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CENTRAL REGION APPLIED RESEARCH PAPERS 88-1 THROUGH 88-7

National Weather Service Central Region
Scientific Services Division
Kansas City, Missouri

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UNITED STATES DEPARTMENT OF COMMERCE
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FOREWORD

This is the first issuance of an ongoing effort to compile and distribute Central Region Applied Research Papers (CRARP). This issue reflects only a small part of the on-station research efforts that currently are being performed by the operational personnel of the Central Region. It is clear as the National Weather Service becomes more involved in using high technology to sample, describe and forecast the weather that a medium be available that will encourage the transfer of useful knowledge and skills to other NWS offices.

Oftentimes on-station research efforts and case studies are only circulated locally due to the time and effort required to put the study into "publishable" form (both text and graphics). This CRARP compilation is a vehicle to distribute scientific and operational information to other NWS offices without forcing the authors to perform the time-consuming work typically required to "pretty up" the figures.

CENTRAL REGION APPLIED RESEARCH PAPERS

Table of Contents

CRH SSD
CRARP 88-1

CENTRAL REGION APPLIED RESEARCH PAPER 88-1

THE CHEYENNE WINDSTORM THAT NEVER CAME — ANOTHER LESSON IN REAL TIME ANALYSIS

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1. Introduction

On Monday, February 8, 1988, a high wind warning was in effect for Cheyenne and much of the wind prone areas of southeast Wyoming. The warning was issued by the day shift from the previous day. The warning went into effect at 12:01 a.m. MST Monday. Even though there were two episodes of relatively strong winds, high wind criteria was not reached at Cheyenne (sustained winds of 40 mph with gusts to 58 mph for an extended period of time). One peak gust from the west of 35 mph occurred at 4:00 a.m. MST and another gust of 41 mph was at 2:00 p.m. MST. Furthermore, around 8:00 a.m. MST, the winds at WSFO Cheyenne were nearly calm.

All numerical guidance and observations upstream (at all levels of the troposphere) from Wyoming on Sunday strongly suggested a high wind event for Cheyenne was going to occur the next day. Included in this guidance was information from a high wind program developed at WSFO Cheyenne. The program is run twice daily on AFOS, and on Sunday evening the program said "WARN" for Monday.

The February 7 warning did not verify! In fact, during the office map discussion at noon time Monday, everyone asked, "Why didn't the wind blow?" As a result, this paper was written to offer an explanation for the forecast "bust." The main point is to illustrate the usefulness that real time monitoring of the troposphere can offer as a short temporal scale forecasting tool (less than 12 hours). Also, some discussion of the "synoptics" of front range Rocky Mountain high wind events is given.

2. Discussion

Figure 1 is the 500 mb analysis for 12Z (5:00 a.m. MST) Monday, February 8, 1988. As many forecasters along the front range of the Rockies know, this type of west-northwest to northwest 500 mb flow is a favorable synoptic scale regime for high wind events. Careful inspection of the velocity, temperature and height tendency data indicates there are two separate maximums in cyclonic relative vorticity, one near southwest Idaho and the other over northwest Montana. Additionally, the magnitude of the velocity field upstream from these

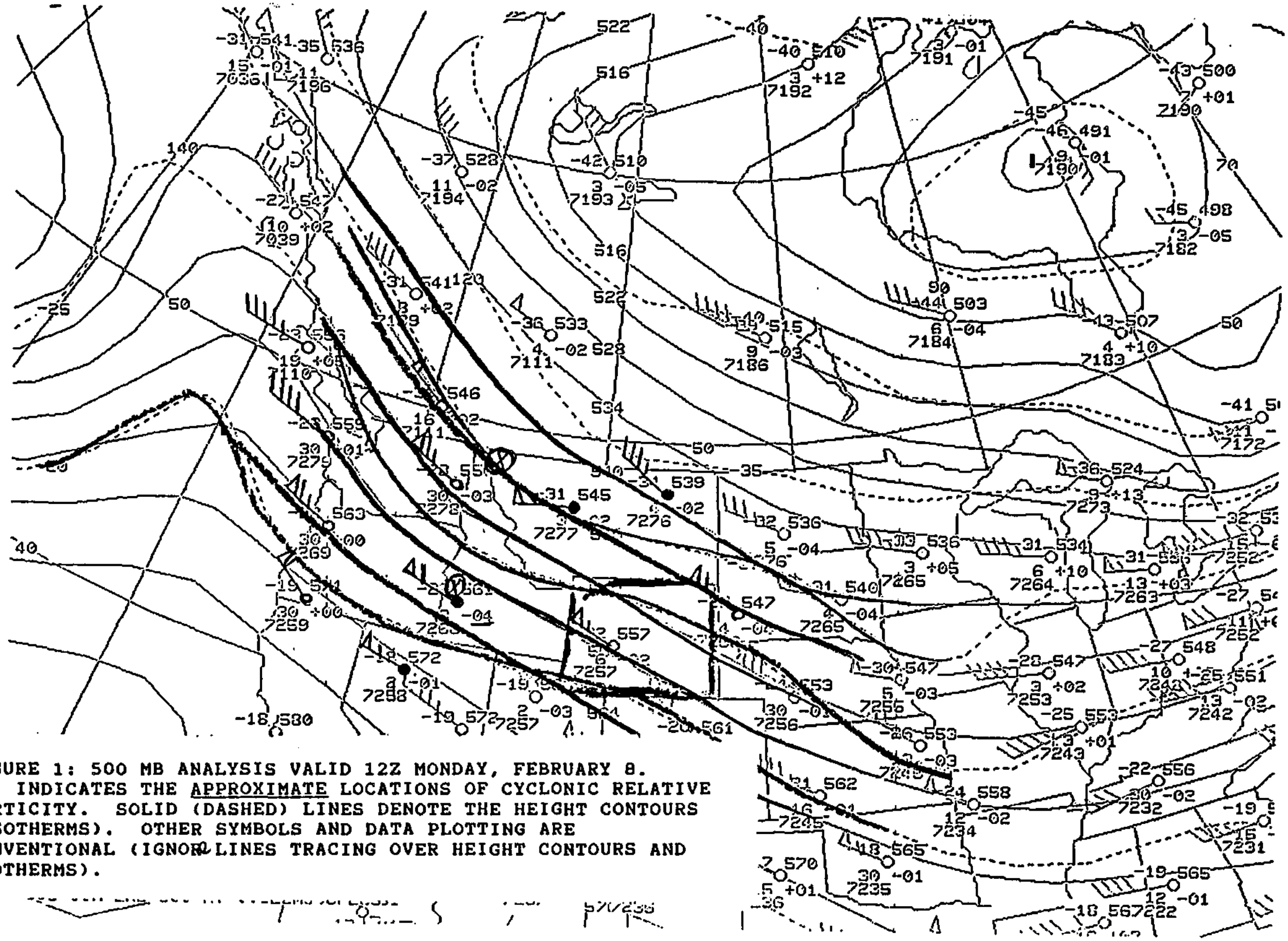

FIGURE 1: 500 MB ANALYSIS VALID 12Z MONDAY, FEBRUARY 8. "X" INDICATES THE <u>APPROXIMATE</u> LOCATIONS OF CYCLONIC RELATIVE VORTICITY. SOLID (DASHED) LINES DENOTE THE HEIGHT CONTOURS (ISOTHERMS). OTHER SYMBOLS AND DATA PLOTTING ARE CONVENTIONAL (IGNORE LINES TRACING OVER HEIGHT CONTOURS AND ISOTHERMS).

features is slightly greater. This suggests that cyclonic vorticity was advecting into the bases of these two short waves which supported continued digging of the troughs.

Figures 2 and 3 are the 24-hour Nested Grid Model (NGM) forecasts valid 12Z Monday (these were the same numerical forecast guidance products used to issue the high wind warning for parts of southeast Wyoming on Sunday afternoon for Monday). Other numerical guidance (LFM and AVN) was similar to the NGM 24-hour forecast solutions at all levels of the troposphere. Figure 2 depicts the 24-hour 500 mb height and vorticity forecasts. Three maximums in absolute vorticity (relative vorticity plus the earth's vorticity — units of 10^{-5} sec^{-1}) are depicted over the Rockies. The one with the greatest magnitude is over northwest Montana, and a weaker one is over the southeast part of that state. A relatively weak maximum is shown over northeast Nevada. Comparing with Figure 1, this forecast is reasonably good for Montana. However, the maximum vorticity observed over southwest Idaho was forecasted to be moving into northwest Utah —a little too fast, too far south, and possibly with not enough magnitude.

Figure 3 depicts the 24-hour sea level pressure and 1000 to 500 mb thickness forecasts. The important thing to observe is the forecast surface pressure gradient across eastern Wyoming with pressures forecast to be greater than 1020 mb over eastern Colorado. Additionally, note the 1007 mb surface low forecast to be over northern South Dakota (in response to cyclogenesis in the lee-side trough due to the Montana short wave trough depicted in Figure 1). Thus, the surface sea level pressure gradient is favorable for vertical momentum transport with apparently sufficient magnitude for a southeast Wyoming high wind event.

Figures 4 and 5 are surface analyses valid for 15Z and 21Z Monday, respectively (8:00 a.m. and 2:00 p.m. MST). Observe from Figure 4 the surface low over eastern South Dakota. Note that lowest surface pressure is 1015.1 mb at Huron, South Dakota (HON) — much greater than 1007 mb that Figure 3 shows for the surface low (a 12Z surface map was not available; however, comparing Figure 4 to Figure 3 is still valid to make the above point). Additionally, there is a weak cyclonic circulation in the lee-side trough with surface pressures roughly two to seven mb lower than the 24-hour NGM predicted over northeast Colorado. Hence, the 24-hour NGM forecasted surface pressures to be too low to the northeast of Wyoming and too high to the south. That is, the NGM over-forecasted a northwesterly geostrophic wind at the surface over southeast Wyoming. From Figure 4 note the very light east-southeast wind at Cheyenne (CYS) — to everyone's surprise in the forecast office!

Figure 5, the surface analysis valid for 2:00 p.m. MST Monday, indicated that the weak cyclonic circulation progressed southward through eastern Colorado (as would be expected quasi-geostrophically — Holton, 1979). Additionally, the low pressure trough shown over northwest Wyoming at 8:00 a.m. MST (Figure 4) underwent cold frontogenesis and is shown as a southward moving cold front over eastern Wyoming. Also, a very small anticyclone was located near Worland (WRL). The cold front farther north was the leading edge of much colder Arctic air. By this time, the wind at CYS was again from a west-northwest direction. The distribution of surface pressure and "fronts, highs, and lows" at 2:00 p.m. MST

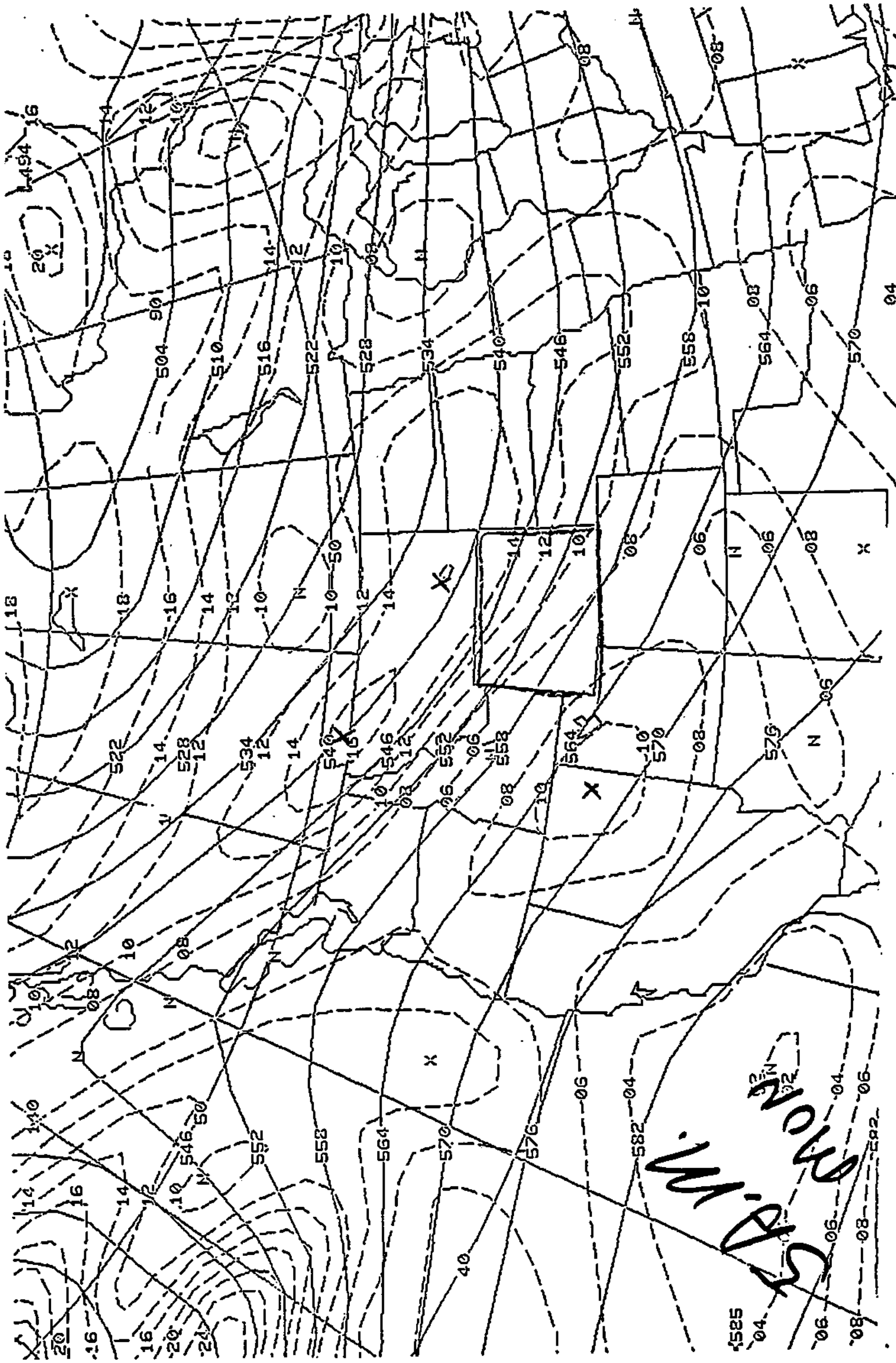

FIGURE 2: 24-HOUR NGM 500 MB HEIGHTS (SOLID) AND VORTICITY (DASHED) FORECASTS VALID 12Z MONDAY, FEBRUARY 8.

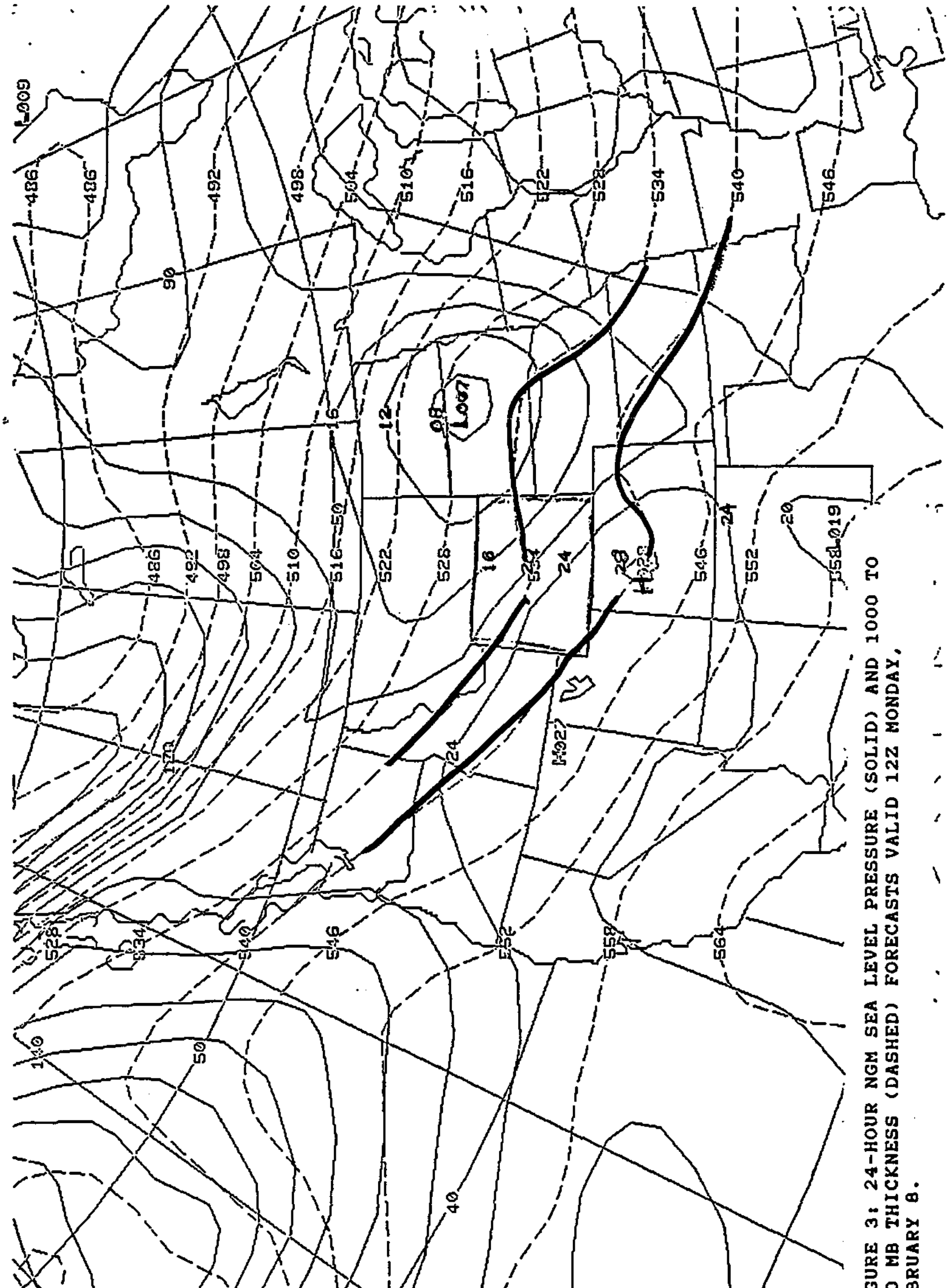

FIGURE 3: 24-HOUR NGM SEA LEVEL PRESSURE (SOLID) AND 1000 TO 500 MB THICKNESS (DASHED) FORECASTS VALID 12Z MONDAY, FEBRUARY 8.

