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OROGRAPHIC LIFT IN A SEEMINGLY FLAT ENVIRONMENT

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1. Introduction

Most meteorologists relate orographic lift and thunderstorm intensification with terrain such as the Rockies, Sierras, or Black Hills, and never with the wide open plains. However, flat as they may seem, the Plains have small abrupt changes in elevation that do have an effect on convective weather.

2. Topography of Northeast South Dakota

The predominant topographic feature in northeast South Dakota is an ancient glacial lake bed, now drained by the James River. It extends from the North Dakota/South Dakota border, north of Aberdeen, south to around Mitchell, about 150 miles in length. Its width is about 50 miles in the middle tapering to around 20 miles at its north and south ends. This ancient lake is bounded on its east and west flanks by glacial moraines which rise 400 to 800 feet above the lake bed. The extreme northeastern portion of South Dakota, east of the eastern moraine, is at a lower elevation than the ancient lake bed/James River Valley. West of the western moraine is the Missouri River Valley (Figs. 1a and 1b).

3. Weather Situation

The morning of July 28, 1989 dawned with a surface low north of Lake Superior and a quasi-stationary front curving southwest through Lake Superior, Wisconsin, Iowa, Nebraska, Wyoming, and eastern Montana north to a surface low in southern Saskatchewan. At 500 mb, a ridge extended south from Manitoba through North Dakota, South Dakota, and into Nebraska, and a short wave was moving east through Montana.

Thunderstorms developed by 2115Z in northeast North Dakota ahead of the 500 mb short wave now located in western North Dakota, and extended southwest

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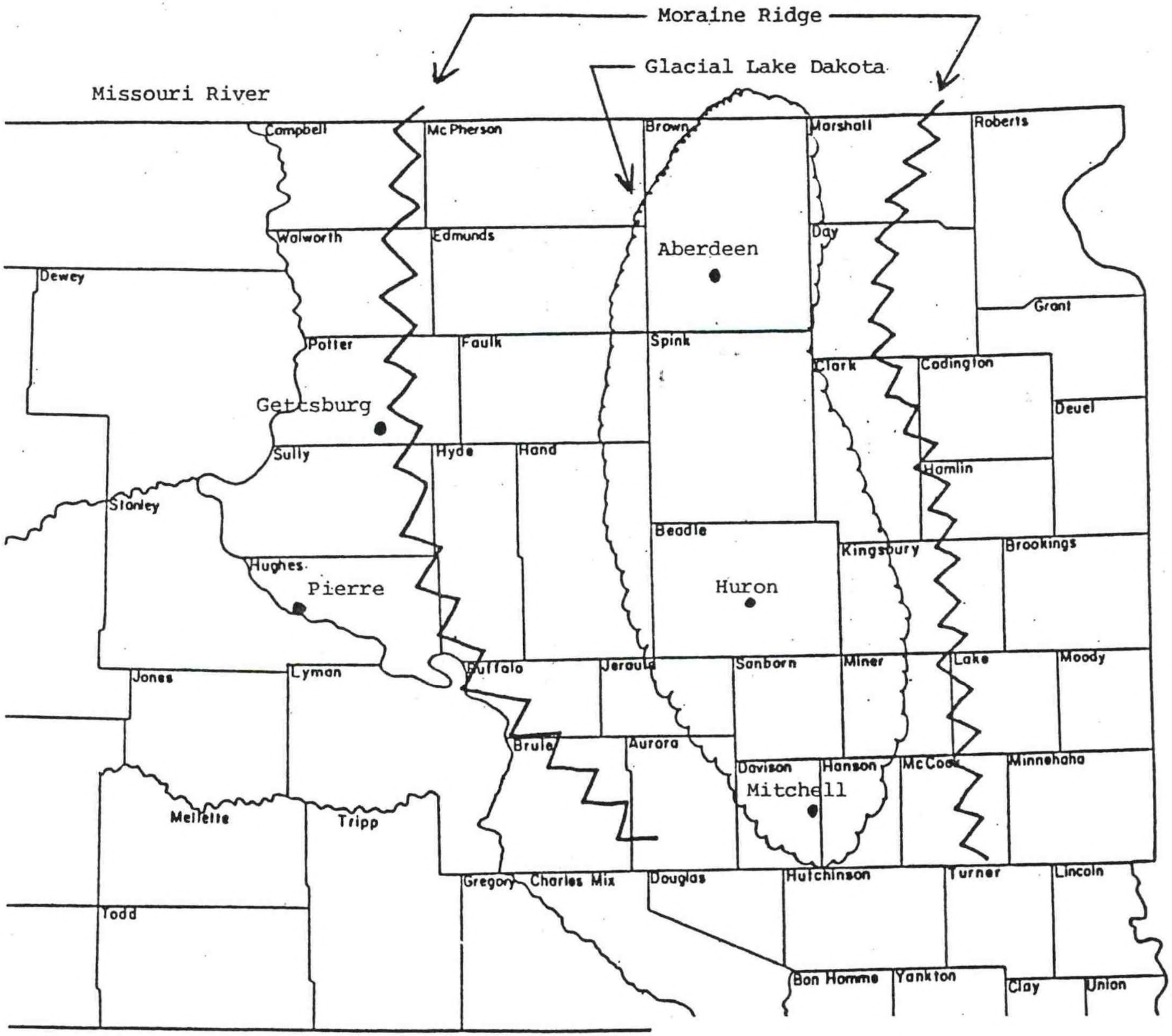

Figure 1a. Predominant topographic features of northeastern South Dakota.

