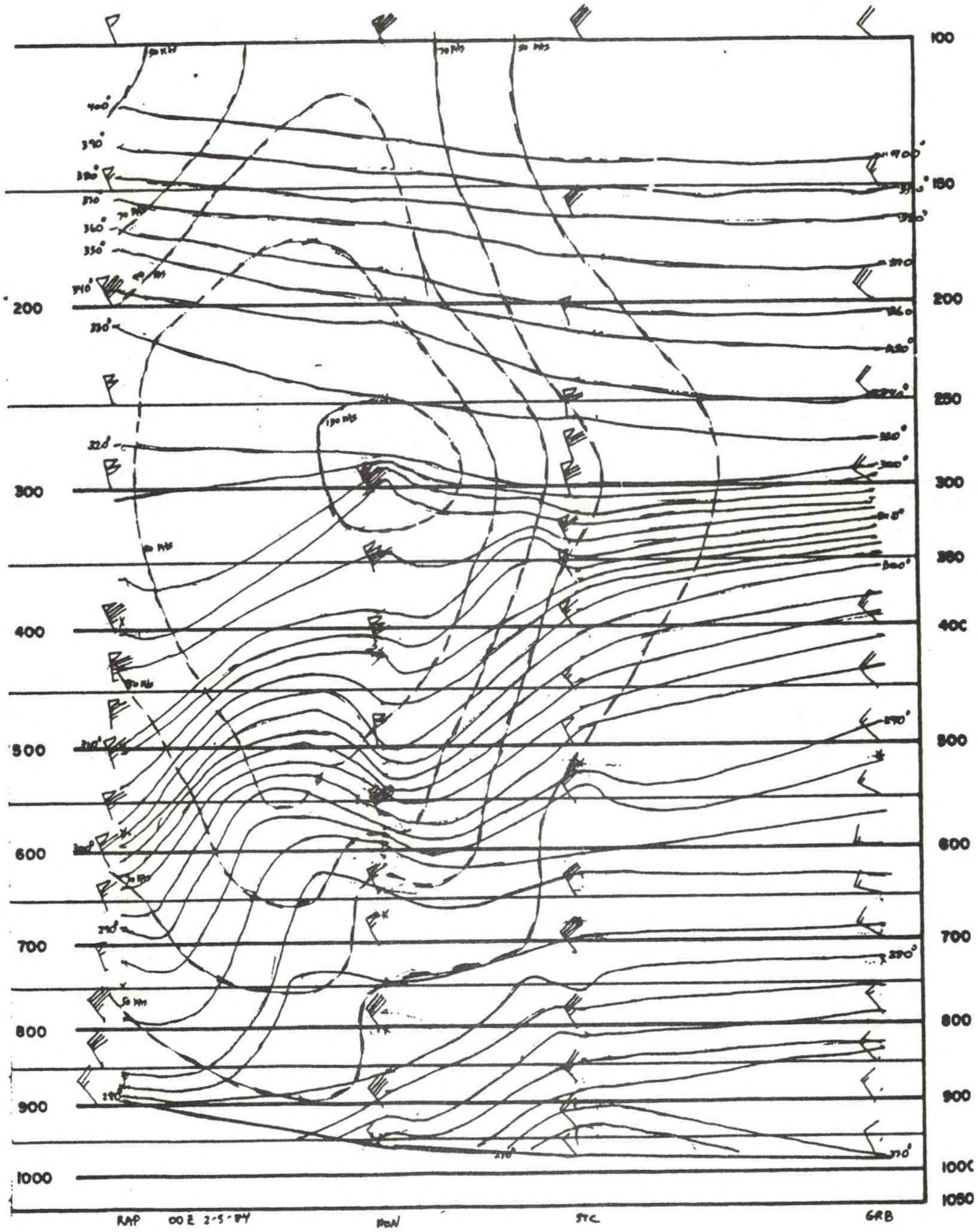


Fig. 6b. Cross section from RAP to GRB at 0000 GMT 5 Feb. 1984.