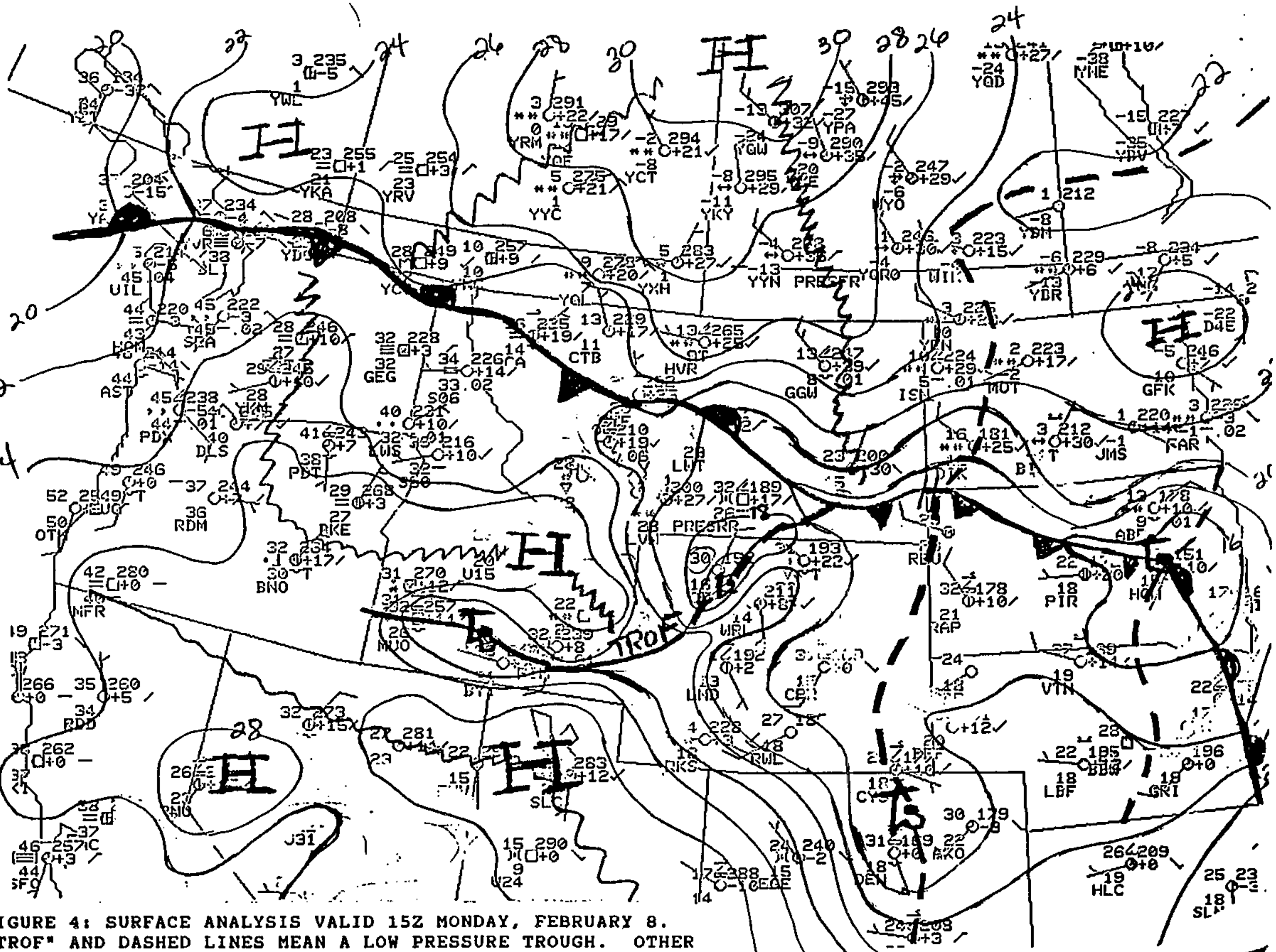

FIGURE 4: SURFACE ANALYSIS VALID 15Z MONDAY, FEBRUARY 8. "TROF" AND DASHED LINES MEAN A LOW PRESSURE TROUGH. OTHER SYMBOLS AND PLOTTING ARE CONVENTIONAL.

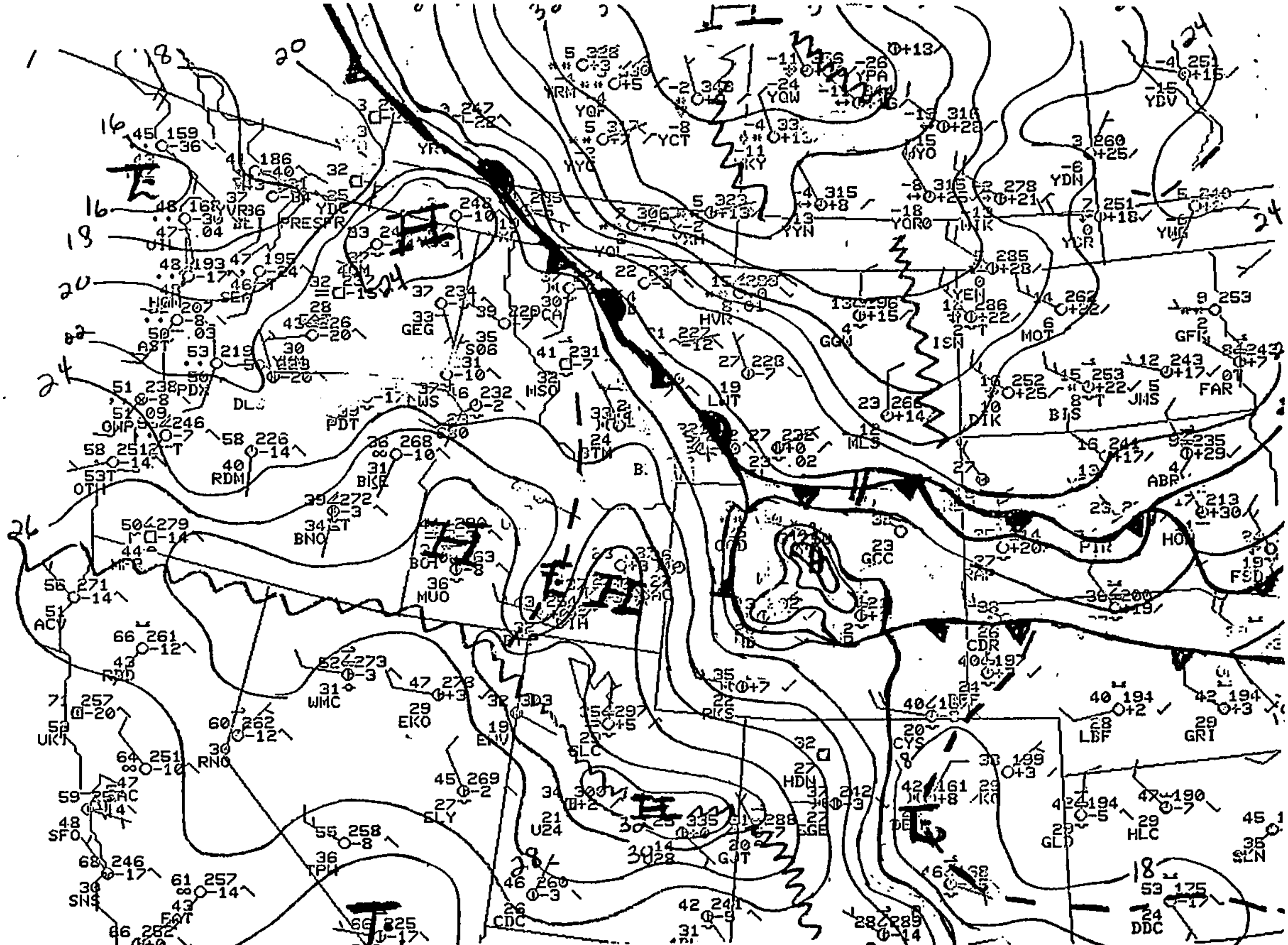

FIGURE 5: SAME AS FIG. 4 EXCEPT FOR 21Z MONDAY, FEBRUARY 8.

21Z MON 2/8/88

was the result of complicated interactions between the short wave trough over Montana at 12Z, the terrain, and apparently dynamics involving much smaller than synoptic scales of motion. To quantify this is well beyond the scope of this paper.

With all the above figures in mind, it appears that the main reason why there was no wind meeting high wind criteria at Cheyenne was the lee-side cyclogenesis over eastern Colorado. That development created a pressure gradient that was not favorable for vertical mixing of westerly momentum air down to the surface at Cheyenne (elevations above 8,000 feet MSL west of Cheyenne did report wind gusts that meet NWS high wind criteria — the elevation of Cheyenne is about 6,000 feet MSL). Essentially, at 8:00 a.m. MST, there is a weak easterly gradient wind opposing the northwesterly geostrophic flow from about the middle troposphere and above (this cyclonic circulation did not extend even as high as 700 mb at 12Z Monday) over Cheyenne.

But why did this surface low form in the lee-side trough over northeast Colorado by 15Z Monday and was not predicted by the 24-hour NGM? The answer may be the short wave trough that was over extreme southwest Idaho at 12Z Monday. This feature was farther north and possibly more intense than the 24-hour NGM predicted. Hence, with cyclonic vorticity advection above the lee-side trough over northeastern Colorado, one, quasi-geostrophically, would expect cyclogenesis to occur in the lee-side trough (Holton, 1979). The southwest Idaho 500 mb short wave trough was located over northeastern Colorado by 00Z Tuesday supporting this qualitative hypothesis (not shown). The NGM may have "missed" this development because of analysis and initialization errors in the 12Z Sunday run (modeling of the complex terrain along the front range of the Rockies may have also contributed).

Interestingly, the clue to a busted high wind warning forecast may have come as early as about 21Z Sunday (2:00 p.m. MST) from the SWIS (Satellite Weather Interpretation System) unit at the WSFO Cheyenne office. Satellite animation did indicate a significant "comma-cloud" feature moving rapidly northeastwards from about 20° North latitude to near the coast of Washington State by 21Z Sunday. The short wave trough over extreme southwest Idaho by 12Z Monday was probably associated with this system (there was a long wave low amplitude middle and upper tropospheric ridge at about 135° West longitude — in the eastern Pacific — that Sunday afternoon). In a relatively data void region like the eastern Pacific Ocean, it is no surprise that the numerical models did not forecast the eastern Pacific short wave trough very well.

The lesson learned from this busted forecast is that SWIS can be used, in future similar "situations," to identify poorly initialized short waves which impact the local forecast. Furthermore, this case represents an excellent example of how monitoring the atmosphere in real time can be used as a short temporal scale forecasting tool (less than 12 hours). This point has been stated "over and over" in the literature, conferences, etc. However, it seems as if it must be stated again since there is a tendency to put too much faith in the numerical guidance.

3. Conclusions

Discussion of why a high event did not occur at Cheyenne, Wyoming, has been presented. As a result of modeling errors, the magnitude of surface west to northwest geostrophic winds were forecasted to be high over eastern Wyoming valid 5:00 a.m. MST Monday, February 8. The main error in all the numerical guidance (NGM, LFM, AVN) was the improper prediction of a middle and upper tropospheric short wave trough that originated in a relatively data void region of the eastern Pacific. It is speculated that this short wave trough initiated cyclogenesis on the lee-side over northeastern Colorado causing a weak easterly gradient wind to occur over Cheyenne. Thus, the pressure gradient force was not favorable for a high wind event.

A clue to this busted high wind forecast came Sunday afternoon, one day before this event was to occur when SWIS animation indicated a fairly significant "comma cloud" feature moving through eastern Pacific, a feature not handled well by the models. If more consideration would have been given to what SWIS showed, the busted forecast may have been avoided.

This case represents yet another example where real time monitoring of the atmosphere can be used as a short time scale forecasting tool to possibly avoid a bust. This monitoring can be done using real time surface and constant pressure analyses, satellite imagery, radar data, etc.

4. Reference

Holton, J.R., 1979: An Introduction to Dynamic Meteorology, 2nd Ed., Academic Press, 391 pp.

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CRARP 88-2

CENTRAL REGION APPLIED RESEARCH PAPER 88-2

A CASE STUDY OF A SIGNIFICANT LAKE ENHANCED SNOW EVENT IN UPPER MICHIGAN

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1. Introduction

On April 1-2, 1987, a strong low pressure system moved across the northern Great Lakes region, bringing snow to northern Wisconsin, much of Michigan, and southern Ontario. Snowfall began in advance of the storm system in Michigan during the early morning hours of April 1 with lingering snow showers continuing until about noon on April 2.

Significant snowfall in the upper and northern lower peninsulas of Michigan was not entirely unexpected. However, in this instance, several factors combined to produce some rather excessive snowfall totals in upper Michigan. On the morning of April 2, WSO Marquette issued the following public information statement for 24-hour snowfall:

PUBLIC INFORMATION STATEMENT
NATIONAL WEATHER SERVICE MARQUETTE MI
815 AM EST THU APR 2 1987

THE COOPERATIVE OBSERVER IN MUNISING REPORTS 27 1/2 INCHES OF
NEW SNOW THIS MORNING FROM YESTERDAYS AND LAST NIGHTS STORM.
CARS ARE REPORTED TO BE COVERED IN DRIFTS UP TO 6 FEET HIGH.
ALL ROADS ARE OPEN THIS MORNING AS THE ROAD COMMISSION HAS
BEEN WORKING ALL NIGHT. FOR THE MOST PART THE SNOW HAS ENDED.
BUT THE WIND IS STILL GUSTY AND THERE IS STILL DRIFTING.

In addition, Figs. 1a and b show other snow amounts as a result of this significant April storm.

Many of the prescribed conditions for lake effect snow were already in place as the storm system moved across Michigan. These conditions, in conjunction with the synoptic scale storm, produced the most significant snowfall event of the winter of 1986-87 in Michigan.

Fig. 1a. Snowfall totals for April 1-2, 1987 (every four inches).

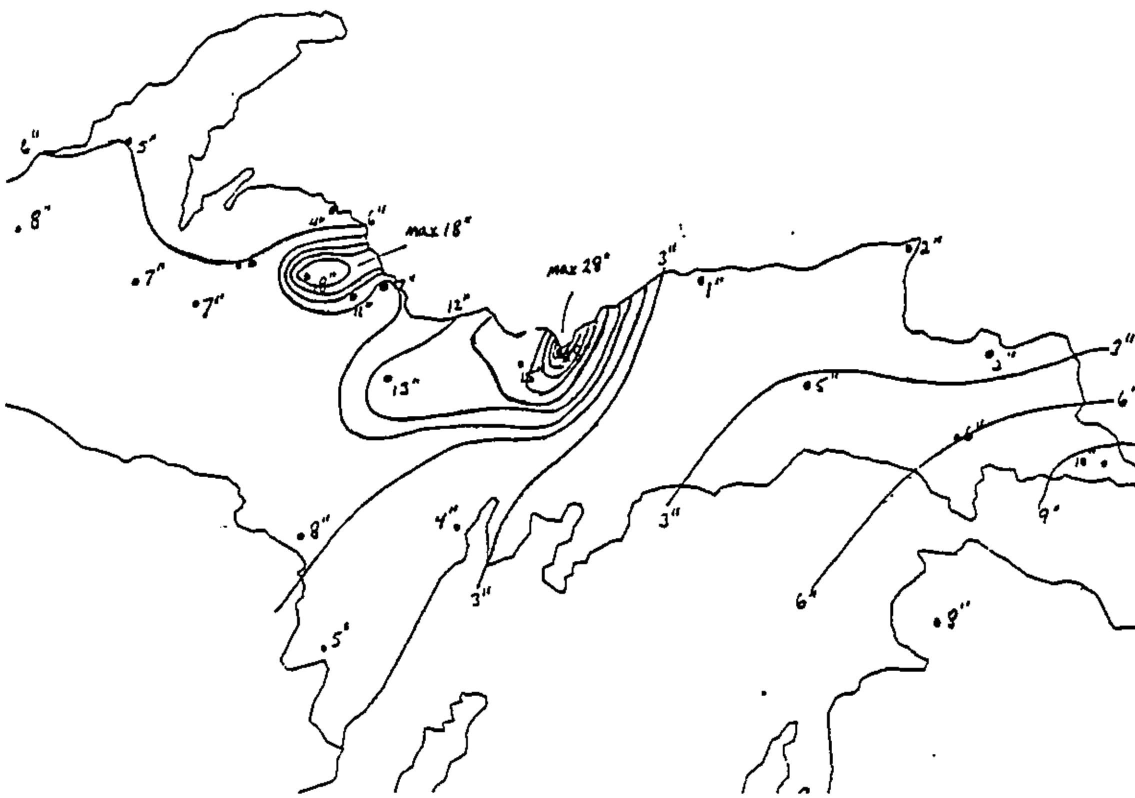

Fig. 1b. Snowfall totals for April 1-2, 1987 (every three inches).