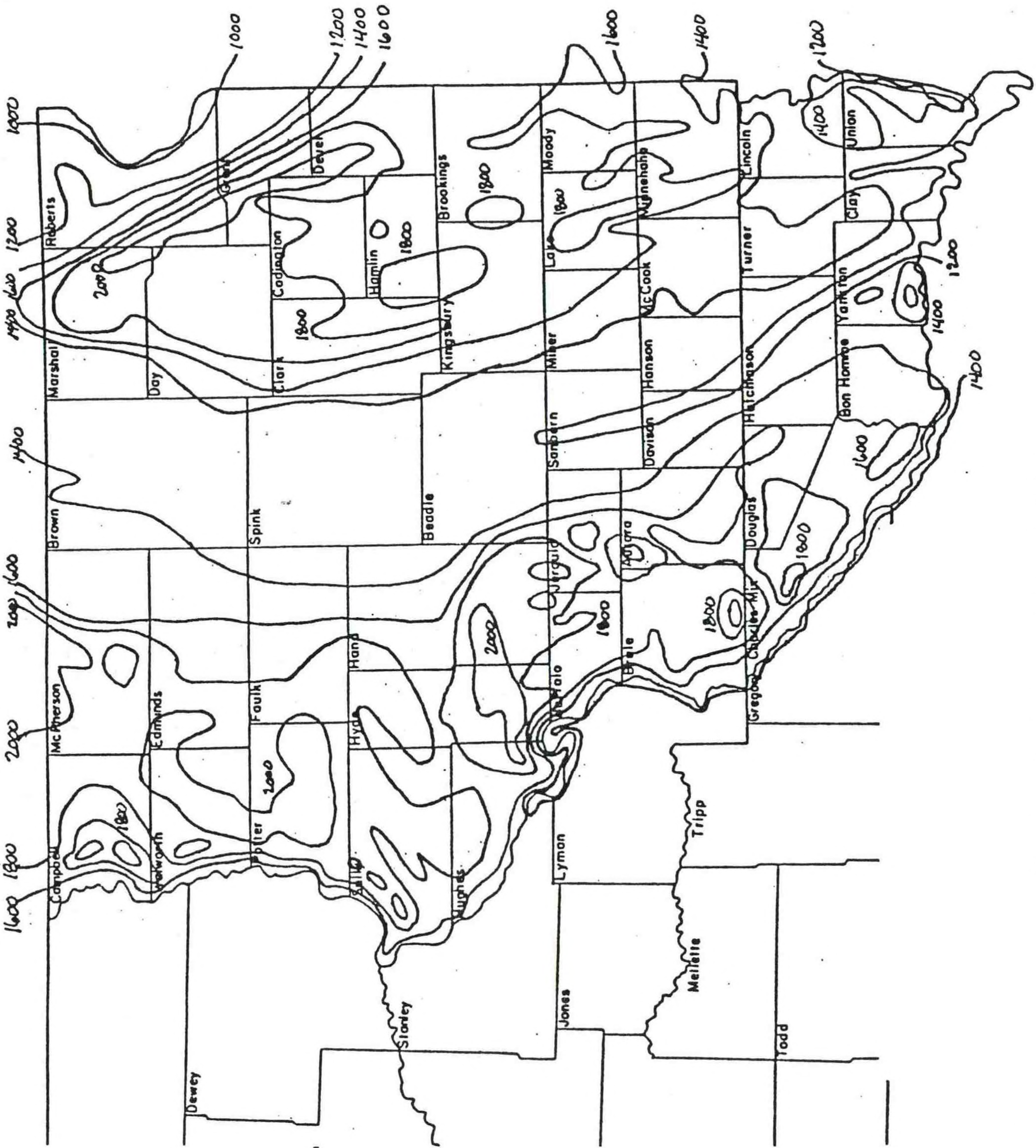

Figure 1b. Topographic map of northeastern South Dakota.

through central North Dakota and into central South Dakota. The thunderstorms formed near the surface front, which was positioned along the North Dakota/South Dakota border. Hot moist air occupied South Dakota with cooler air found in North Dakota. Increasing southeast surface winds over South Dakota enhanced the convergence of hot moist air and the cooler air of North Dakota, focusing thunderstorm development in north central and northeast South Dakota, south central and eastern North Dakota, and northwest Minnesota.

A check of the Severe Thunderstorm Key Parameters (Maddox and Doswell, 1982) against the 00Z, July 29, 1989 Huron, South Dakota sounding (Fig. 2) revealed the following classifications:

(1)	500 mb vorticity advection	weak to moderate
(2)	Stability - Totals Index	weak to moderate
(3)	500 mb wind speed	weak
(4)	300-200 mb wind speed	weak
(5)	850 mb wind speed	weak
(6)	850 mb dew point	moderate to strong
(7)	850 mb temperature ridge location	moderate
(8)	700 mb winds	weak
(9)	12 hour surface pressure fall	strong
(10)	500 mb height change	weak
(11)	Surface pressure over threat area	weak to moderate
(12)	Surface dew point	moderate

At 00Z, July 29, 1989, Huron's Lifted Index was minus 2 and, using SELS' method of calculation, the index increased to minus 7 in north central South Dakota. This, coupled with the pressure fall/rise pattern over north central and northeast South Dakota, prompted SELS to anticipate severe thunderstorm development between 00Z and 02Z over these sections of the state.

The first severe thunderstorm warning was issued at 0023Z, July 29, 1989, for northeast South Dakota and included southwest Marshall and northwest Day Counties. The warning verified with large hail reported in southwest Marshall County. A second warning was issued at 0129Z for the same area. Golfball size hail and two to three inches of rain fell during the warning period. A third warning was then issued for the same area at 0230Z. While no severe weather was reported, two inches of rain fell in the warned area in a 20 minute time period (Figs. 3 through 7).

As the preceding weather was occurring, SELS statements indicated warm advection and instability were still favorable for severe thunderstorm development, but wind fields at all levels were relatively weak limiting vertical shear.