Two isallobaric charts at 1800 GMT Feb. 4 and 0000 GMT Feb. 5 are shown in Fig. 7. At 0000 GMT Feb. 5 the pressure tendency difference between FAR and AXN was 6.1 mb/3 hrs. Putting the observed values into the above equation we get for the isallobaric component a wind from the northwest of 58 knots.* Admittedly this is over a small area, but the magnitude is so large that it was no doubt an important contribution to the observed wind in this case. Forecasters should be on the alert for strong rise-fall couplets like this.

Another contributing factor to the large speeds was the vertical mixing of momentum which would allow stronger speeds aloft to be mixed down to the surface.

SUMMARY

The very strong winds and resulting ground blizzard of February 4 and 5, 1984 over parts of the northern plains were not readily obvious from data during the day on February 4. Expected strong winds of 20 to 30 mph during that time were actually 40 to 70 knots. The transfer of winds aloft to the surface and the isallobaric addition to the geostrophic winds created the observed winds at the surface. A closer look at the flow aloft and the changes that were taking place in the upper atmosphere along with a closer look at the isallobaric vector that was to occur would have made for a better forecast.

ACKNOWLEDGMENTS

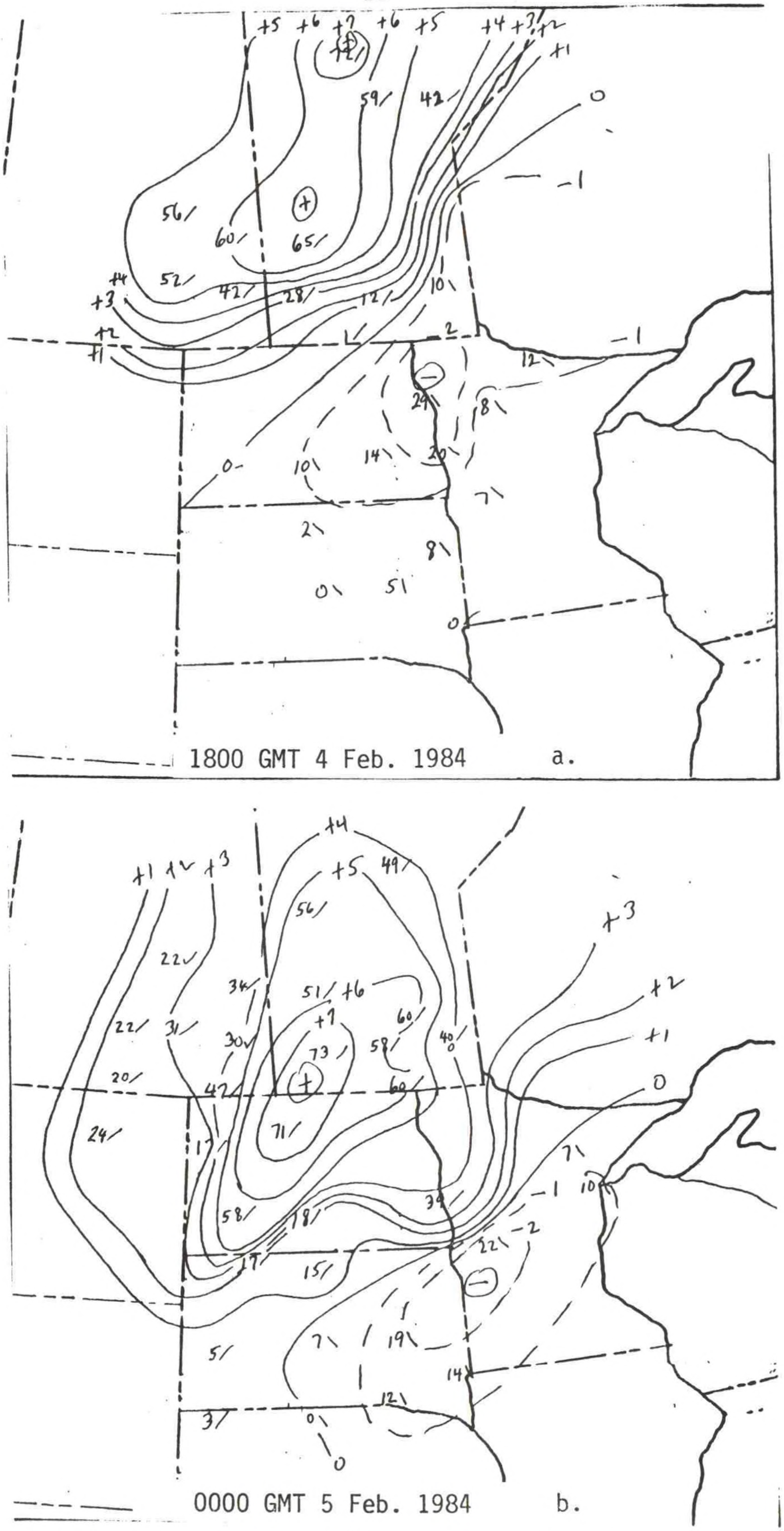
I would like to acknowledge the assistance of Mr. Rusty Kapela of the WSFO Sioux Falls, SD. Thanks is also extended to members of Weather Service Offices in the northern plains for their help.