2. Synoptic Evolution

At 12Z, April 1, a broad upper trough was entrenched across the eastern half of the United States with a 500 mb low centered near James Bay. To the southwest of the upper low, a significant short wave was digging southeastward toward Lake Superior. By that evening (00Z, April 2), this impulse would contribute to the formation of yet another upper low center over western Lake Superior. This low would then become dominant and proceed southeastward across upper Michigan through the night. As a result, throughout April 1st and into the 2nd, the upper flow pattern over Michigan was strongly diffluent.

At lower levels, closed circulations existed from the surface through 700 mb on April 1 and also continued through April 2 (Figs. 2a-f; 3a-d). Those circulations would follow similar tracks from northern Wisconsin at 12Z/April 1, into northern lower Michigan by 00Z/April 2. By the morning of April 2, the surface system had begun to fill and occlude as it moved over Lake Huron. During its entire track across the Great Lakes, the speed of the surface low was less than 20 mph. This would play a significant role in the development of heavy snow in Michigan.

Available moisture was plentiful with a large area of one to 2 degree dew point depressions in the vicinity of the 850 mb and 700 mb lows; and, as mentioned earlier, cold air was already in place as the storm system moved into the Great Lakes.

Even though high temperatures did manage to climb to around 10^{o}C in extreme southeast Wisconsin and southern lower Michigan on April 1, the 850 mb zero degree isotherm only nosed as far north as extreme southern lower Michigan. The 2840 m 1000-700 mb thickness line did reach as far north as central lower Michigan but still remained well south of the surface low. Interestingly, the 2840 1000-700 mb thickness matched up fairly well with the rain/snow line during the event.

Using parameters discussed by Hanks et al. (1967), such as track of the vorticity center, etc. (Fig. 4), one could place a four to eight inch swath of snow from northwest upper Michigan eastward through northern lower Michigan (Fig. 5). This estimate actually seems to correlate rather well with the observed snowfall pattern away from the lakes. However, where the lakes were in position to enhance snowfall, the synoptic scale contribution was but a small pattern of the storm total.

3. Discussion of Favorable Lake Enhancement Conditions

Meteorological conditions necessary for the development of lake effect precipitation are well known and documented. One of the most important factors is a strong flow of Arctic air across the relatively warm lakes, thus creating lapse rates near dry adiabatic to a depth of over 5000 feet. Dockus (1985) further elaborates, describing the -10^{o}C 850 mb isotherm as critical for the generation of "lake effect" snow in the absence of larger scale upper dynamics.

Dockus goes on to classify "lake enhanced" snow where the critical 850 mb temperature is -5^{o} (to a lake temperature of 36^{o}F) in the presence of an

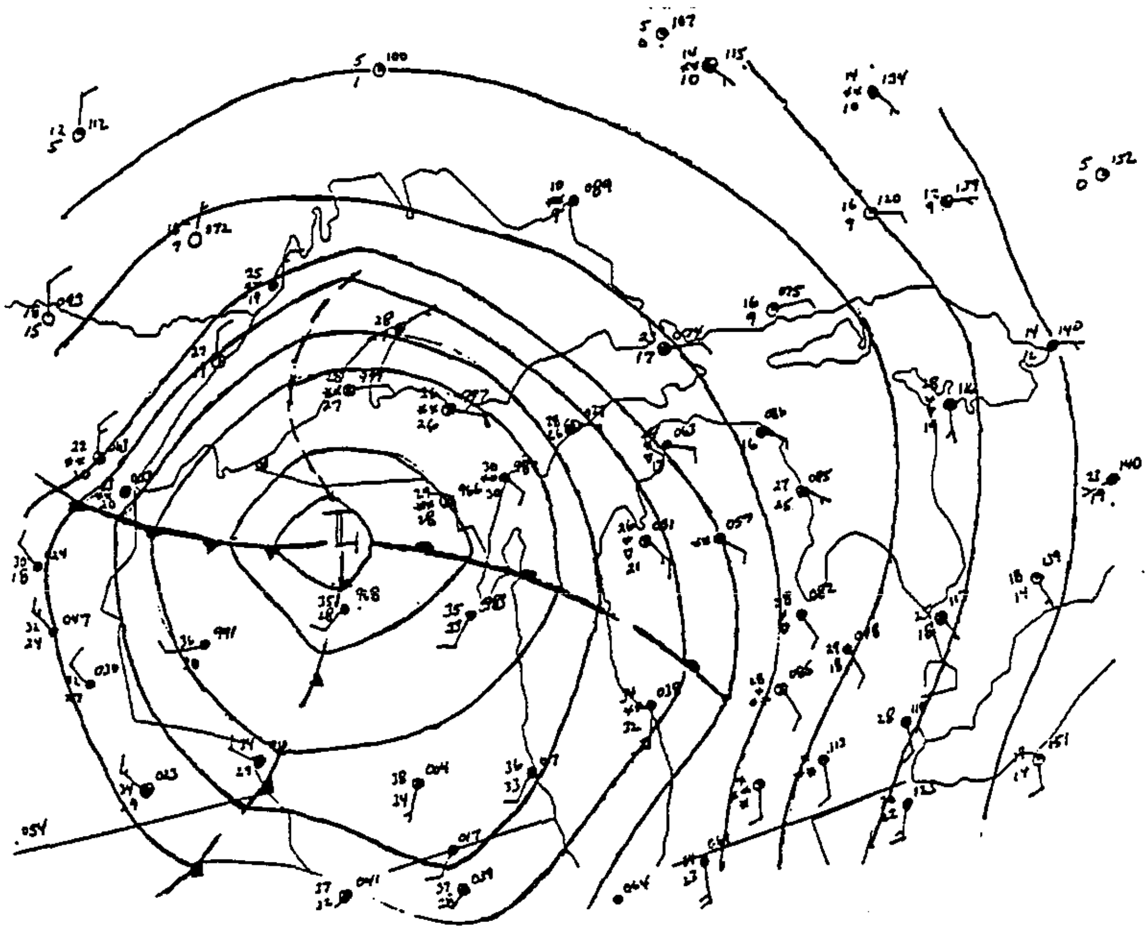

Fig. 2a. Surface analysis at 12Z on April 1, 1987.

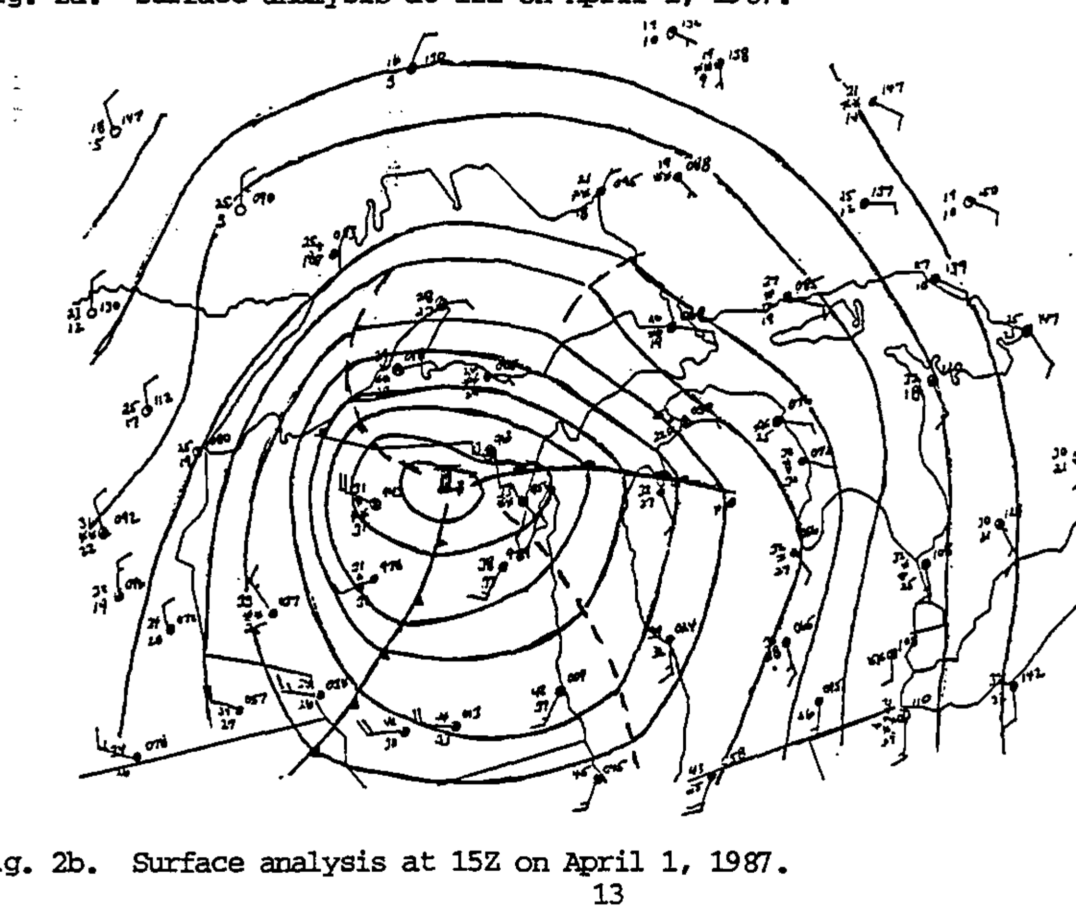

Fig. 2b. Surface analysis at 15Z on April 1, 1987.

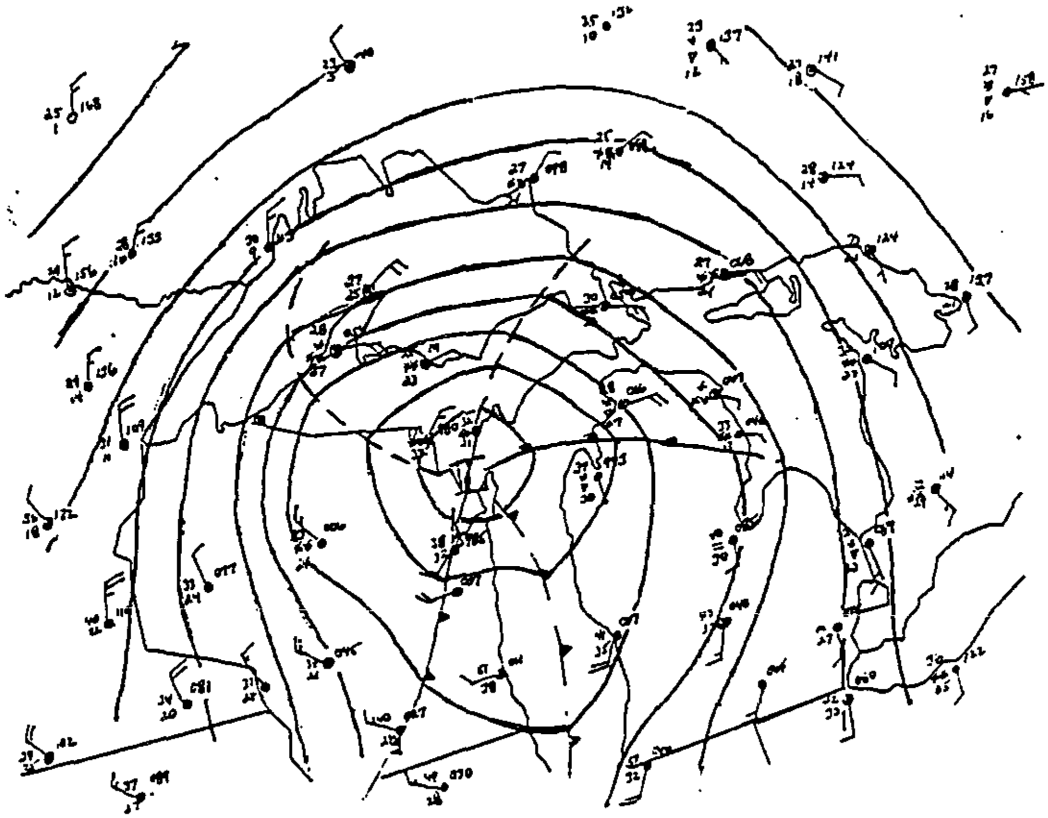

Fig. 2c. Surface analysis at 18Z on April 1, 1987.

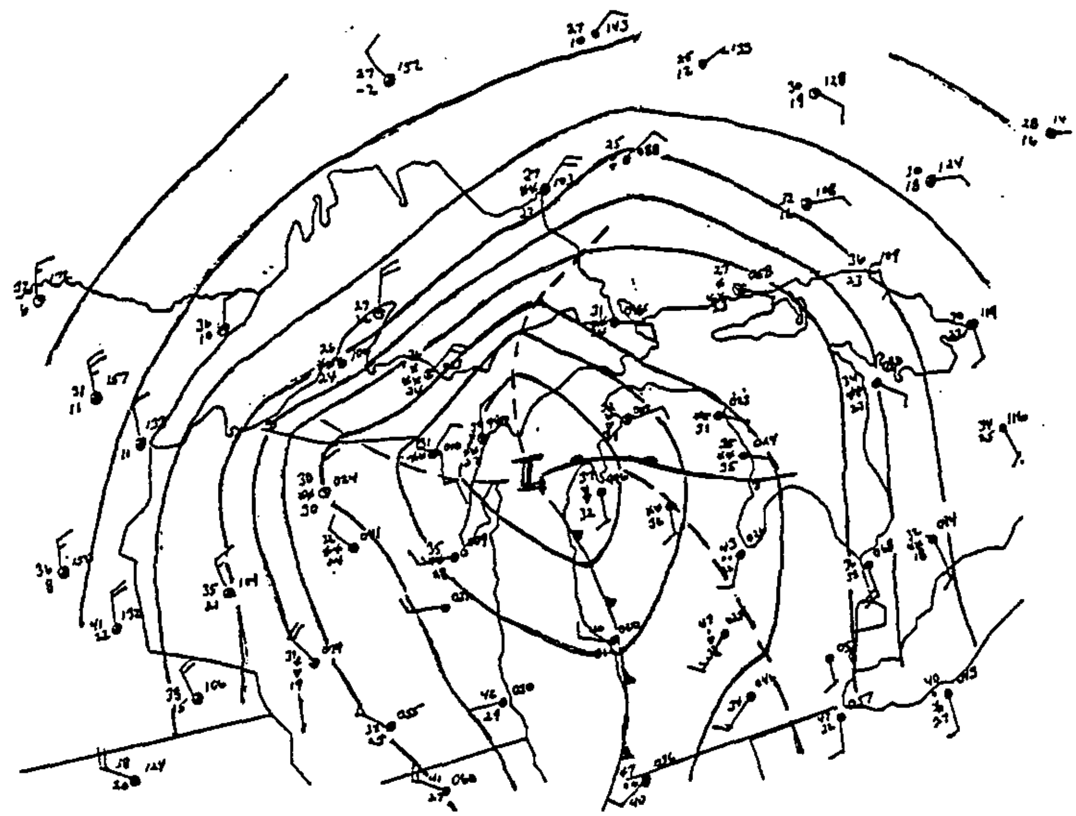

Fig. 2d. Surface analysis at 21Z on April 1, 1987.

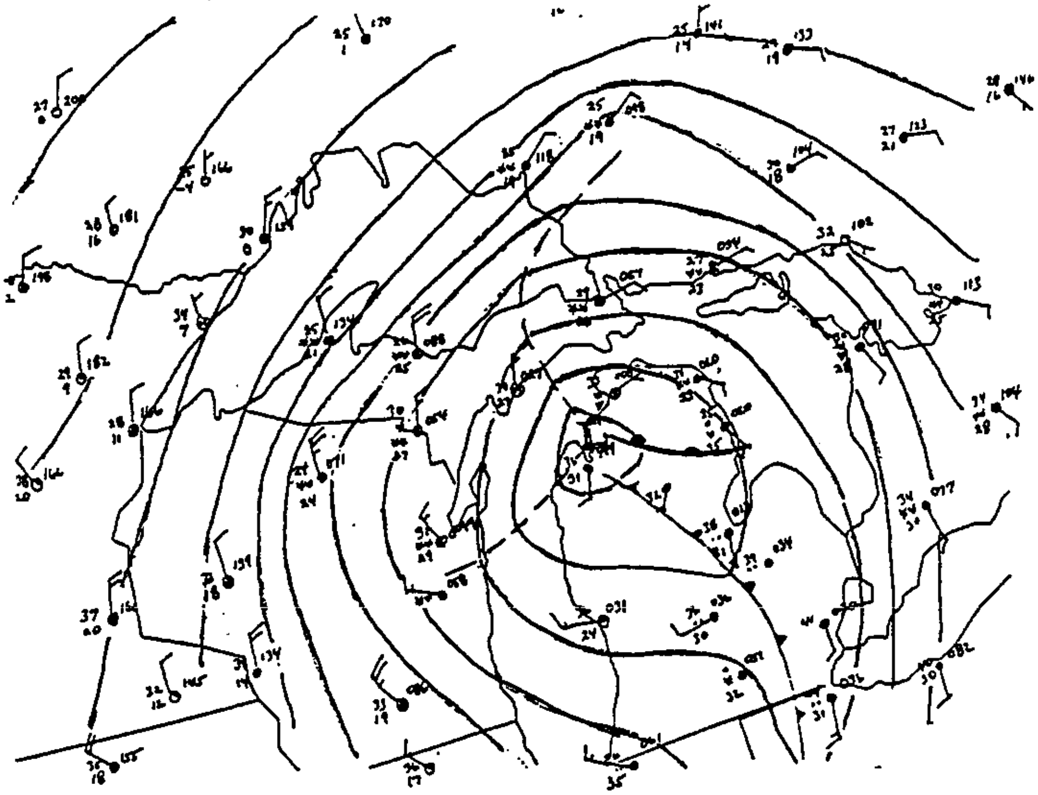

Fig. 2e. Surface analysis at 00Z on April 2, 1987.