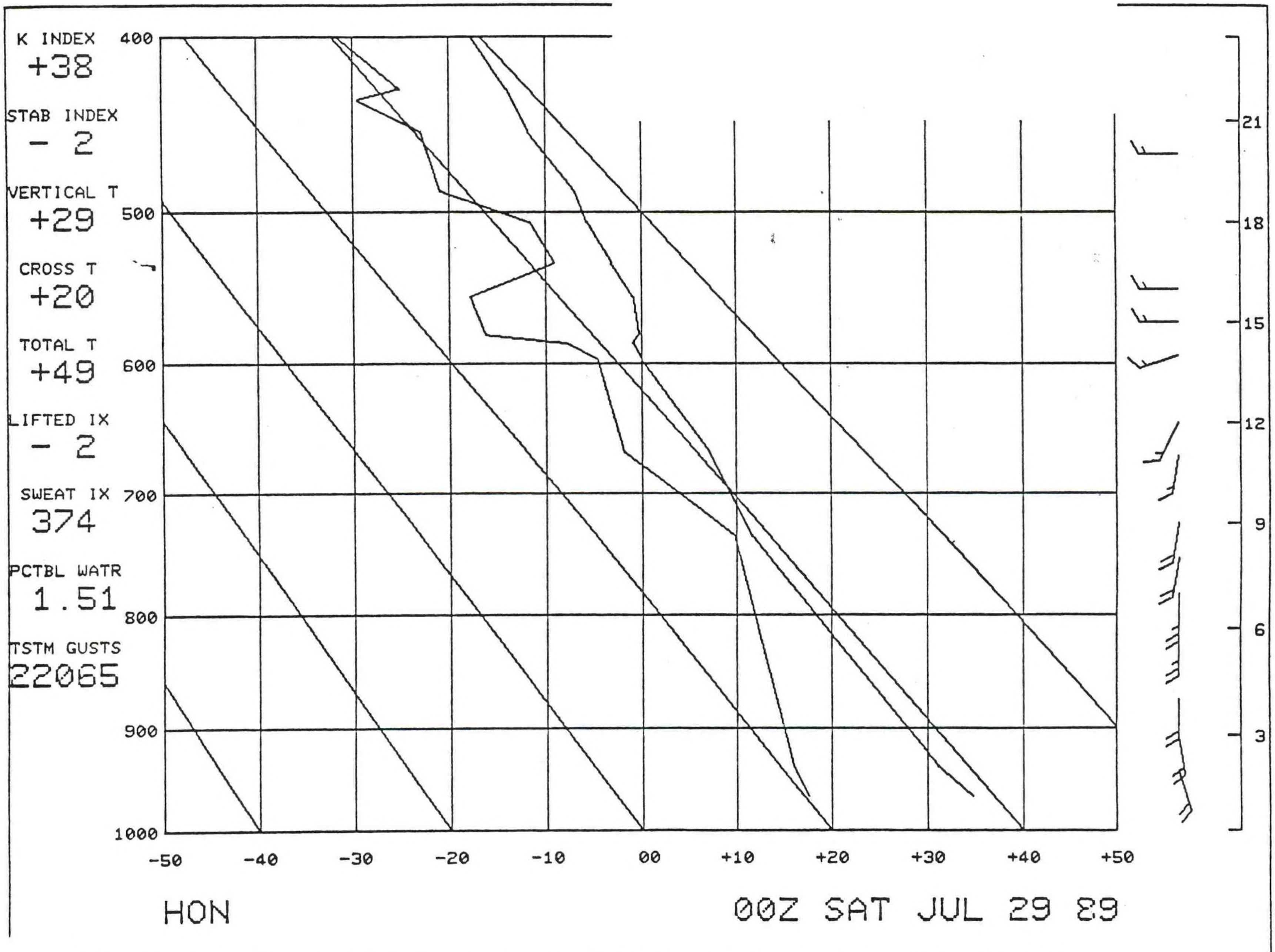

Figure 2. Sounding analysis for Huron, South Dakota for 00Z Saturday, July 29, 1989.

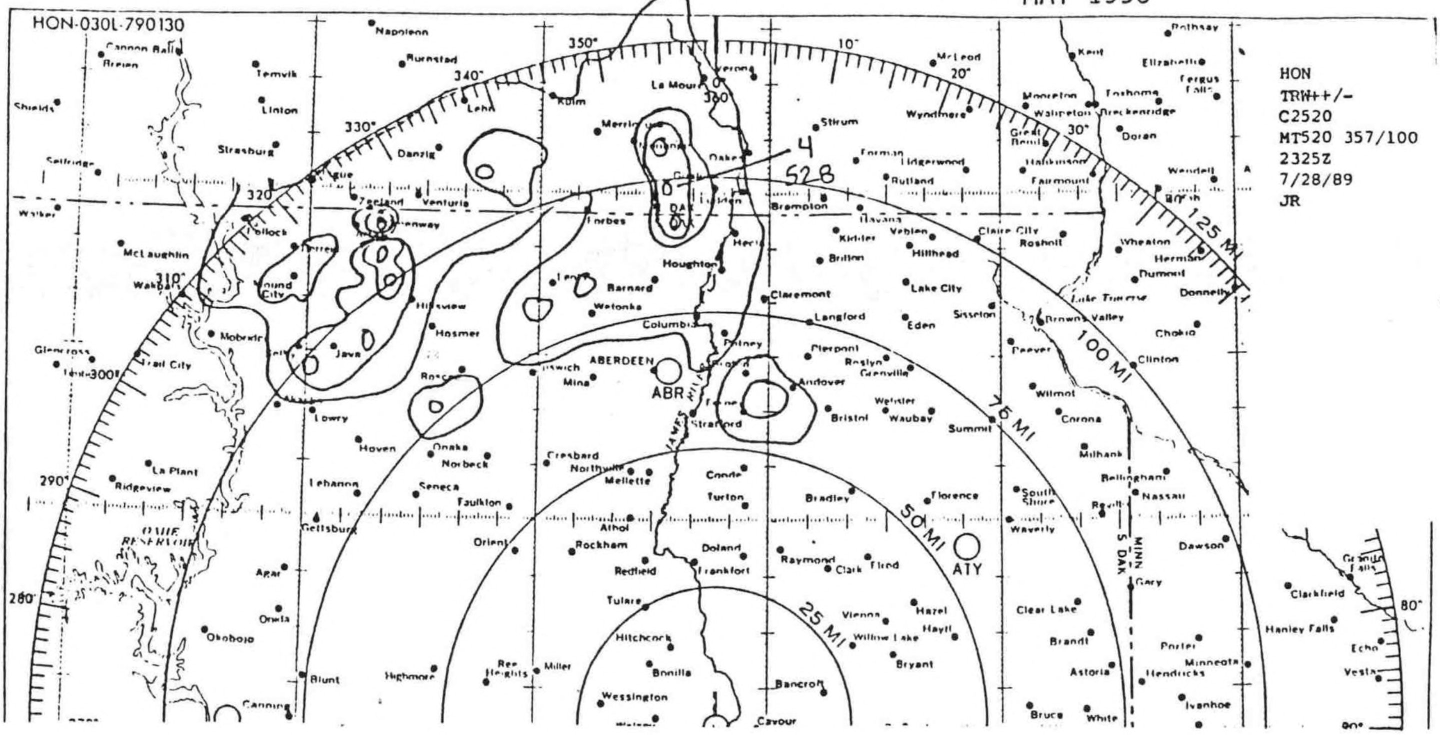

Figure 3. Huron radar chart for 2335Z, July 28, 1989.