REFERENCES

Black, R. E., 1971: A synoptic climatology of blizzards on the north-central plains of the United States. NOAA Technical Memorandum NWS CR-39, 33 pp.

Haltiner, G. J., and Frank L. Martin, 1957: Dynamic and Physical Meteorology. McGraw-Hill Book Company, 470 pp.

*As a matter of interest the isallobaric component can be determined from an ordinary geostrophic wind scale at 40° latitude. At this latitude the Coriolis parameter is nearly exactly the reciprocal of the number of seconds in three hours, so factors in (1) cancel. At 50° latitude the resulting speed from the scale should be multiplied by .79 and 30° latitude by 1.27 to account for the variation of f with latitude.



1800 GMT 4 Feb. 1984 a.

0000 GMT 5 Feb. 1984 b.

Fig. 7. Three-hour isallobars and pressure tendencies and traces at a) 1800 GMT 4 Feb. 1984 and b) 0000 GMT 5 Feb. 1984. Isopleths are whole millibars and station values are tenths of a millibar.

APPENDIX

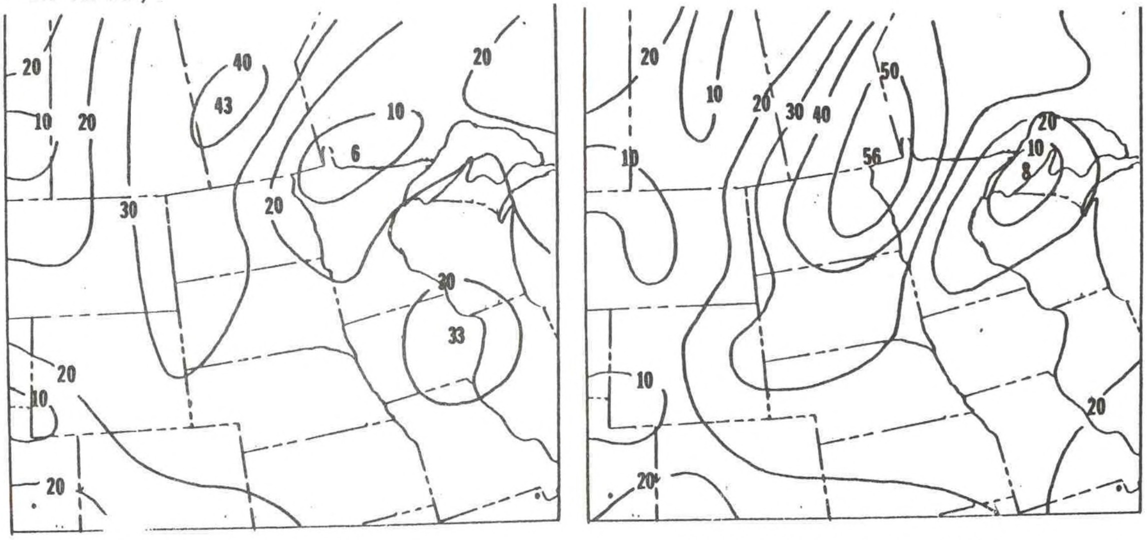
SURFACE GEOSTROPHIC WIND SPEEDS

A new version of the surface geostrophic wind chart run at the National Meteorological Center, but developed in the Central Region Scientific Services Division, was run for this case and isotachs of geostrophic wind speeds for four times from 1800 GMT Feb. 4 to 1200 GMT Feb. 5, are shown in Fig. A1a - d.