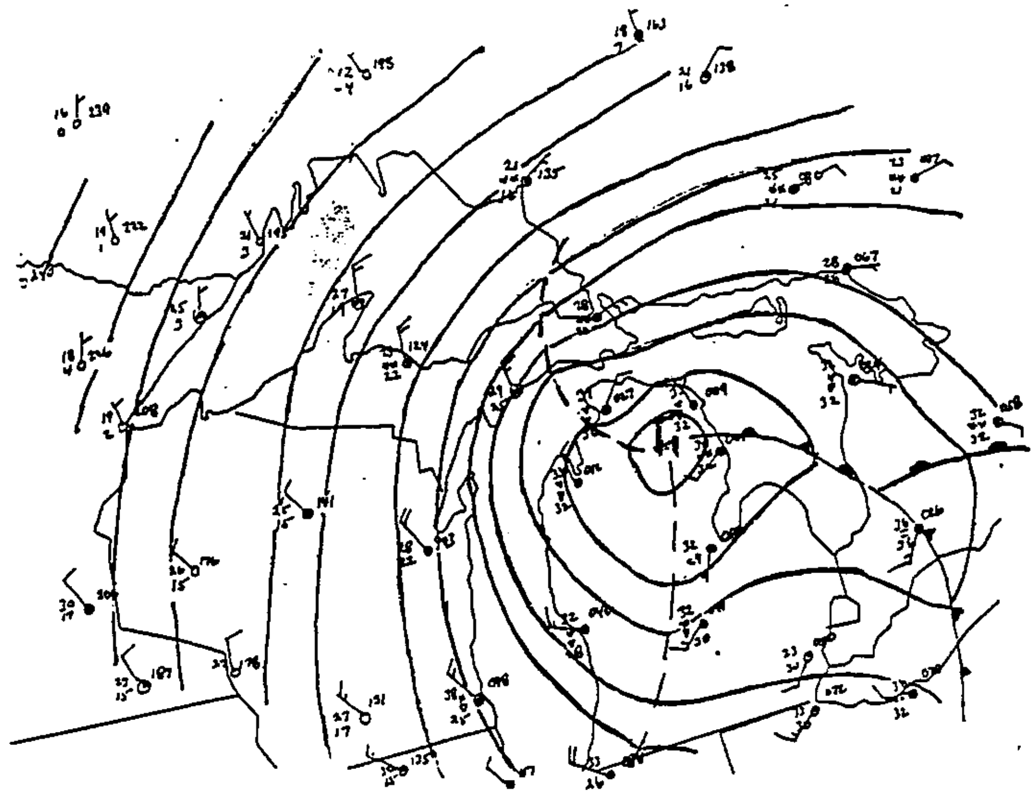

Fig. 2f. Surface analysis at 06Z on April 2, 1987.

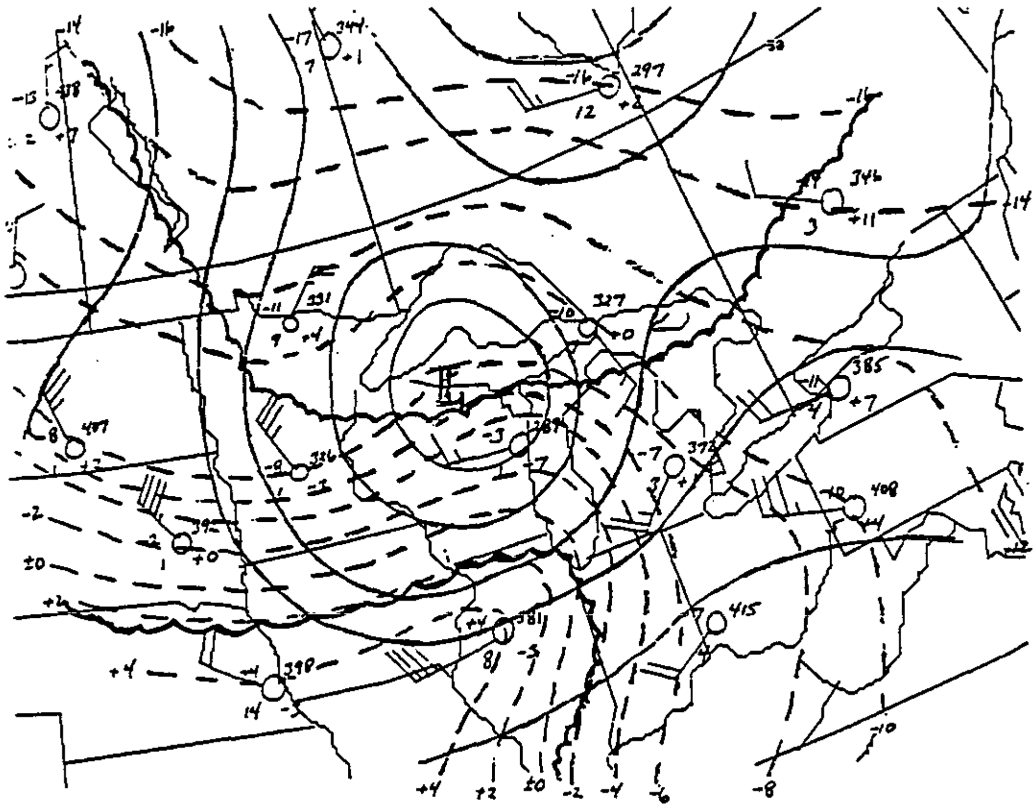

Fig. 3a. 850 mb analysis at 12Z on April 1, 1987.

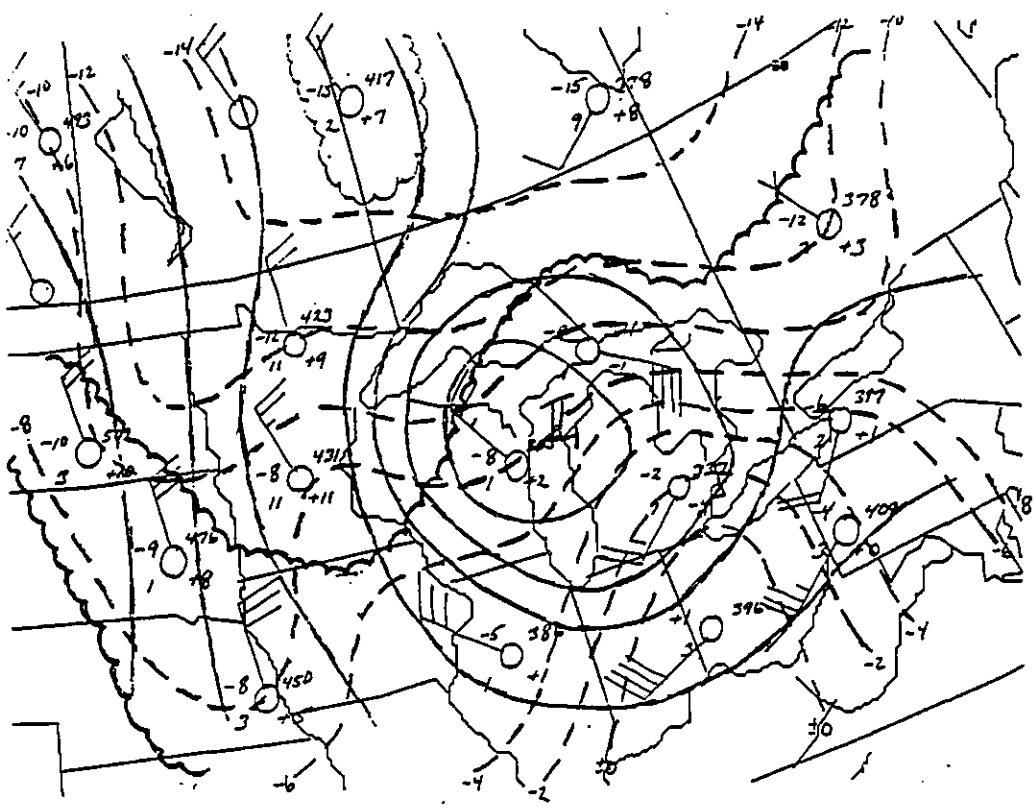

Fig. 3b. 850 mb analysis at 00Z on April 2, 1987.

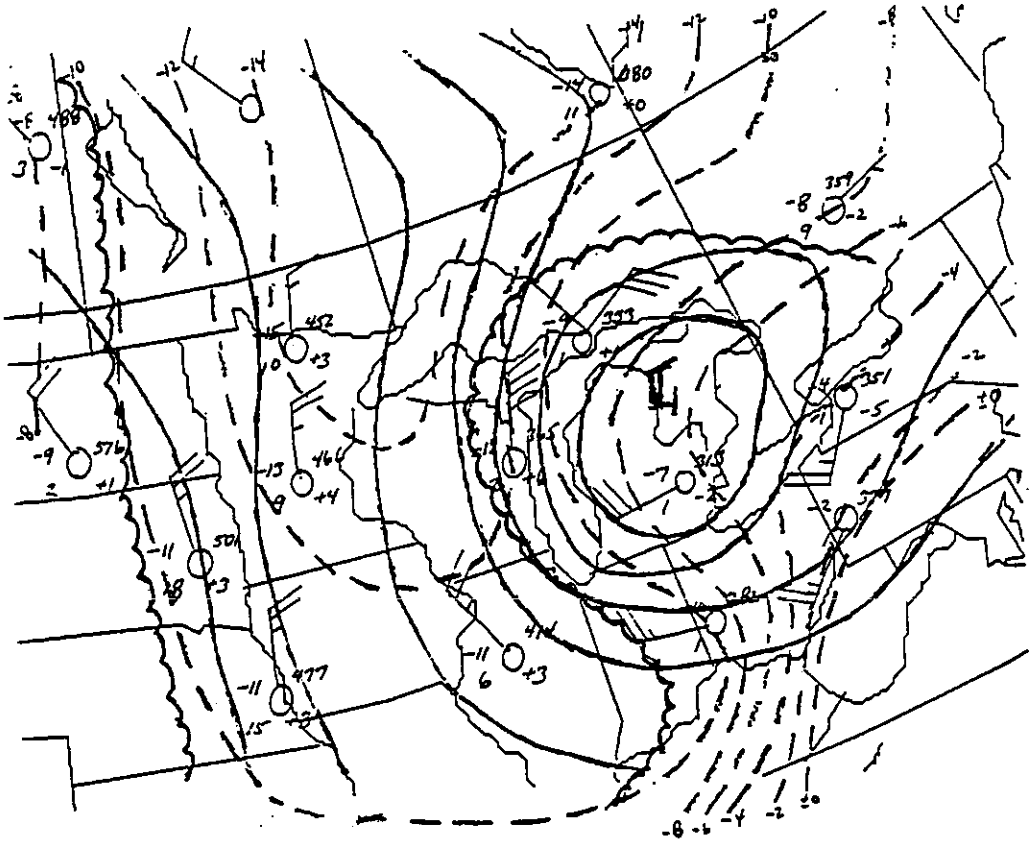

Fig. 3c. 850 mb analysis at 12Z on April 2, 1987.

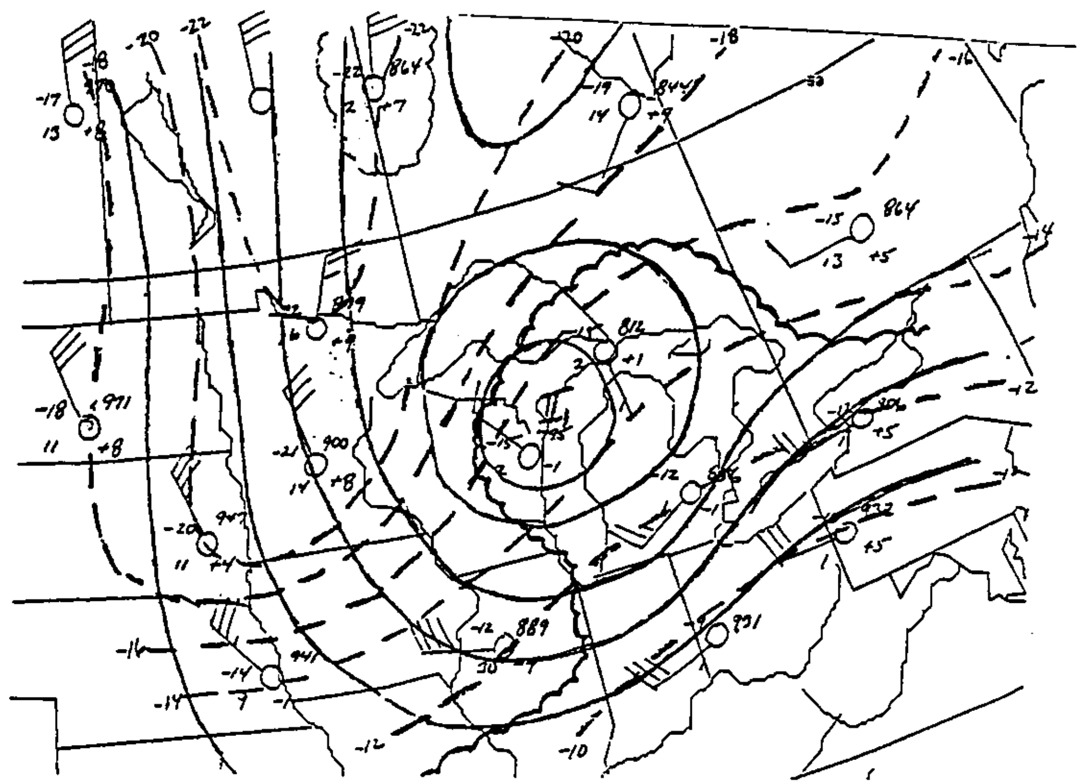

Fig. 3d. 700 mb analysis at 00Z on April 2, 1987.

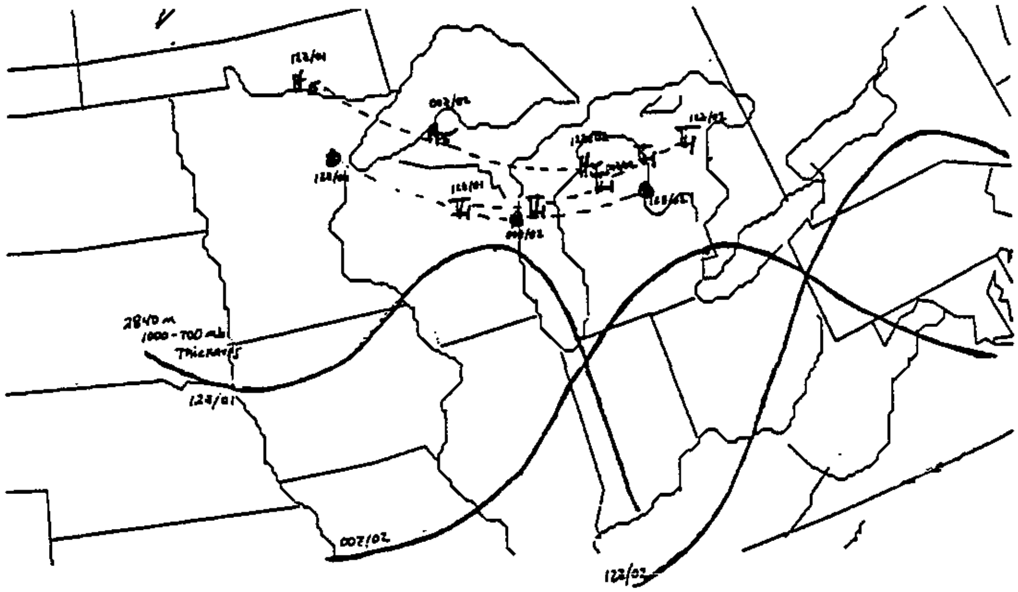

Fig. 4. Composite chart of weather situation for April 1-2, 1987. H_5 indicates track of 500 mb low (12Z/April 1-12Z/April 2); circled x indicates track of 500 mb vorticity max (12Z/April 1-12Z/April 2); L indicates track of surface low. Maximum surface relative vorticity 11×10^{-5} sec^{-1} (12Z/April 1-12Z/April 2). Maximum 500 mb relative vorticity 22×10^{-5} sec^{-1} (12Z April 1-12Z/April 2).

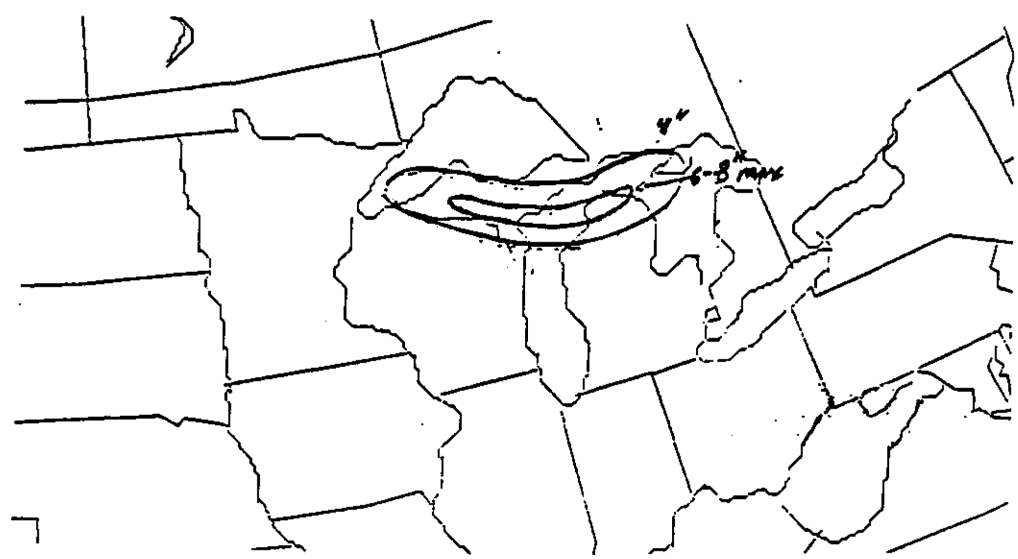

Fig. 5. Estimate of synoptic scale snowfall contribution.

independent lifting mechanism. (This rule of thumb is to be used with extreme caution with warmer lake temperatures usually seen in early fall. Although over-lake instabilities can be rather impressive, the warm lake temperatures can result in a wet bulb zero height too high to yield anything but rain or a rain/snow mix.)