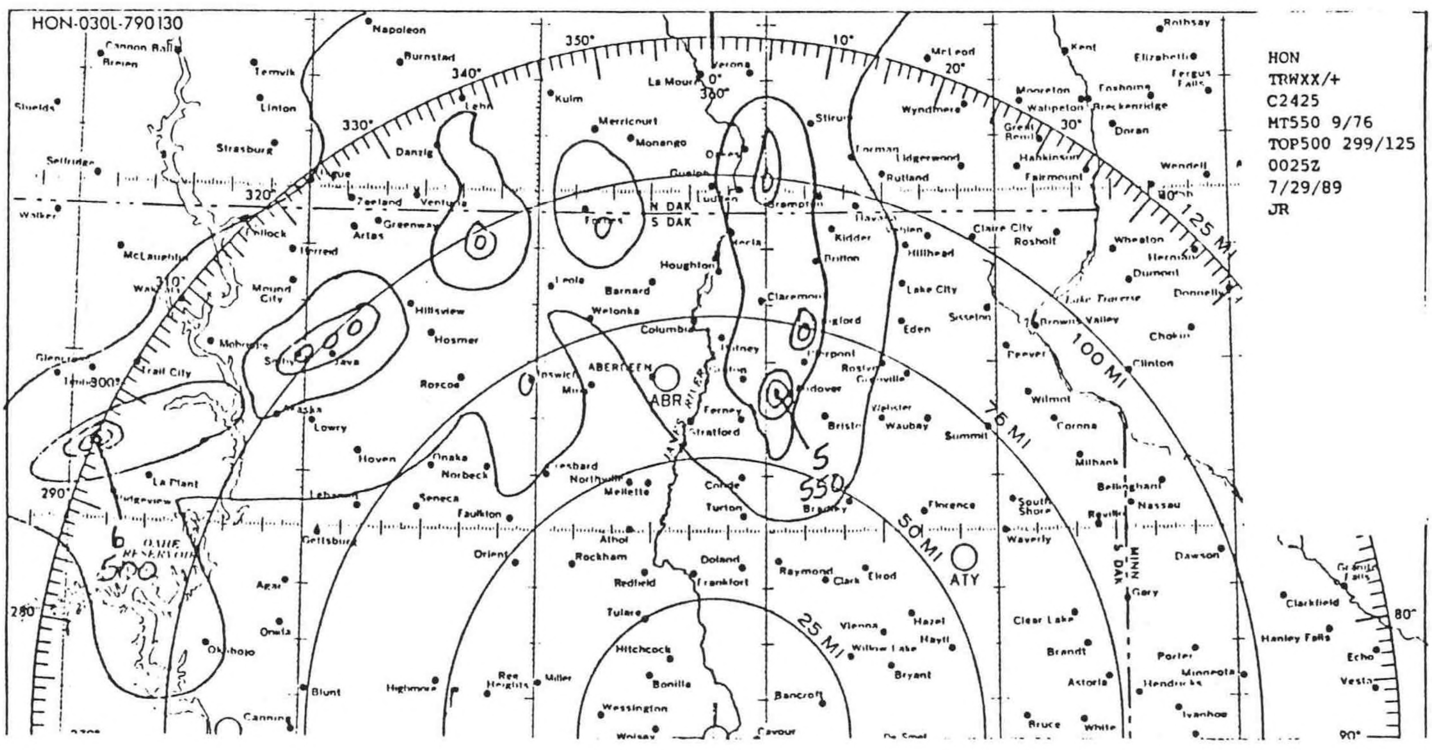

Figure 4. Huron radar chart for 0025Z, July 29, 1989.