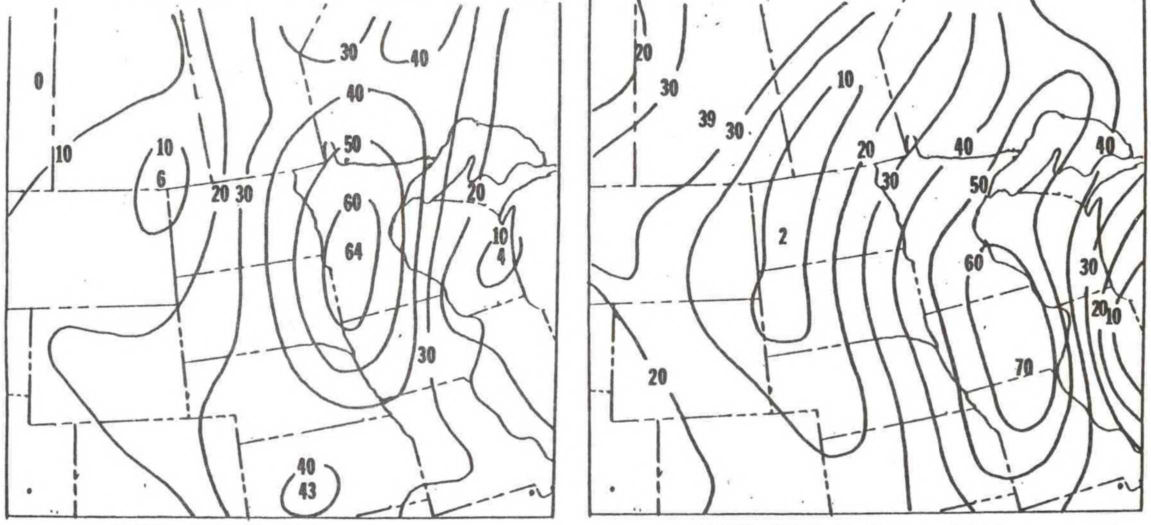
It will be seen that a 43 knot maximum over Manitoba at 1800 GMT increased to 56 knots at 0000 GMT as it moved south-southeastward. At 0600 GMT a maximum of 64 knots was over western Minnesota. The last chart in the series shows a 70 knot maximum over southern Iowa.

It would appear that winds were highly ageostrophic during the afternoon of Feb. 4 just behind the cold front, probably mainly due to the very intense isallobaric gradient with the front, as mentioned in the paper.

The geostrophic wind speeds shown here were 10 to 15 knots greater than those shown by the operational (at that time) surface geostrophic wind chart (9AM on AFOS).



1800 GMT 4 Feb. 1984 a. 0000 GMT 5 Feb. 1984 b.



0600 GMT 5 Feb. 1984 c. 1200 GMT 5 Feb. 1984 d.

Fig. A1. Isotachs of surface geostrophic winds from the new (see TPB 341) version of the program used at the National Meteorological Center.

CENTRAL REGION TECH MEMOS

(continued from front inside cover)

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NWS CR 72	The Standard SHEF Decoder Version 1.1. Geoffrey M. Bonnin. August 1984.

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