In the case of April 1-2, 1987, it appears the best of both worlds were in place. Water temperatures across Lake Superior averaged 3 to 4°C, and the lake was completely ice-free. SSM temperatures at 850 mb hovered near -10°C from 12Z/April 1 to 12Z/April 2 with temperatures further west over mid-lake likely a few degrees cooler. As alluded to earlier, significant lifting on the synoptic scale was certainly present given the broad low level convergence around the cyclone and the impressive upper level divergence. In fact, the 12Z/01 NGM forecast cycle indicated upward vertical velocities (via FRHT67) would be in excess of 4.5 microbars per second from 12Z/April 1 to 12Z/April 2. Even the LFM similarly forecast upward vertical velocities in excess of 2.0 microbars per second over this same period.

Thus, for an extended period of time, surface to 850 mb lapse rates near dry adiabatic existed over Lake Superior with strong synoptic scale lift acting on those instabilities. Surface fetch over the lake upstream from the heaviest snowfalls was well in excess of 100 miles, especially over eastern Lake Superior. Fetch over the western half of the lake was somewhat less during this snow event but still considered sufficient for lake enhanced snow.

4. Other Low Level Considerations

We have shown that conditions on April 1 and 2, 1987 were quite conducive to the development of significant lake enhancement of the synoptic scale snowfall. But, there were certainly other low level considerations crucial to the development of heavier snow squalls.

Snowfall totals on Figs. 1a and b indicate certain mesoscale processes played a significant role in the enhancement of snow in three locations. The first, an 18-inch maximum snowfall west and northwest of Marquette, was probably the primary result of orographic enhancement of persistent onshore flow. This area includes the highest elevations in Michigan, approaching 2000 feet MSL with the Lake Superior surface at about 600 feet MSL.

The other two snowfall maximums, near Munising and Ironwood in far northwest upper Michigan, were likely the indirect result of the slow movement of the larger scale storm system. This slow movement allowed the development of quasi-stationary confluent bands over the lake, which would allow an increase in both snow intensities and duration in localized areas.

Available wind convergence charts and surface analyses (Figs. 6a-d) indicated the formation of two areas of convergence over Lake Superior and upper Michigan during the event. The stronger of the two was centered over Ironwood at 12Z/April 1 and persisted through that day before finally diminishing toward evening. The second and weaker convergence maximum developed by mid-morning of

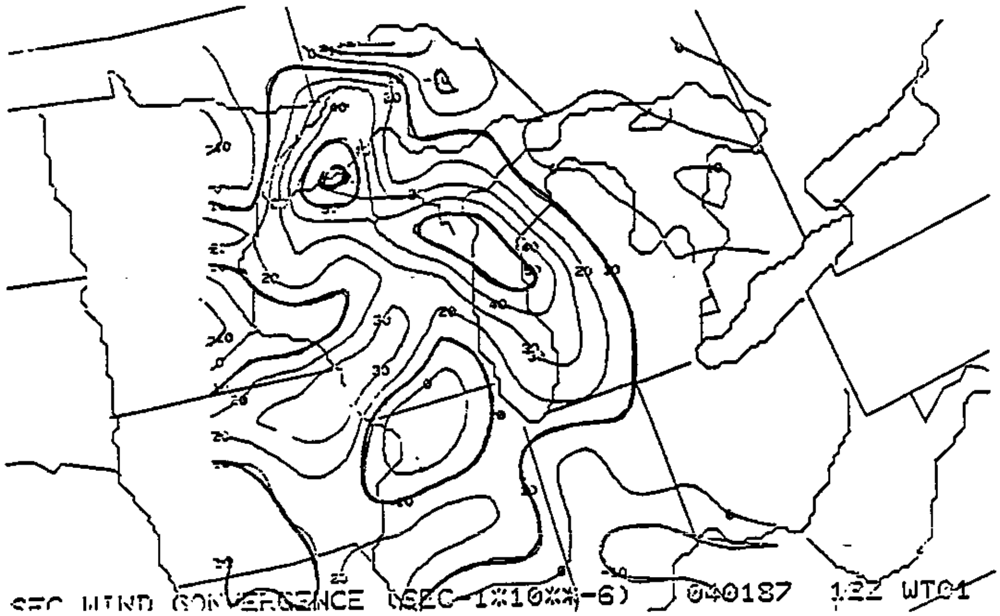

Fig. 6a. Surface wind convergence ($sec^{-1} \times 10^{-6}$) at 12Z on April 1, 1987.

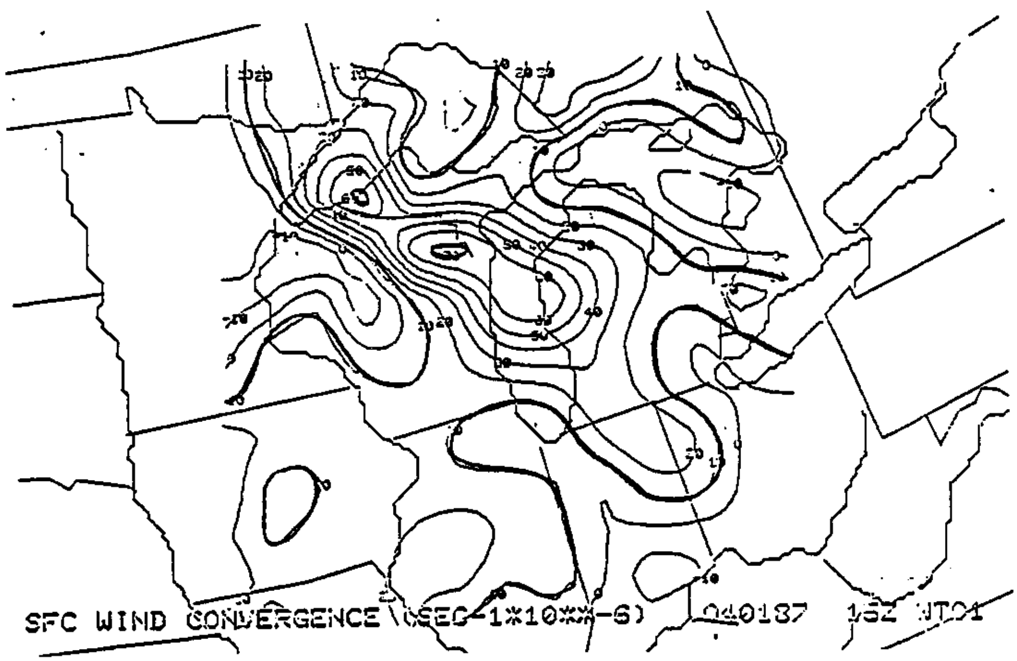

Fig. 6b. Surface wind convergence ($sec^{-1} \times 10^{-6}$) at 16Z on April 1, 1987.

Fig. 6c. Surface wind convergence ($sec^{-1} \times 10^{-6}$) at 18Z on April 1, 1987.

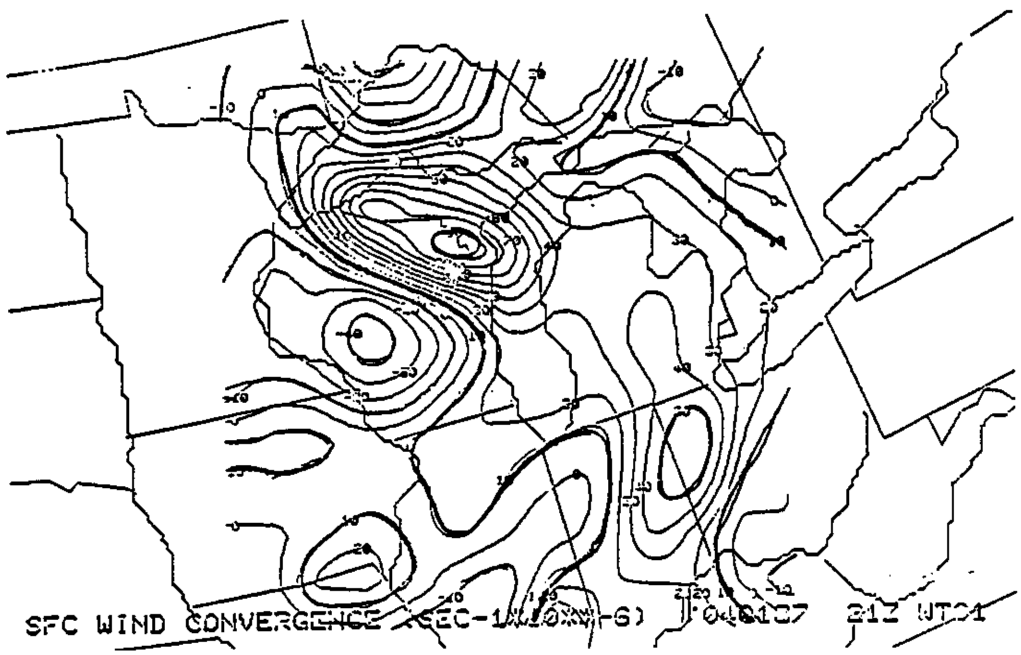

Fig. 6d. Surface wind convergence ($sec^{-1} \times 10^{-6}$) at 21Z on April 1, 1987.

April 1 from just north of Whitefish Bay to near Grand Marais. This maximum also persisted in that area throughout the day before weakening and moving eastward by approximately 06Z/April 2.

However, the fact that the lighter snowfall amounts reported were associated with the stronger convergent area raises some rather interesting questions and points. Furthermore, other factors also pointed toward far northwest upper Michigan as being a more favored area for lake effect snows.

It has been mentioned that over lake instabilities were a bit more impressive over western Lake Superior throughout the event (as opposed to the eastern half of the lake). In addition, since the surface convergence maximum in this area coincided with onshore flow over the Porcupine Mountain range, it would appear as though orographic enhancement should have also boosted snowfall totals in northwest upper Michigan (Fig. 7).

Although only a ten inch snowfall maximum was actually recorded in northwest upper Michigan, it is entirely likely that much higher totals actually fell in this vicinity but just went undetected by the observation network. Indeed, satellite photos hinted at a band of colder-topped convection at that time.

This is further supported by an examination of directional shears in the lowest 10,000 feet of the atmosphere during the event. Directional shears, generally considered detrimental to lake effect snowfalls, were rather substantial over Lake Superior on April 1 (frequently in excess of 60°). However, it appears they finally did approach more acceptable values (30° or less) over the western half of the lake sometime during the afternoon of April 1, increasing the likelihood of heavy snow.

Over the eastern half of Lake Superior, it appears as though the flow didn't stack up well until about 06Z/April 2. Still, nearly 2 1/2 feet of snow was measured at Munising when one might have suspected higher amounts further west.

Although the observation network lacked the temporal resolution to determine when snowfall intensities were greatest at Munising, one might surmise that the heaviest snow occurred between 01Z and 08Z. Heaviest snowfall at Marquette occurred in this time frame and satellite pictures again appear to support this contention.

Furthermore, personal communication with the observer in Munising indicated that heavy snowfall did occur during the late afternoon hours on April 1. This would be at a time when low level shears were anything but favorable.

If so, this would seem to suggest that in the presence of strong large scale vertical motions and deep moisture, directional shears may not play the significant role in inhibiting convection as in more classical lake effect snow scenarios.

Fig. 7. Surface topography map, elevations in feet above mean sea level.

5. Summary and Conclusions

Analyses of the heavy snowfalls of April 1 and 2, 1987, in Michigan illustrates the snowfall potential of slow moving synoptic scale storm systems through the Great Lakes in winter. For this particular storm, nearly 2 1/2 feet verified while MOS POSA forecasts indicated no more than two inches in 24 hours for Michigan.

Interestingly, the Nested Grid Model (NGM) performed rather well during this event. Using the NGM, Hank's method of forecasting snow amounts also gave a fairly accurate depiction of what was considered to be the synoptic scale contribution to the snowfall totals.

But, subtracting this larger scale contribution still leaves a nearly two foot mesoscale contribution near the lake shore. In fact, from all appearances, it looks like a good deal of this fell in a relatively short period of time with some incredible snowfall rates. Even an estimate using the "Dockus Decision Tree" (Dockus, 1985) of nine to 12 inches in six hours was likely a bit conservative.

The difficulty in forecasting an event of this magnitude is quite apparent. But, hopefully, results of this paper will make it a bit easier to recognize the potential in such a system. And, once such an event is underway, we have shown that MESOS, in addition to radar, can be a valuable tool in making a timely nowcast.

6. Acknowledgements

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CENTRAL REGION APPLIED RESEARCH PAPER 88-3

A COLLECTION OF SEVERE WEATHER PARAMETERS USED FOR A CHECKLIST

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Forecasters must examine a number of variables to acquire an adequate understanding of the current state of the atmosphere. In order to make specific forecasts of a particular type of phenomena, for example severe storms, many synoptic and subsynoptic parameters should be checked closely. The expected values of the variables for a forecast period can help the forecaster get a better understanding of the potential of significant weather developments.

Several severe weather parameters have been compiled from three different sources including a work sheet from one of the references. The parameters have been organized into a checklist. A list of ratings of the parameters has been included in this paper. By using the list of ratings, the forecaster can assess a value to each parameter.

SEVERE WEATHER CHECKLIST

DATE/TIME: AREA OF FORECAST:

Parameter	Initial Value	Rating	Forecast Value	Rating
Surface (Sea Level Pressure) Parameters:				
Dew Point				
Sea Level Pressure				
12-Hour Sea Level Pressure Change				
Low Level (Moisture) Convergence				
Average Mixing Ratio (Lowest 100 mb)				
Upper Air Parameters:				
Low Level Jet				
Low Level Moisture (850 mb dew point)				
850 mb Thermal Advection				
Low Level Thermal Ridge Versus Low Level Moisture Axis				
700 mb Dry Intrusion				
700 mb No-Change Line				
500 mb Vorticity Advection				
Mid Level Jet (500 mb)				
Mid Level Shear				
500 mb Height Change				
850-500 mb Speed Shear				
850-500 mb Directional Shear				
Upper Level Jet (Speed)				
Upper Level Shear				

Miscellaneous Parameters:

Mean Relative Humidity
Vertical Motion
Height of Wet-Bulb Zero
Lifted Index
Total Totals Index

Some Limiting Factors for Severe Weather Areas (Johns et al., 1986)

1. —— Surface boundary.
2. —— Surface dew point of 55°F.
3. —— 1016 mb Isobar.
4. —— 1000/500 mb Thickness < 5520 m, (5580 m if the system is not intensifying).
5. —— 1000/500 mb Thickness > 5790 m.
6. —— Dry side of 45% RH line (mean RH).
7. —— Wet side of 75% RH line.
8. —— Lifted index 0 line.
9. —— Warm side of -6°C isotherm at 500 mb.
10. —— Warm side of 14°C isotherm at 700 mb.
11. —— East side of 850 mb jet axis.
12. —— Dry side of 850 mb 8°C isodrosotherm.
13. —— 500 mb Temperature (December-February = -16°C; March, April, October and November = -14°C; May and June = -12°C; July-September - -10°C).

Forecast:

1. General thunderstorms if most parameters are weak.
2. Thunderstorms approaching severe or a few thunderstorms if most parameters are moderate.
3. Severe thunderstorms and tornadoes if most of the parameters are strong.