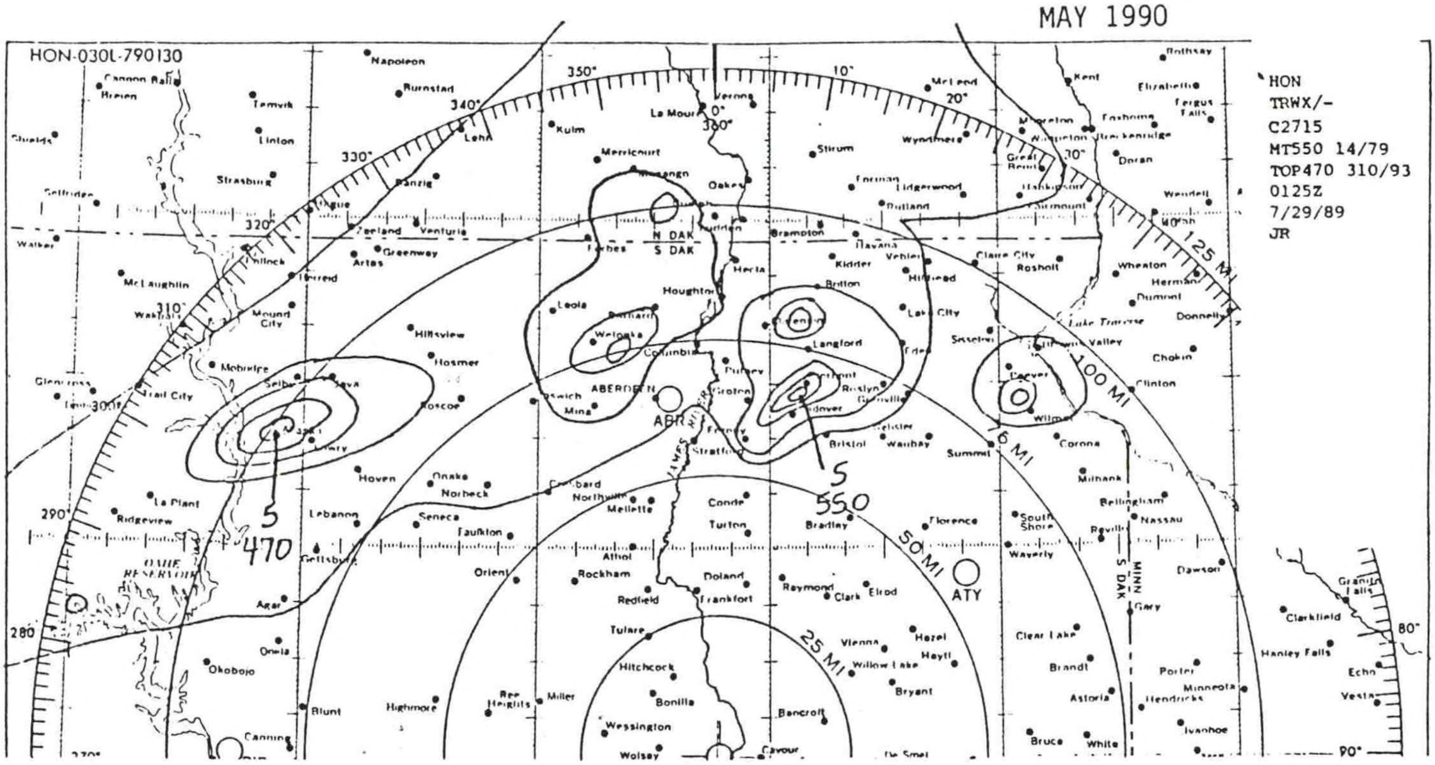

Figure 5. Huron radar chart for 0125Z, July 29, 1989.

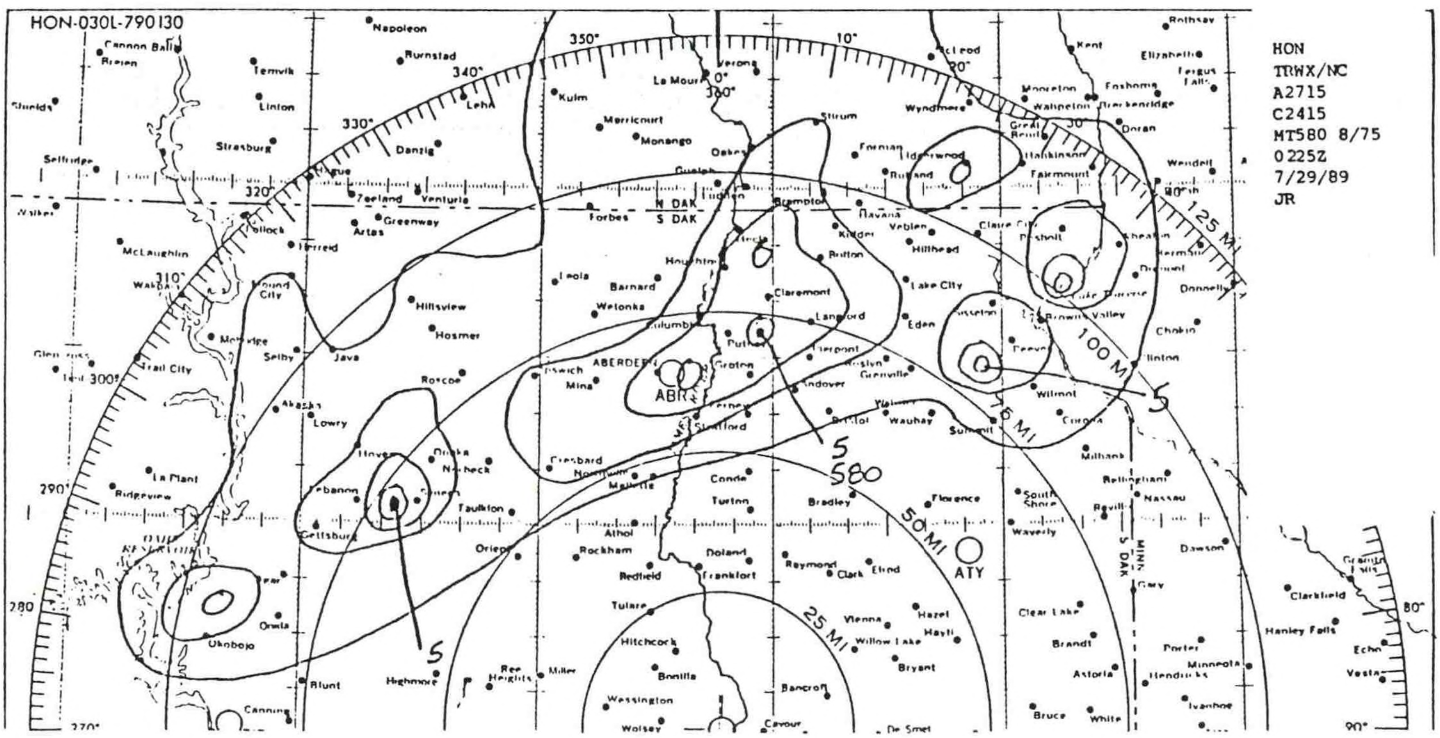

Figure 6. Huron radar chart for 0225Z, July 29, 1989.

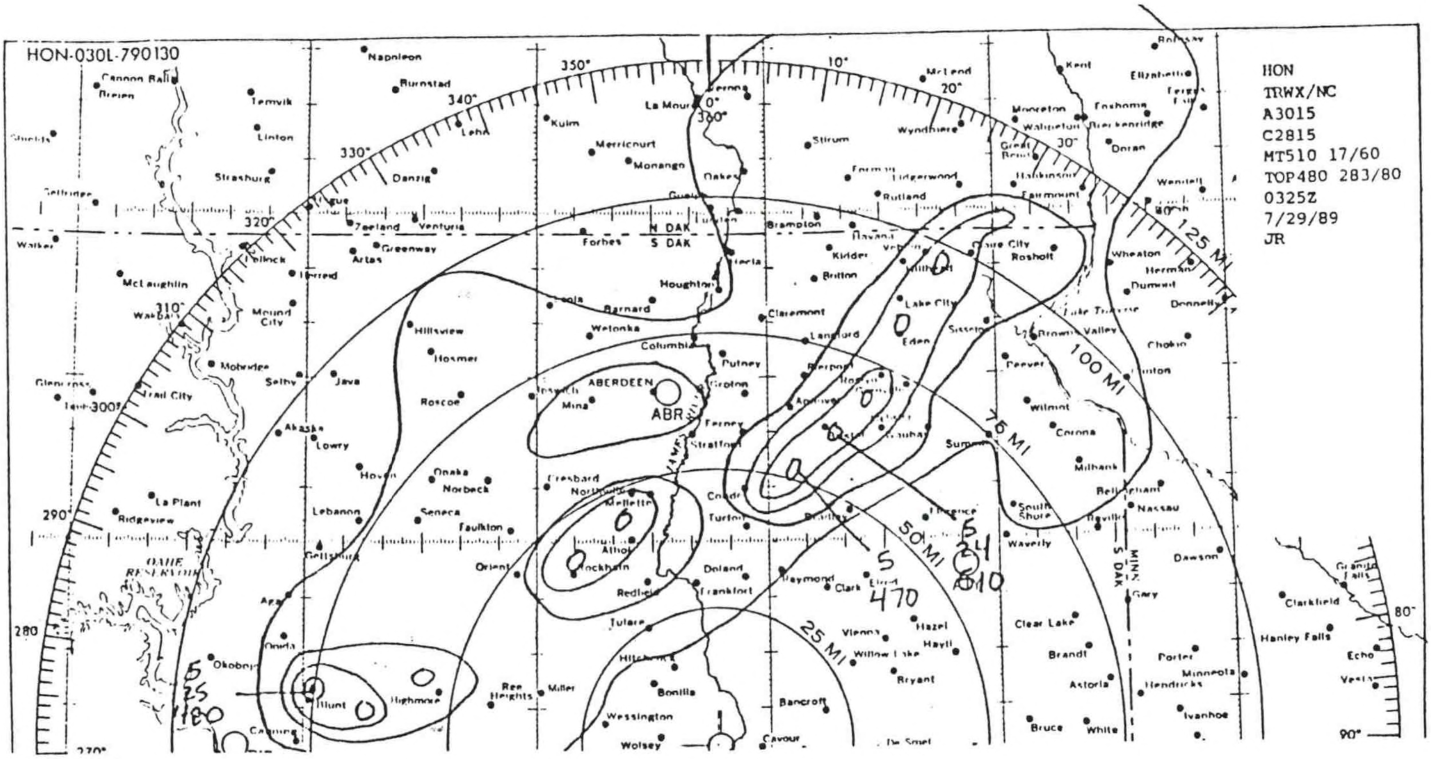

Figure 7. Huron radar chart for 0325Z, July 29, 1989.

4. Orographic Lift

The topography of northeast South Dakota, as discussed in section two of this paper, had a dramatic effect on thunderstorm development. It is believed that the preceding weather events were, in part, caused by orographic lifting over the glacial moraine east of Aberdeen. The author has observed, on many occasions, that whenever the mid-level steering flow is west to east individual thunderstorms developing to the west of this moraine tend to dissipate on its eastern boundary, a span of about 50 miles. A close examination of the moraine shows a 550 foot rise in 15 miles from the Brown/Day, Brown/Marshall County lines east, with a equal or greater drop to the east of the moraine. Kapela (1985) briefly highlighted the glacial moraines and their general effect on regional weather in his lecture on "Terrain Induced Mesoscale Weather Phenomena in South Dakota." The effect on convective activity has also been witnessed by weather radar operators in Huron.

A reexamination of Figures 3 through 7 will clearly show the thunderstorm development and dissipation in relation to the moraine. In fact, the orographic effect occurs along both moraines bounding the ancient glacial lake bed. In the preceding weather event, a developing thunderstorm was observed 55 miles northeast of Pierre, at Gettysburg, by both satellite and radar (Figs. 4 through 6). This thunderstorm intensified as it moved west to east into the moraine where the elevation rises about 700 feet in 20 miles. The thunderstorm decreased in intensity as it moved from a DVIP Level 5 at Gettysburg to a Level 3 forty-five miles northwest of Huron.

A second episode of thunderstorms occurred in the same general area as the first. Figures 8 through 11 illustrate the thunderstorm development on August 21, 1989 as they moved southwest to northeast over the eastern moraine. Note again the rapid dissipation of the thunderstorms as they crossed the ridge axis.

5. Comments and Conclusions

Experiences suggest and these case studies support the notion that, regardless of severity, thunderstorms can be expected to intensify as they move "upslope" over one of the glacial moraines on either side of the James River Valley of South Dakota. Likewise, weakening can be expected as the storm moves east of the moraine ridge axis. Any continued thunderstorm development east of the moraines, and in the vicinity of previous thunderstorm activity, will have the potential to produce heavy rainfall and possible flooding. When the thunderstorm decreases in intensity east of the moraine ridge axis, gusty winds with the decaying thunderstorm can be expected.

The main point of this paper is to suggest that thunderstorm development and intensity can be affected by the glacial moraines of eastern South Dakota. Forecasters need to be alert to the subtle influences of topography when evaluating any weather situation.

6. References

Kapela, A. F., 1985: Terrain Induced Mesoscale Weather Phenomena in South Dakota. Unpublished seminar notes available from WSFO Sioux Falls, SD.

Maddox, R. A., and C. A. Doswell III, 1982: Forecasting Severe Thunderstorms: A Brief Evaluation of Accepted Techniques. Preprints, 12th Conference on Severe Local Storms (San Antonio), Amer. Meteor. Soc., Boston, MA, 92-95.