SEVERE WEATHER PARAMETERS RATINGS
(SELS/AFGWC)

1. Surface Dew Point
   less than 55°F = weak
   55 to 64°F = moderate
   greater than 64° = strong

2. Sea Level Pressure
   > 1010 mb = weak
   1010 to 1005 mb = moderate
   < 1005 mb = strong

3. 12-Hour Sea Level Pressure Change
   < -4 mb = weak
   -4 mb to -8 mb = moderate
   > -8 mb = strong

4. Low Level (Moisture) Convergence
   flow diverging = weak
   flow parallel to boundaries = moderate
   flow converging = strong

5. Average Mixing Ratio (Lowest 100 mb)
   < 8 g/kg = weak
   8 to 12 g/kg = moderate
   > 12 g/kg = strong

6. Low Level Jet
   less than or equal to 20 kts = weak
   21 to 35 kts = moderate
   > 35 kts = strong

7. Low Level Moisture (850 Dew Point)
   less than or equal to 8°C = weak
   9 to 12°C = moderate
   > 12°C = strong

8. 850 mb Thermal Advection
   cold advection = negative
   neutral advection = weak
   warm advection = moderate

9. Low Level Thermal Ridge (850 mb) Versus Low Level Moist Axis
   ridge east (downstream) of moist axis = weak
   coincident = moderate
   ridge west (upstream) of moist axis = strong

10. 700 mb Dry Intrusion
wind field weak or non-existent = weak
wind from dry to moist at an angle of 10 to 40° and speed of 15 to 25 kts = moderate
wind intruding at an angle of 40 to 90° and a speed > 25 kts = strong

11. 700 mb No-Change Line
wind crossing line at angle < 30° = weak
wind crossing line at angle 30 to 40° = moderate
wind crossing line at angle > 40° = strong

12. 500 mb Vorticity Advection
neutral or NVA = weak
PVA with wind crossing vort isopleths at angle of less than or equal to 30° = moderate
PVA with wind crossing vort isopleths at angle of greater than 90° = strong

13. Mid Level Jet (500 mb)
< 35 kts = weak
36 to 50 kts = moderate
> 50 kts = strong

14. Mid Level Shear
< 15 kts = weak
15 to 30 kts = moderate
> 30 kts = strong

15. 500 mb Height Change (use 12-hour height fall from late fall to early spring and 24-hour falls from late spring to early fall)
< 30 meters = weak
30 to 50 meters = moderate
> 60 meters = strong

16. 850-500 mb Speed Shear
< 20 kts = weak
20 to 35 kts = moderate
> 35 kts = strong

17. 850-500 mb Directional Shear
< 30° = weak
30 to 60° = moderate
> 60° = strong

18. Upper Level Jet
< 55 kts = weak
55 to 85 kts = moderate
> 85 kts = strong

19. Upper Level Shear

< 15 kts	= weak
15 to 30 kts	= moderate
> 30 kts	= strong

20. Mean Relative Humidity

R.H. < 40% or R.H. > 80%	= weak
70 to 80% or 40 to 50%	= moderate
Between 50 to 70%	= strong

21. Vertical Motion (microbars/second)

< +1	= weak
+1 to +4	= moderate
> +4	= strong

22. Height of the Wet Bulb Zero (agl)

< 5,000 ft or > 11,000 ft	= weak
5,000 to 7,000 ft or 9,000 to 11,000 ft	= moderate
7,000 to 9,000 ft	= strong

23. Lifted Index

greater than or equal to -2	= weak
-3 to -5	= moderate
less than or equal to -6	= strong

24. Total Totals Index

less than or equal to 50	= weak
51 to 55	= moderate
> 55	= strong

Notes:

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CRH SSD
CRARP 88-4

CENTRAL REGION APPLIED RESEARCH PAPER 88-4

A MEDITATION ON MILLER

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1. Introduction

Forecasting the occurrence of severe thunderstorms has been the specialty of the National Severe Storms Forecast Center (NSSFC) for well over 30 years. During this period, research efforts and empirical forecast studies have concentrated on the severe thunderstorm event. The U.S. Air Force Technical Report 200 (revised), Notes on Analysis and Severe-Storm Forecasting Procedures of the Air Force Global Weather Central (Miller, 1972), summarizes the basic approach currently used to forecast severe thunderstorms. Although much has been learned about severe weather occurrence since 1972, particularly in the use of satellite imagery, Technical Report 200 remains the premier tutorial on the subject.

In carrying out their responsibilities NSSFC forecasters ask the question "Will severe thunderstorms occur today?" Their response is based upon the traditional severe weather forecasting techniques outlined by Miller. As the National Weather Service (NWS) moves into the 1990's and severe weather forecasting responsibility is absorbed into the operations of the Warning and Forecast Office (WFO), a more meaningful set of questions might be "Will thunderstorms occur today?" and, "If thunderstorms occur, will they reach severe intensity?"

The occurrence of both severe and non-severe thunderstorms in a NWS office's area of warning responsibility demands increased activity in the form of statements, manpower, and if the situation dictates, warnings. The purpose of this note is to suggest that severe thunderstorm forecasting be addressed as a two step, rather than a one step, process. This two step process would answer the two questions posed above by the WFO forecaster. By taking this approach the WFO forecaster will be better able to distinguish situations that produce non-severe thunderstorms from those that produce severe events. This ability will allow the NWS to better serve the needs of the weather information consumer.

2. Thunderstorm Forecasting

A conceptual approach to forecasting significant thunderstorms was addressed by McNulty (1985). Significant thunderstorms are those thunderstorms that produce hail of any size, wind gusts of 35 mph or greater, and/or storms producing sufficiently intense rainfall to possess a potential for flash flooding. Significant thunderstorms include severe weather events.

From a basic (conceptual) point of view, four parameters are necessary for the occurrence of significant convection:

(1) unstable air or a source of destabilization,
(2) moisture,
(3) synoptic scale lift aloft, and
(4) low level convergence.

Each factor is briefly discussed below. These discussions will outline why the ingredients are important to thunderstorm occurrence. For a more detailed discussion see McNulty (1985).

a. Instability or Destabilization

The first element needed to produce thunderstorms is instability or a source of destabilization. Convective weather systems rely to a high degree on the thermal and moisture structure of the atmospheric column in which they develop. Specifically, accelerations attained by the convective core significantly depend upon thermal buoyancy. The potential of an atmospheric column to produce this buoyancy is commonly measured in terms of the column's convective stability.

Two approaches to stability determination are used operationally: stability indices and sounding analysis. Numerous stability indices exist and need not be discussed in detail. Sounding analysis includes parcel theory manipulations as well as modifications by advection or heating effects. Once the presence of instability is determined, other factors must be considered prior to forecasting the occurrence of significant convection.

b. Moisture

Thunderstorms need moisture in the lower layers to develop and grow. Areas favorable for development of thunderstorms are identified from isodrosotherm analyses at the surface and aloft, and through calculations of moisture convergence. Similarly, deep moisture in the vertical column can indicate a potential for heavy rainfall and flash flooding.

c. Synoptic Scale Lift Aloft

Studies of upper tropospheric divergence (McNulty, 1978) and warm advection (Maddox and Doswell, 1982) lead to the conclusion that synoptic scale upward motion is a factor favorable for the development of significant convection. This lift, by itself, will not generate convection but will produce an environment conducive to the development of significant convection. Synoptic scale lift aloft can also act as a destabilizing mechanism, if allowed to act long enough on certain types of vertical thermal and moisture structure.

Synoptic scale lift has been associated with positive vorticity advection (PVA) increasing with height, upper tropospheric divergence, and warm advection, primarily at the 850 mb and 700 mb. These factors are readily identified from synoptic analyses. Satellite imagery has introduced a new dimension to lift determination. The presence of clouds is generally an indicator of upward moving air somewhere in the vertical column.

d. Low Level Convergence

The fourth element required for significant convection is low level convergence. In some ways, this may be the most important of the four parameters. Without low level convergence to start and focus the forcing from the bottom, significant convection usually does not occur. An area, zone or line of convergence provides the mesoscale mechanical lift needed to get the air beyond the level of free convection.

Low level forcing is caused primarily by terrain features and boundaries. Terrain, combined with a particular surface wind flow, can enhance convergence in local areas and lead to convection. A boundary is a characteristic feature common to many mesoscale systems, and refers to any low level, quasi-linear discontinuity characterized by cyclonic shear and convergence. Boundaries are important because they tend to maximize geostrophic relative vorticity and moisture convergence. Significant convection, more often than not, forms along boundaries.

e. Forecast Implications

The four parameters discussed above occur somewhere in the atmosphere most of the time. It is only when they occur over the <u>same geographic area</u> at the <u>same time</u> that significant convection results.

When the four parameters in (a) through (d) are derived from synoptic scale analyses, relatively broad areas can be defined where thunderstorm occurrence is possible. In order to reduce this area in both space and time, surface data must be examined. Mesoanalysis allows the forecaster to identify the low level forcing mechanisms, e.g., boundaries, localizing the area for potential thunderstorm occurrence.

During the forecast process, all available data must be examined, and areas of instability, moisture and synoptic scale lift aloft identified. The forecaster must determine if all factors will occur in the presence of a low level forcing mechanism. When everything comes together in a timely manner, thunderstorms are likely.

3. Severe Thunderstorm Forecasting

The description in section 2 answers the first question posed by the WFO forecaster. To answer the second question, an examination of Miller's "Summary of Key Parameters" (KP-List) is in order. This summary tabulates 14 parameters that are frequently associated with severe weather occurrence. For each parameter a range of values is given that characterizes the severe weather potential as weak, moderate or strong. The "Summary of Key Parameters" list forms the basis for the one step approach to severe weather forecasting mentioned in section 1.

It is useful to compare the KP-List with the four factors discussed in section 2. Table 1 lists the 14 parameters from the KP-List rearranged into six subsets.

Set A contains two parameters that measure instability or destabilization. Indices (#2) are a direct indicator of instability while the 700 mb no-change line (#8) indicates the area where mid-tropospheric cold advection will reduce the cap. Set B contains moisture measures while Set C are factors that indicate where synoptic scale lift is most likely to occur. Using the arguments of section 2, the simultaneous occurrence of the parameters in Sets A through C define a broad area with a potential for thunderstorms.

The only low level convergence feature in the KP-List is shown in Set D. Miller discusses the importance of other low level forcing mechanisms, such as convectively-induced boundaries, but does not explicitly list them on the KP-List.

Set E lists two parameters which have been statistically correlated with severe weather, but don't fit any of the conceptual categories of section 2. These parameters are more analog than conceptual in nature.

At this point in the comparison with section 2 it becomes apparent that a majority of the factors on the KP-List are parameters needed to forecast the occurrence of significant, but not necessarily severe, thunderstorms. Set F lists the remaining parameters from the KP-List. The implication is that these parameters, extreme instability, strong vertical wind shear, and the mid-level dry intrusion, are the primary factors that indicate a potential for severity.

Instability is listed only once on the KP-List, but has been divided into extreme instability and instability in general. This division was dictated by experience. However, this division is supported by a recent article (Bluestein, Marx and Jain (1987)) that found stronger instability in composite soundings for a severe squall line environment than for a non-severe squall line environment.

Experience has also shown that the KP-List works best during the spring. The spring is typically a time of strong dynamic systems. As spring turns into summer, dynamic systems weaken and move poleward. The primary weakness of the KP-List is its poorer performance as a forecast tool during the summer months. This raises a question: "Are the three factors listed in Set F valid indicators of severe weather during the summer?"

As a general rule, strong vertical wind shears are absent during the summer (Schaefer and Livingston, 1988). Instability, on the other hand, is widespread in the maritime tropical air mass that typically engulfs the eastern two-thirds of the U.S. In a study of the differential advection of wet bulb potential temperature at 850 mb and 500 mb, McNulty (1980) found that the magnitude of the differential advection was significantly stronger with severe convection during the summer than with non-severe convection. This result supports retention of extreme instability and mid-level dry intrusions as severe weather indicators during the summer.

4. Conclusions

A comparison of the four ingredients needed for the occurrence of thunderstorms and the 14 factors used to forecast severe weather leads to the conclusion that only three parameters (extreme instability, strong vertical wind shear and the mid-level dry intrusion) on Miller's "Summary of Key Parameters" actually indicate a potential for severe weather occurrence. The remaining factors on the list indicate a potential for significant convection. These results suggest that a forecaster can first anticipate the occurrence of thunderstorms, and then decide if these storms will reach severe limits. This two step approach to severe weather forecasting differs from the more traditional one step approach described by Miller and employed by NSSFC.

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Table 1
Miller's "Summary of Key Parameters" (rearranged)

Numbers in parentheses refer to Miller's original list.

SET A - instability or destabilization measures

(2) stability (lifted index, totals)
(8) 700 mb no-change line

SET B - moisture measures

(6) low-level moisture
(7) 850 mb warm axis versus moist axis
(14) surface dew point

SET C - synoptic scale lift aloft measures

(1) 500 mb vorticity advection
(3) middle level jet
(4) upper level jet
(10) 12-hr surface pressure falls
(11) 500 mb height change

SET D - low level forcing measures

(5) low level jet

SET E - miscellaneous factors

(12) height of wet bulb zero
(13) surface pressure

SET F - severe weather factors

(2) extreme instability
(3) middle level shear
(4) upper level shear
(9) 700 mb dry intrusion

CENTRAL REGION APPLIED RESEARCH PAPER 88-5

TECHNICAL REPORT ON TEMPERATURE, PRECIPITATION, AND AVIATION VERIFICATION AT WSFO SIOUX FALLS FOR 1987

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Overall in 1987, Sioux Falls forecasters made good improvements over guidance (Table 1). The staff's average improvement per four period forecast of +1.6 degrees over temperature guidance was a good yearly mark. The absolute error of 4.1 degrees tied for the lowest mark since this verification began in 1981! A three percent improvement over precipitation probability guidance is also considered a fairly good mark because precipitation frequency was low in 1987 and gains over guidance are much harder to obtain in dry periods than in wet ones. The years ELSI (Effective Log Score Improvement over guidance = 1/3 [2 x CIG IMPVMT OVR GUID + VSBY IMPVMT OVR GUID]), looked excellent at +32.2 percent, but this was actually about five percent lower than the staff's average over the last two years. Of course, we could only verify 45 percent of this year's aviation data because of the delay in receiving the verification software for the new terminal release times.

Table 1
WSFO Sioux Falls Monthly Verification Statistics for 1987

Month	Staff Absolute Error	Improvement Over Guidance
Jan	5.5	+4.0
Feb	4.8	+3.2
Mar	5.0	+1.2
Apr	4.2	+0.4
May	3.9	+0.8
Jun	3.1	+0.4
Jul	3.6	+2.8
Aug	3.5	+0.8
Sep	3.6	+0.8
Oct	4.1	+0.8
Nov	4.1	+0.4
Dec	4.3	+2.0

Table 2
WSFO Sioux Falls Verification Statistics for Years 1981-1987

	1987	1986	1985	1984	1983	1982	1981
Staff Absolute Error	4.1	4.1	4.39	4.45	4.43	4.65	4.56
Guidance Absolute Error	4.5	4.4	4.92	5.03	4.97	5.02	4.95
Improvement Over Guidance	+1.6	+1.2	+2.12	+2.32	+2.17	+1.48	+1.56

The attached TEMPCHECK tables and graphs show that Sioux Falls forecasts were moderately better for Sioux Falls than were for Rapid City. However, improvements over guidance were made on all periods at both locations. The lowest improvement (+3 percent) occurred in the first period at Rapid City. This anomaly, although not very frequent, has popped up before. One possible explanation is that forecasters tend to expect that they will beat guidance in the first period and so vary from guidance on most forecasts, perhaps even when guidance is very good. In latter periods the technique may be to only change the guidance temperatures that stick out as bad. In 1987 no significant high or low bias was noted at Rapid City while a definite low bias was noted for local forecasters and especially for guidance. The opposite trend was noted in 1986. Since 1987 was Sioux Falls' fourth warmest year on record, so the low bias was not surprising.

Finally, the bar graphs show that the greatest number of temperature forecasts by Sioux Falls forecasters were in the -3 to +3 error category. However, there were more temperature forecasts that were ten degrees or more too cold than in the previous year. Again, the extremely warm year certainly was most likely the reason for this low bias. However, local forecast error was less than guidance error, once again.

The three percent improvement over probability of precipitation guidance was a result of a modest Brier score point gain of approximately +1300 points. The staff did about as well at Rapid City this year (+3 percent) as at Sioux Falls (+4 percent) (see the attached precipitation tables). Local forecasters were again able to improve on all periods at both Sioux Falls and Rapid City. Note, from the yearly reliability graphs attached, that the local forecasters curve at Sioux Falls was excellent. This curve (1) was very near the ideal curve along the 45 degree axis, (2) was closer to ideal than guidance at nearly all PoP's, and (3) corrected very well for underforecasting that had showed up in previous years. The local and MOS curves at Rapid City were also closer to ideal than in the previous two years.

A review of the reliability graphs and tables for warm season precipitation for data from May 1st through August 31st shows, once again, that warm season precipitation forecasts at Rapid City had no obvious bias. Local forecaster's underforecasting of warm season probabilities of previous years at Sioux Falls was nearly completely corrected in 1987! Note that guidance still showed an underforecasting bias although not as great as in the past two years. Precipitation frequency in 1987, though, was significantly lower than in the past few years, so it's logical to assume that if precipitation frequency had been up, guidance would probably have showed more underforecasting bias.

	1987	1986	1985	1984
Staff Yearly Improvement (Percent)	+3	+6	+1.0	+3.6
Brier Score Point Gain	+1309	+2849	+324	Not Computed

The attached aviation tables show that local forecasters were categorically correct on ceiling and visibility forecasts at Rapid City and Sioux Falls 89 to 98 percent of the time. This improved on the guidance marks which were in the 86 to 97 percent range. As was the case last year, guidance IFR forecasts were poor because they verified VFR most of the time. Guidance IFR ceiling forecasts were better, but still mediocre. Local forecasters verified well on IFR ceiling and visibility forecasts at Sioux Falls, as they did last year. However, local IFR forecasts at Rapid City, though few, tended to verify VFR, so it is not surprising that about twice as much log score improvement was recorded at Sioux Falls as compared to Rapid City.