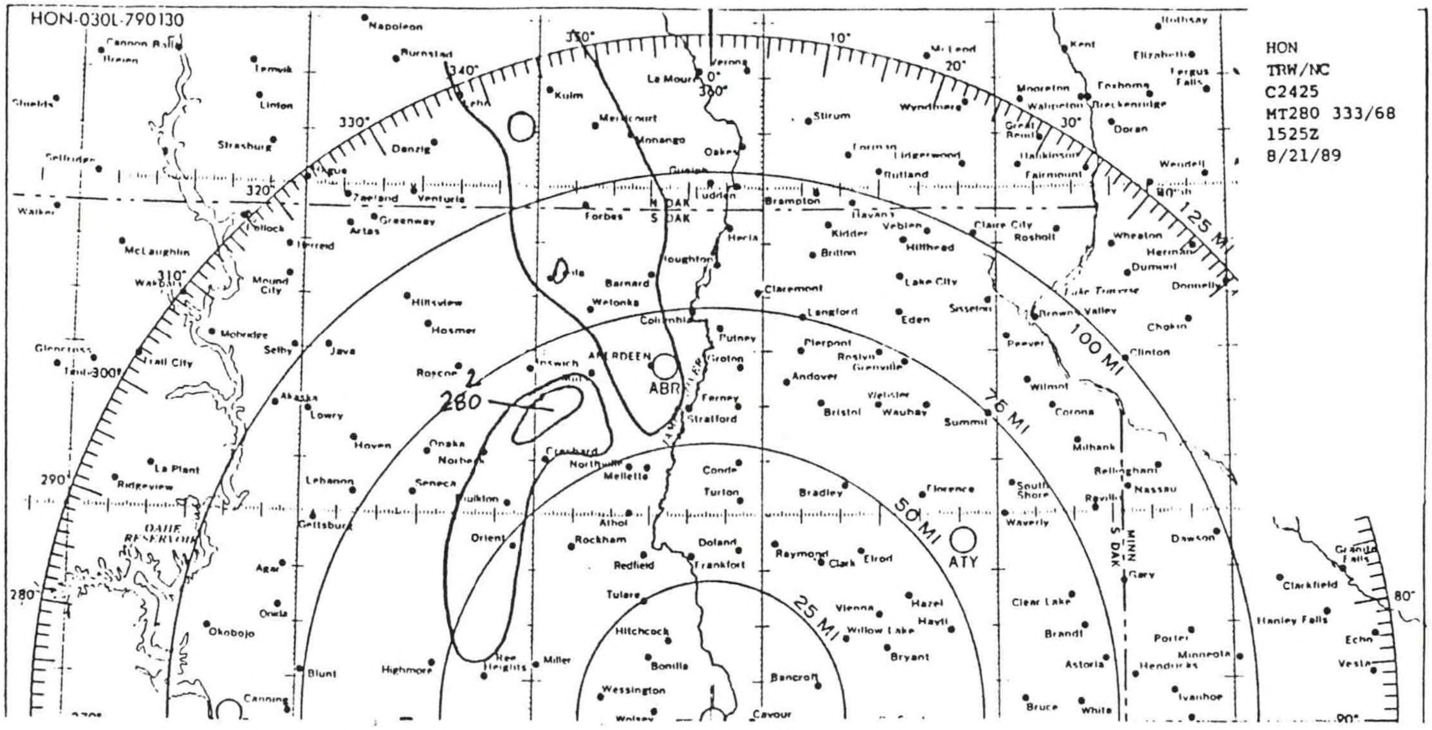

Figure 8. Huron radar chart for 1525Z, August 21, 1989.

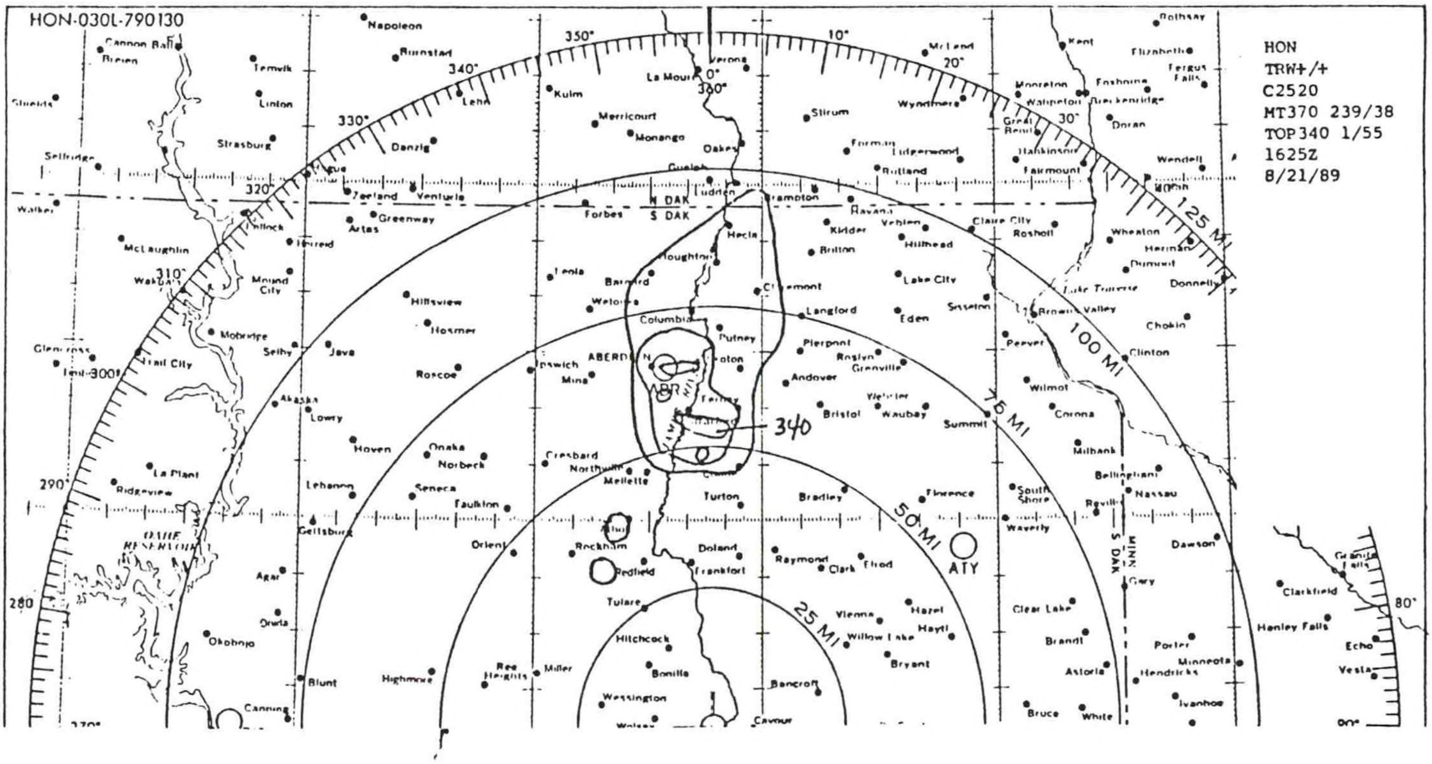

Figure 9. Huron radar chart for 1625Z, August 21, 1989.