	1987	1986	1985	1984
Staff ELSI	32.2	38.6	37.5	38.9

TEMPCHECK

TEMPERATURE VERIFCATION

FROM 1/ 1/ 87 TO 12/ 31/ 87 FCSTR:ALL SEASON: BOTH
CYCLE: BOTH STATION: FSD PERIOD:ALL

	1		2		3		4		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
# FCSTS	727		725		725		725		2902	
MAE (DEG)	3.4	3.7	4.0	4.5	4.4	4.8	5.1	5.7	4.2	4.7
% FCSTR IMP OVR MOS (MAE)	9		12		8		9		9	
% HIGH	41	33	40	33	38	33	38	34	39	33
% LOW	49	58	51	59	54	59	55	60	52	59
% CORRECT	9	7	8	6	6	7	6	4	7	6
% GE 2 DEG ERR....	71	75	75	78	77	79	81	80	76	78
% GE 10 DEG ERR ..	3	4	6	10	8	11	15	19	8	11
% MOS UNCHANGED ..	25		31		31		33		30	
% MOS RAISED	50		47		43		40		45	
% MOS LOWERED	23		21		25		25		23	
% MOS CHGD CORRECT	57		59		57		59		58	
# ACTUAL TEMP CHGS > 10 DEG	179		180		180		180		719	
MAE (DEG) WHEN > 10 DEG CHGS ...	4.9	5.1	5.5	5.6	6.0	6.2	7.2	7.5	5.9	6.1

TEMPCHECK

TEMPERATURE VERIFCATION

FROM 1/ 1/ 87 TO 12/ 31/ 87 FCSTR:ALL SEASON: BOTH
CYCLE: BOTH STATION: RAP PERIOD:ALL

	1		2		3		4		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
# FCSTS	726		726		725		724		2901	
MAE (DEG)	3.4	3.6	3.8	4.1	4.2	4.5	4.8	5.2	4.1	4.3
% FCSTR IMP OVR MOS (MAE)	3		8		6		6		6	
% HIGH	42	38	44	41	45	42	46	45	44	42
% LOW	50	53	46	50	45	50	46	47	47	50
% CORRECT	7	7	9	8	8	6	7	7	8	7
% GE 2 DEG ERR....	71	72	72	75	75	78	77	81	74	76
% GE 10 DEG ERR ..	3	4	7	9	9	11	13	15	8	10
% MOS UNCHANGED ..	31		35		36		40		35	
% MOS RAISED	42		39		39		31		38	
% MOS LOWERED	25		25		24		27		25	
% MOS CHGD CORRECT	51		57		56		56		55	
# ACTUAL TEMP CHGS > 10 DEG	175		177		175		175		702	
MAE (DEG) WHEN > 10 DEG CHGS ...	4.7	4.6	5.1	4.9	6.0	5.6	7.0	6.9	5.7	5.5

PCPNTABLE

PRECIPITATION VERIFICATION

FROM 1/ 1/ 87 TO 12/ 31/ 87 FCSTR = ALL SEASON: BOTH

CYCLE: BOTH PERIOD: ALL STATION: FSD

	1		2		3		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
# FCSTS	727		725		724		2176	
OBSVD PCPN FREQ ...	129		129		129		387	
MEAN POP	17	14	17	13	17	14	17	14
MEAN POP (DRY).....	11	9	12	9	13	10	12	9
MEAN POP (WET).....	48	37	39	32	35	28	40	32
BRIER SCORE	9	10	10	11	11	12	10	11
% IMPRV OVR MOS ...	7		0.9		4		4	
% MOS UNCHANGED ...	86		88		88		88	
% MOS RAISED	11		9		9		10	
% MOS LOWERD	2		1		1		1	
% MOS CHGD RGT DIR.	56		39		46		48	
TOTAL % CORRECT ...	86	85	64	84	83	83	84	84

PCPNTABLE

PRECIPITATION VERIFICATION

FROM 1/ 1/ 87 TO 12/ 31/ 87 FCSTR = ALL SEASON: BOTH

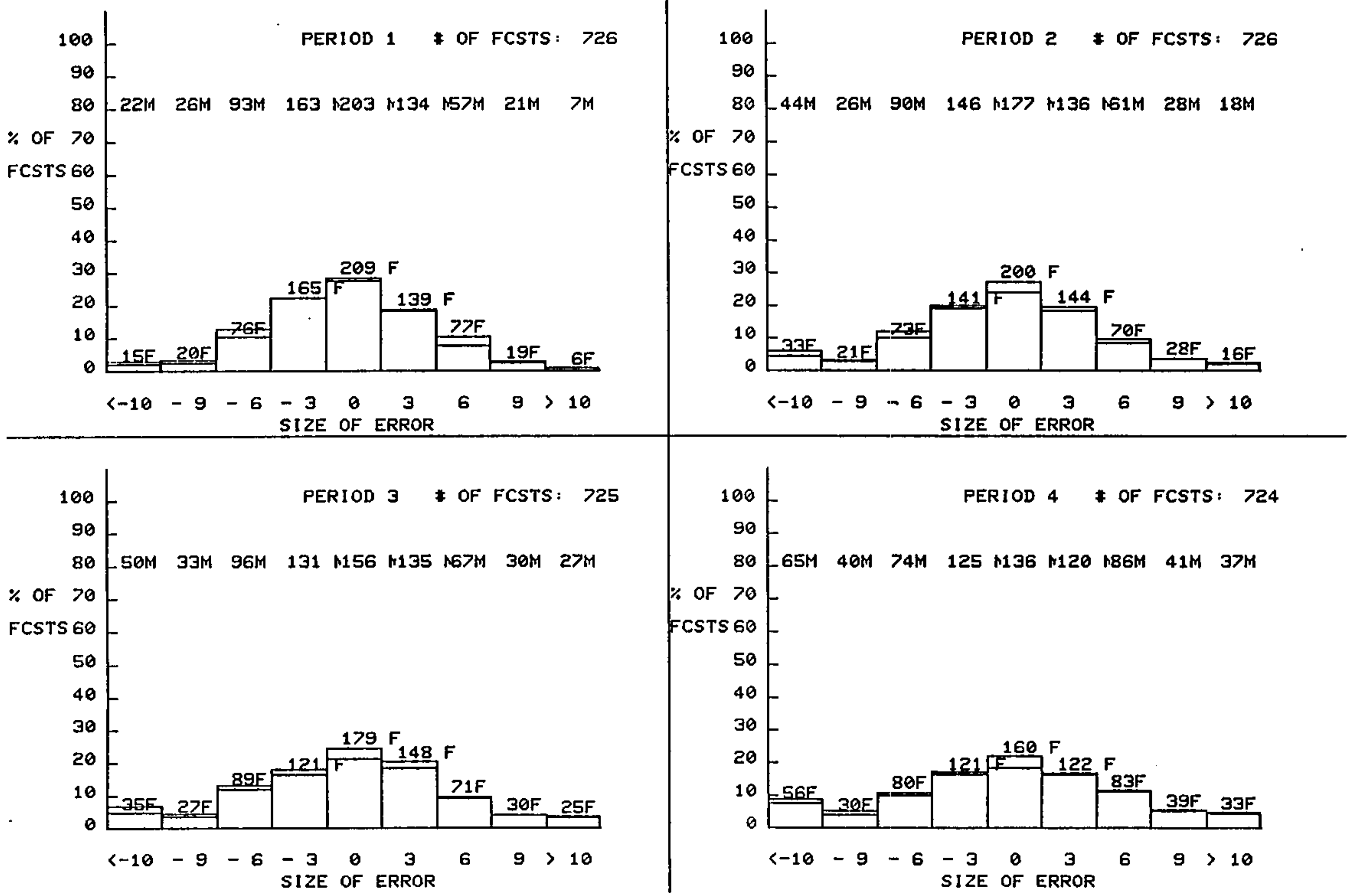
CYCLE: BOTH PERIOD: ALL STATION: RAP

	1		2		3		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
# FCSTS	728		726		725		2179	
OBSVD PCPN FREQ ...	105		106		106		317	
MEAN POP	16	13	16	13	15	14	16	13
MEAN POP (DRY).....	11	8	12	10	12	11	12	10
MEAN POP (WET).....	45	37	38	32	34	30	39	33
BRIER SCORE	8	8	9	9	9	10	9	9
% IMPRV OVR MOS ...	5		2		2		3	
% MOS UNCHANGED ...	90		91		92		91	
% MOS RAISED	6		6		5		6	
% MOS LOWERD	2		1		2		2	
% MOS CHGD RGT DIR.	61		48		51		54	
TOTAL % CORRECT ...	89	88	87	86	87	85	88	86

TEMPERATURE VERIFICATION

STATION: RAP SEASON: BOTH STARTING: 1/ 1/87

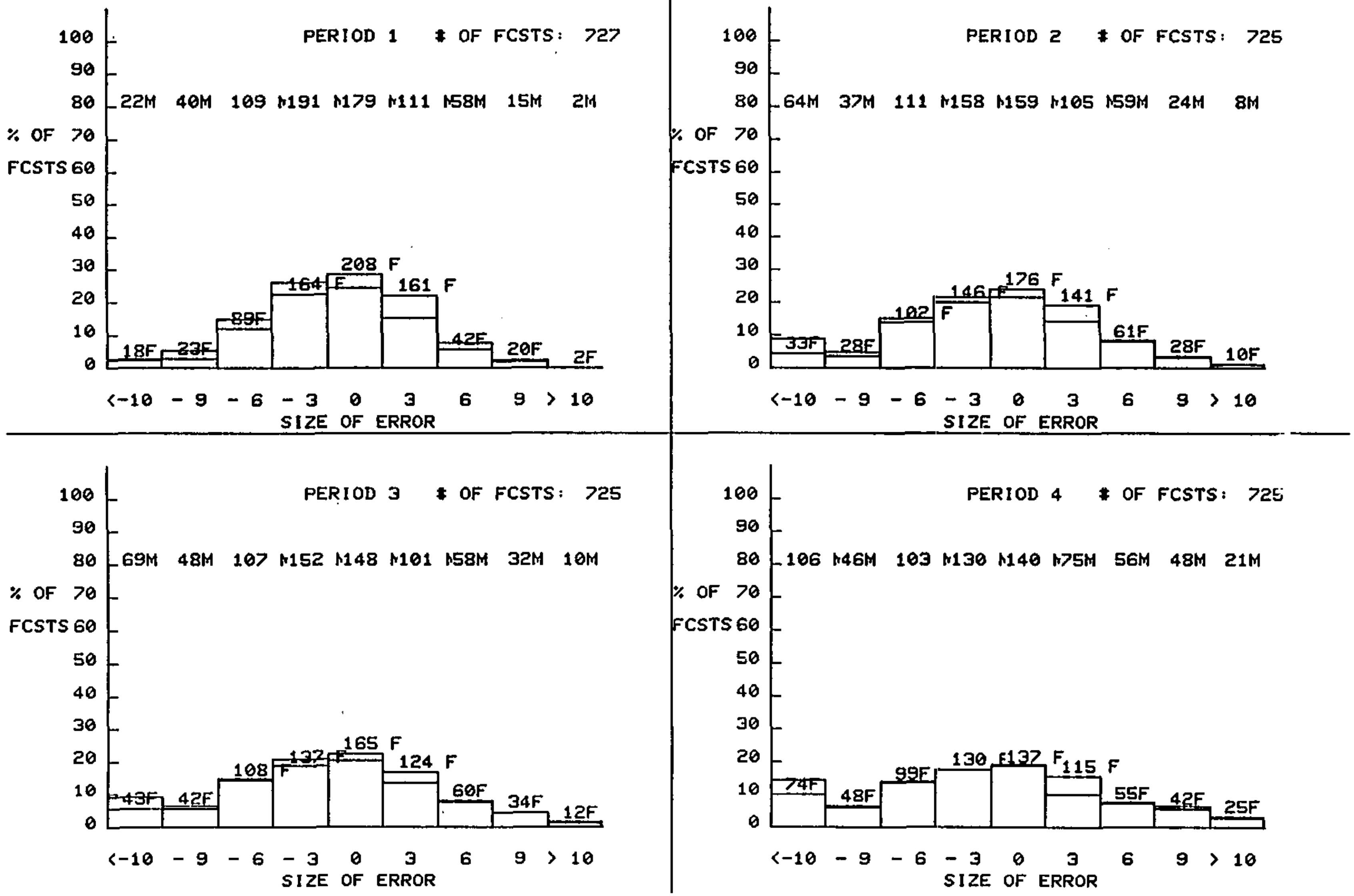
CYCLE: BOTH FORECASTER: ALL ENDING: 12/31/87

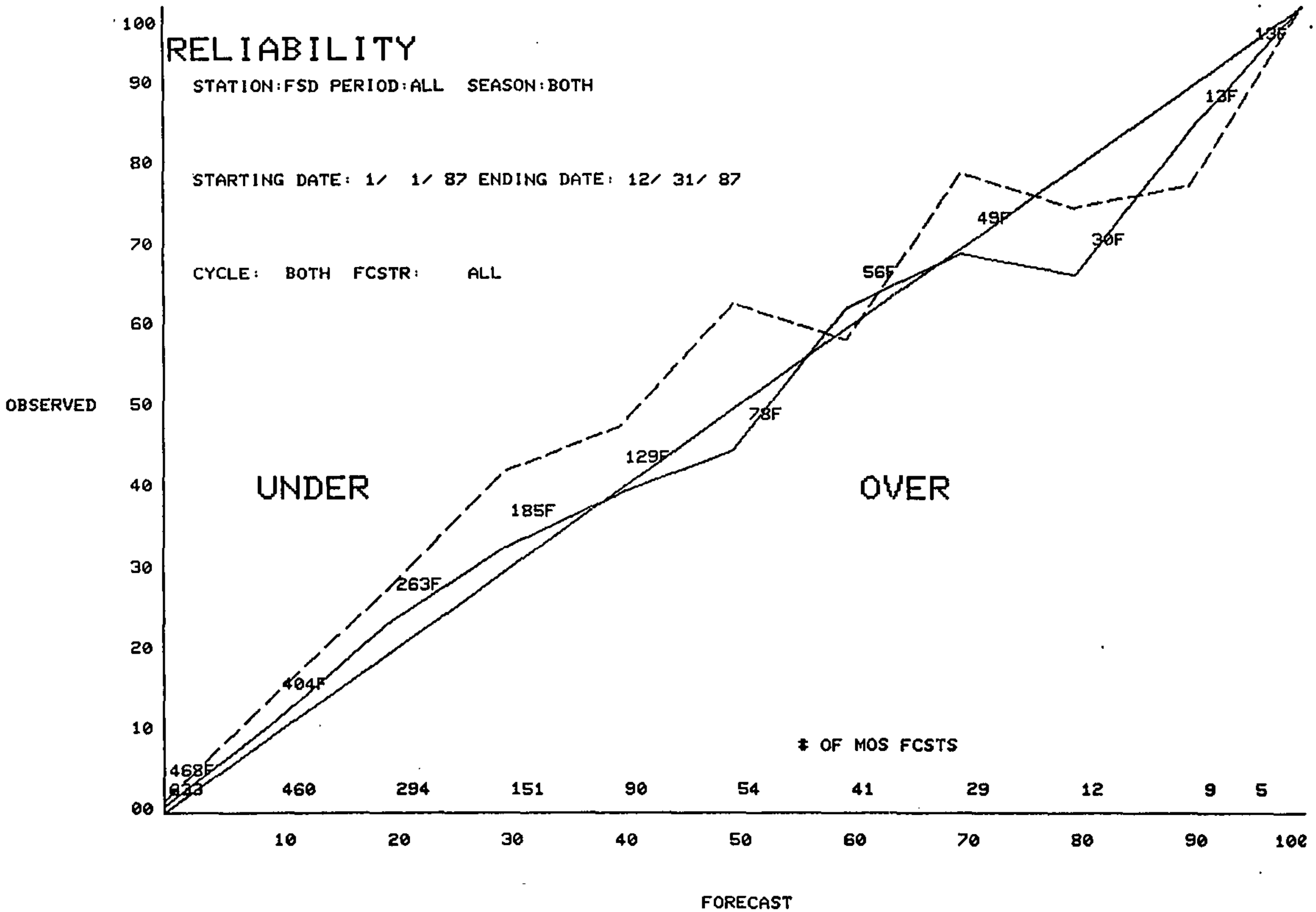


TEMPERATURE VERIFICATION

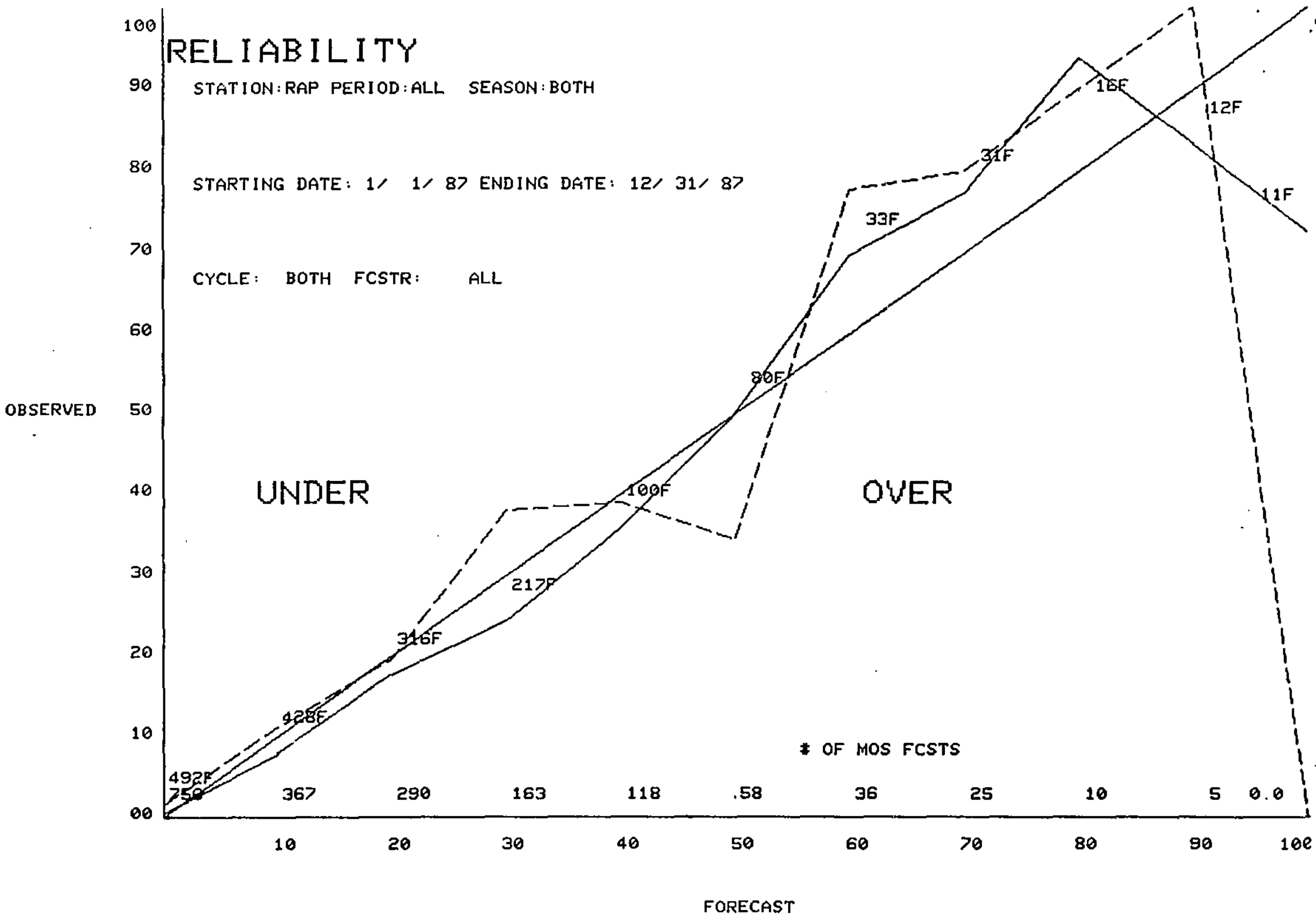
STATION: FSD SEASON: BOTH STARTING: 1/ 1/87