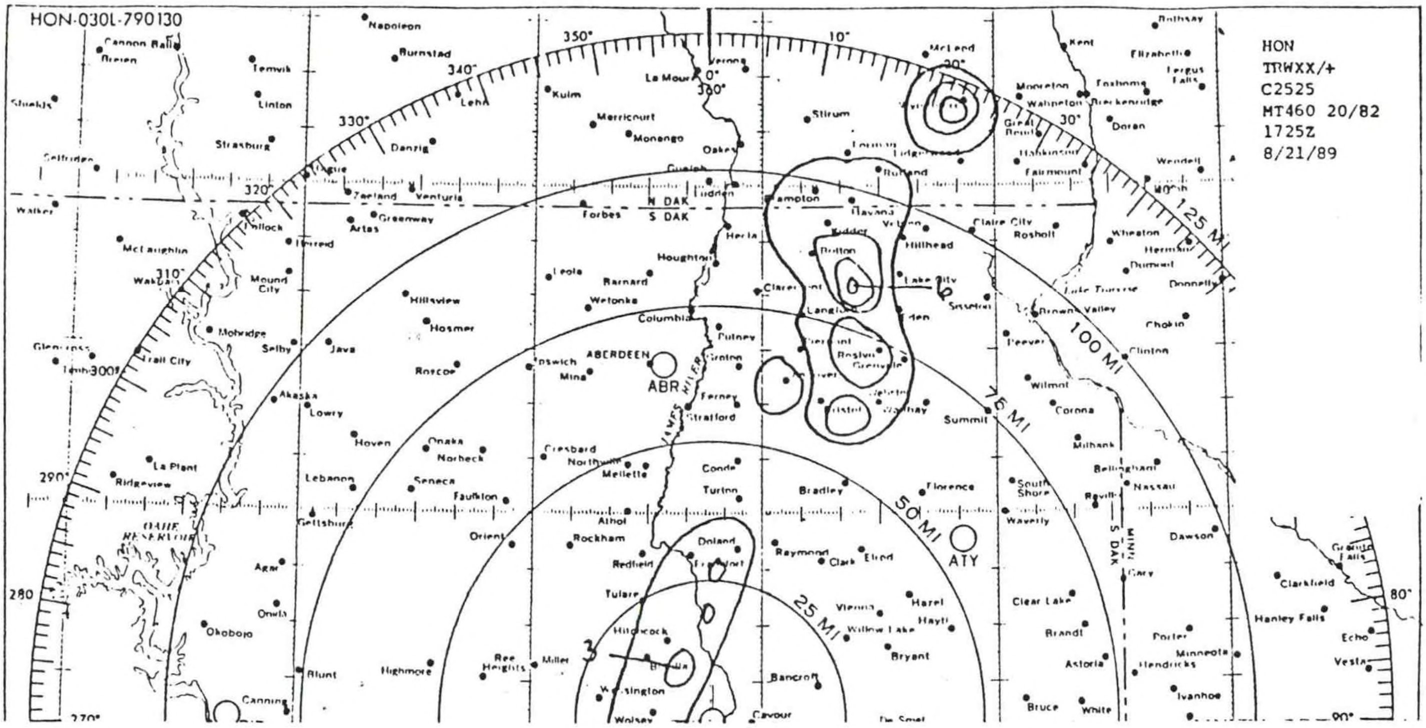

Figure 10. Huron radar chart for 1725Z, August 21, 1989.

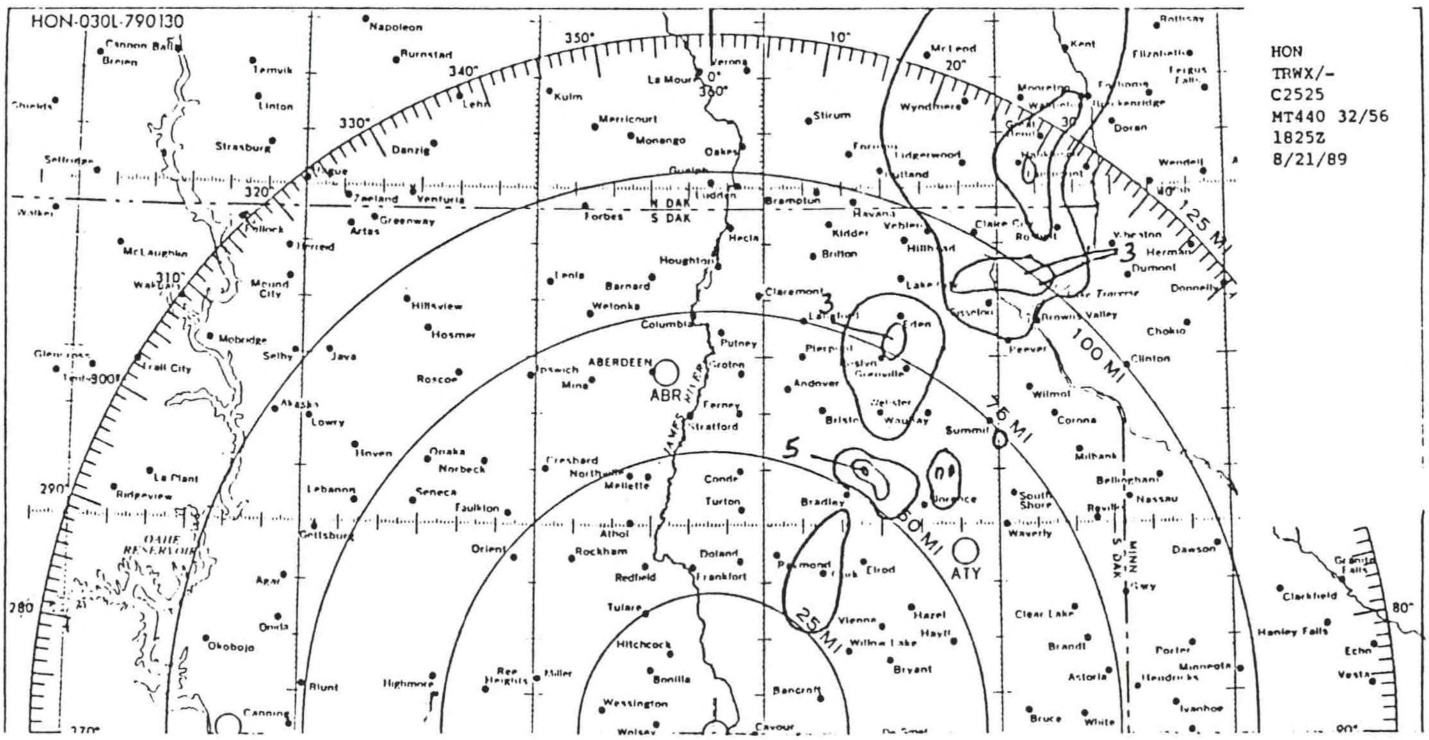

Figure 11. Huron radar chart for 1825Z, August 21, 1989.