CYCLE: BOTH FORECASTER: ALL ENDING: 12/31/87





RELIABILITY
STATION:FSD PERIOD:ALL SEASON:BOTH
STARTING DATE: 1/ 1/ 87 ENDING DATE: 12/ 31/ 87
CYCLE: BOTH FCSTR: ALL
OBSERVED
FORECAST
UNDER
OVER
OF MOS FCSTS
468F
833
460
294
151
90
54
41
29
12
9
5
404F
263F
185F
129F
78F
56F
49F
30F
13F
13F
00
10
20
30
40
50
60
70
80
90
100


RELIABILITY
STATION:RAP PERIOD:ALL SEASON:BOTH
STARTING DATE: 1/ 1/ 87 ENDING DATE: 12/ 31/ 87
CYCLE: BOTH FCSTR: ALL
OBSERVED
FORECAST
UNDER
OVER
OF MOS FCSTS
492F
428F
316F
217F
100F
80F
33F
31F
16F
12F
11F
759 367 290 163 118 .58 36 25 10 5 0.0
00 10 20 30 40 50 60 70 80 90 100
10 20 30 40 50 60 70 80 90 100

PCPNTABLE

PRECIPITATION VERIFICATION

FROM 5/ 1/ 87 TO 8/ 31/ 87 FCSTR = ALL SEASON: BOTH

CYCLE: BOTH PERIOD: ALL STATION: FSD

	1		2		3		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
* FCSTS	245		244		244		733	
OBSVD PCPN FREQ ...	56		56		55		167	
MEAN POP	23	18	22	18	22	18	22	18
MEAN POP (DRY).....	16	13	18	14	17	15	17	14
MEAN POP (WET).....	47	37	36	31	36	28	39	32
BRIER SCORE	11	12	14	14	13	15	13	14
% IMPRV OVR MOS ...	8		0.9		8		5	
% MOS UNCHANGED ...	81		85		85		84	
% MOS RAISED	15		11		13		13	
% MOS LOWERD	3		2		1		2	
% MOS CHGD RGT DIR.	53		38		47		47	
TOTAL % CORRECT ...	82	80	79	78	79	78	80	79

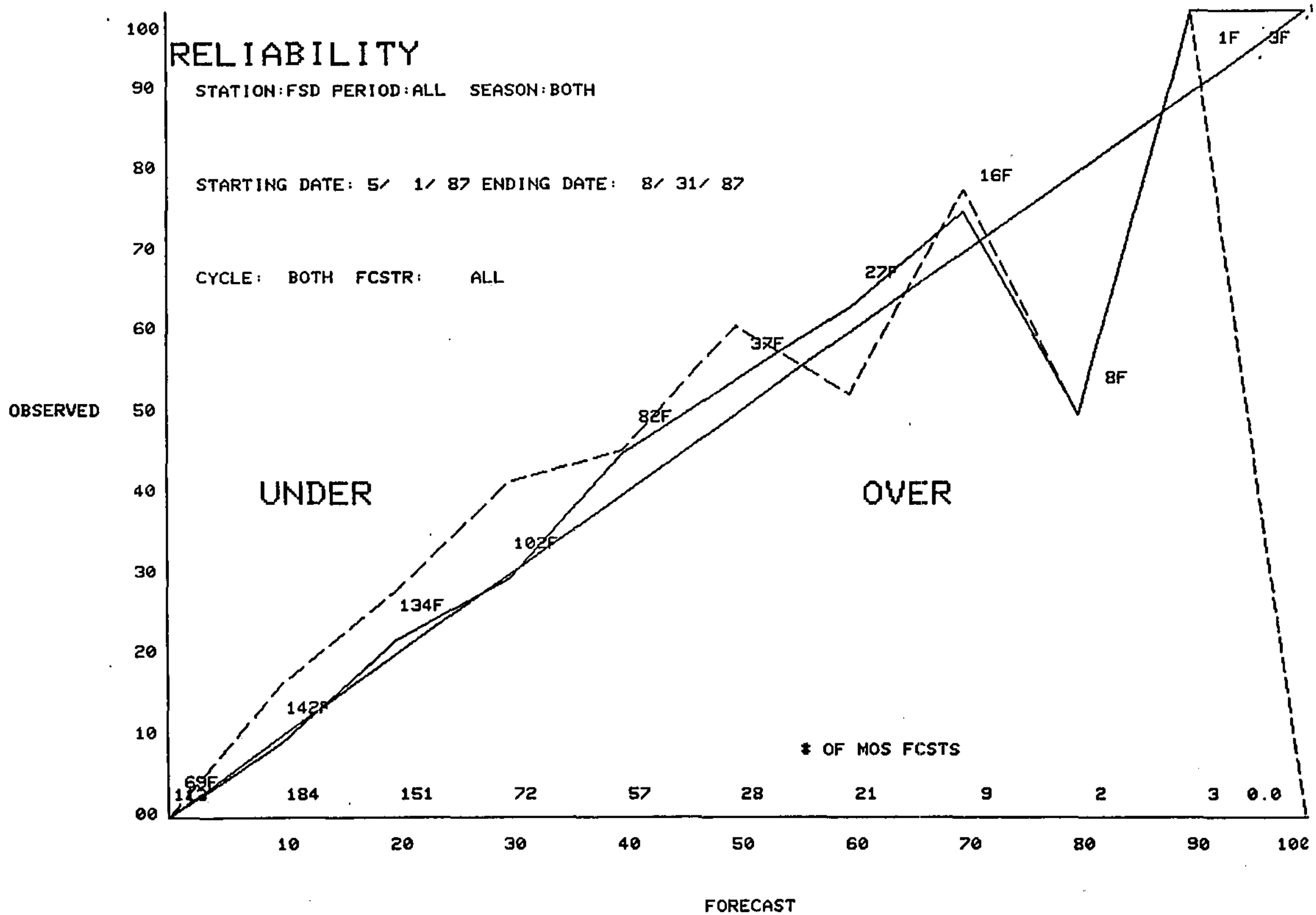
PCPNTABLE

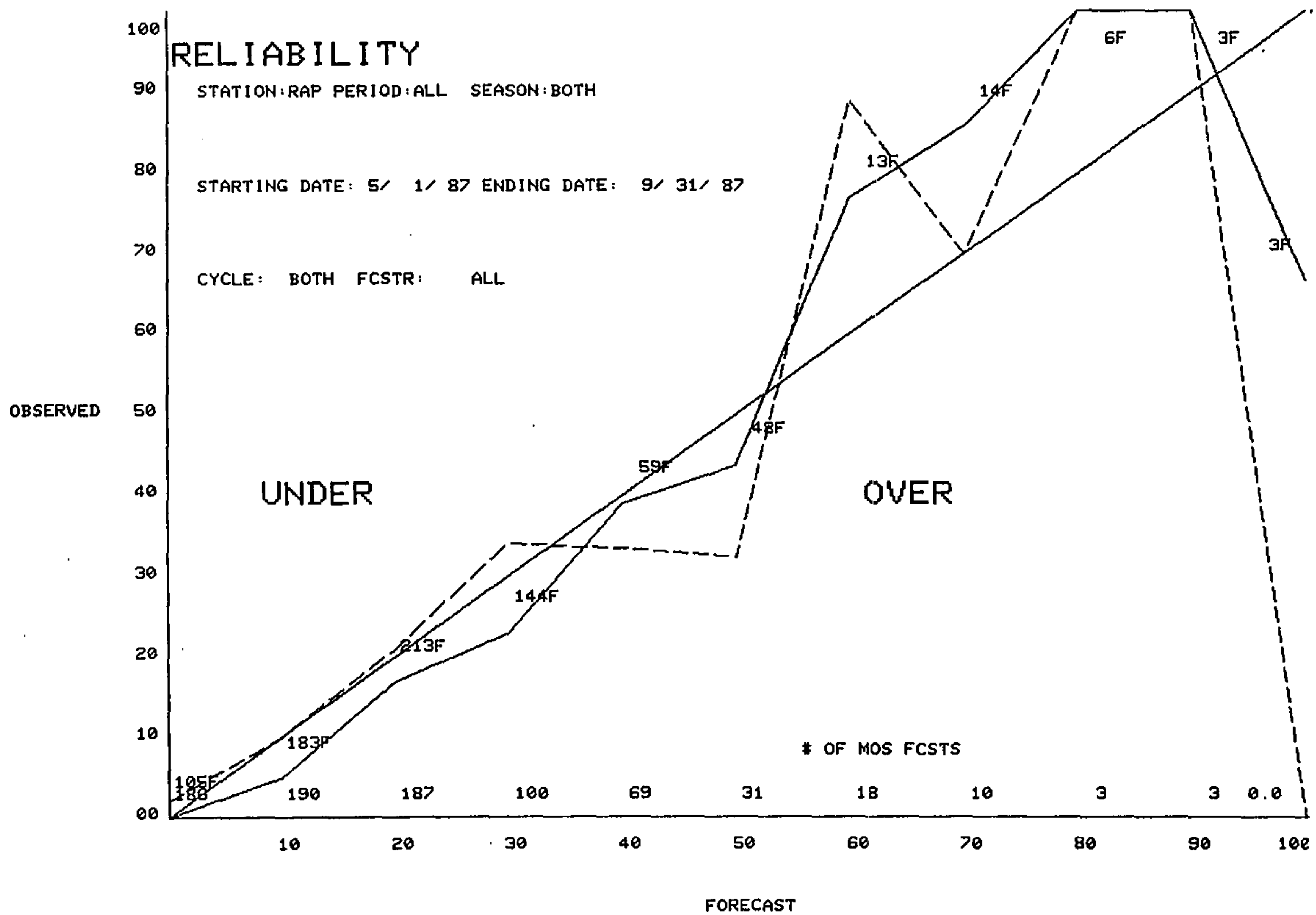
PRECIPITATION VERIFICATION

FROM 5/ 1/ 87 TO 9/ 31/ 87 FCSTR = ALL SEASON: BOTH

CYCLE: BOTH PERIOD: ALL STATION: RAP

	1		2		3		ALL	
	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS	FCSTR	MOS
* FCSTS	307		306		306		919	
OBSVD PCPN FREQ ...	53		54		54		161	
MEAN POP	20	17	20	17	19	17	20	17
MEAN POP (DRY).....	16	13	16	13	16	15	16	13
MEAN POP (WET).....	43	37	38	33	33	30	38	33
BRIER SCORE	10	10	11	11	12	12	11	11
% IMPRV OVR MOS ...	4		1		3		3	
% MOS UNCHANGED ...	89		91		91		90	
% MOS RAISED	6		7		5		6	
% MOS LOWERD	3		1		2		2	
% MOS CHGD RGT DIR.	59		44		50		51	
TOTAL % CORRECT ...	86	84	84	84	83	82	84	83


RELIABILITY
STATION:FSD PERIOD:ALL SEASON:BOTH
STARTING DATE: 5/ 1/ 87 ENDING DATE: 8/ 31/ 87
CYCLE: BOTH FCSTR: ALL
OBSERVED
00
10
20
30
40
50
60
70
80
90
100
UNDER
OVER
69F
142F
134F
102F
82F
37F
27F
16F
8F
1F
3F
OF MOS FCSTS
184
151
72
57
28
21
9
2
3
0.0
10
20
30
40
50
60
70
80
90
100
FORECAST


RELIABILITY
STATION:RAP PERIOD:ALL SEASON:BOTH
STARTING DATE: 5/ 1/ 87 ENDING DATE: 9/ 31/ 87
CYCLE: BOTH FCSTR: ALL
OBSERVED
FORECAST
UNDER
OVER
OF MOS FCSTS
105F
188
183F
190
213F
187
144F
100
59F
69
48F
31
13F
18
14F
10
6F
3
3F
3
3F
0.0
00
10
20
30
40
50
60
70
80
90
100

FT CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	77	44	78	199
MVFR	22	79	105	206
VFR	22	65	2764	2851
TOTAL	121	188	2947	3256
BIAS	1.6	1.0	0.9	

% CORRECT 89 LOG SCORE 3.9 IM/MOS 31.2

VS. MOS 3.8

FT VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	26	22	60	108
MVFR	3	13	35	51
VFR	12	30	3055	3097
TOTAL	41	65	3150	3256
BIAS	2.6	0.7	0.9	

% CORRECT 95 LOG SCORE 1.5 IM/MOS 34.3

VS. MOS 1.6

MOS CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	56	35	61	152
MVFR	27	36	92	155
VFR	38	63	1959	2060
TOTAL	121	134	2112	2367
BIAS	1.2	1.1	0.9	

% CORRECT 86 LOG SCORE 5.6

MOS VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	24	9	51	84
MVFR	7	4	28	39
VFR	53	28	2163	2244
TOTAL	84	41	2242	2367
BIAS	1.0	0.9	1.0	

% CORRECT 92 LOG SCORE 2.4

STATION:ALL PERIOD:ALL SEASON:BOTH
STARTING DATE:01/ 01/ 87 ENDING DATE: 12/ 31/ 87
CYCLE:BOTH FORECASTER: ALL

FT CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	74	42	46	162
MVFR	20	50	56	126
VFR	16	33	1291	1340
TOTAL	110	125	1393	1628
BIAS	1.4	1.0	0.9	

% CORRECT 86   LOG SCORE 4.9   IM/MOS 35.4

VS. MOS 4.7

FT VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	26	21	47	94
MVFR	3	13	34	50
VFR	6	20	1458	1484
TOTAL	35	54	1539	1628
BIAS	2.6	0.9	0.9	

% CORRECT 91   LOG SCORE 2.4   IM/MOS 37.8

VS. MOS 2.4

MOS CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	53	32	37	122
MVFR	23	20	52	95
VFR	27	38	903	968
TOTAL	103	90	992	1185
BIAS	1.1	1.0	0.9	

% CORRECT 82   LOG SCORE 7.3

MOS VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	24	9	39	72
MVFR	7	4	27	38
VFR	40	27	1008	1075
TOTAL	71	40	1074	1185
BIAS	1.0	0.9	1.0	

% CORRECT 87   LOG SCORE 3.9

STATION:FSD   PERIOD:ALL   SEASON:BOTH

STARTING DATE:01/ 01/ 87 ENDING DATE: 12/ 31/ 87

CYCLE:BOTH   FORECASTER: ALL

FT CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	3	2	32	37
MVFR	2	29	49	80
VFR	6	32	1473	1511
TOTAL	11	63	1554	1628
BIAS	3.3	1.2	0.9	

% CORRECT 92 LOG SCORE 2.9 IM/MOS 23.3

VS. MOS 2.9

FT VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	0.0	1	13	14
MVFR	0.0	0.0	1	1
VFR	6	10	1597	1613
TOTAL	6	11	1611	1628
BIAS	2.3	0.0	1.0	

% CORRECT 98 LOG SCORE 0.6 IM/MOS 20.6

VS. MOS 0.7

MOS CEILING

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	3	3	24	30
MVFR	4	16	40	60
VFR	11	25	1056	1092
TOTAL	18	44	1120	1182
BIAS	1.6	1.3	0.9	

% CORRECT 90 LOG SCORE 3.9

MOS VISIBILITY

FORECAST / OBSERVED	IFR	MVFR	VFR	TOTAL
IFR	0.0	0.0	12	12
MVFR	0.0	0.0	1	1
VFR	13	1	1155	1169
TOTAL	13	1	1168	1182
BIAS	0.9	1.0	1.0	

% CORRECT 97 LOG SCORE 1.0

STATION:RAP PERIOD:ALL SEASON:BOTH
STARTING DATE:01/ 01/ 87 ENDING DATE: 12/ 31/ 87
CYCLE:BOTH FORECASTER: ALL

CRH SSD
CRARP 88-6

CENTRAL REGION APPLIED RESEARCH PAPER 88-6

PREPARING STORM DATA

Steven D. Schurr
National Weather Service Forecast Office
Topeka, Kansas

1. Introduction

This paper describes the procedures developed by the author for preparing the monthly Storm Data report for Kansas. These procedures proved an efficient as well as effective approach to compiling data and preparing required submissions. They are presented here with the hope they might assist other Warnings and Preparedness Meteorologists (WPM's) and others who prepare Storm Data.

The author served as WPM for Kansas and prepared Storm Data reports from October 1980 through September 1987. These procedures represent seven years of experience, and have evolved over the years into an efficient, computer-assisted process.

Storm Data serves two main functions. It is a record of all reported severe and damaging weather, and reported injuries and deaths related to adverse weather. Secondly, it serves as a data base of weather events used to evaluate watches and warnings. This data base is used for a variety of research purposes as well. It is important to keep these two purposes in mind through the entire preparation process, so the final report will satisfy both functions.

The preparation process includes five general tasks. They are: gathering data, assembling data, writing the report, printing, and finally, submitting input to Outstanding Storms.

2. Gathering Data

The Storm Data preparer should investigate all practical information sources for data on weather events. Examine all products generated by the weather office, including statements, warnings, Local Storm Reports (LSR's), and logs. It helps to organize all WSFO and WSO products related to severe weather each day. A stack of each day's products, in chronological order, with LSR's on top followed by warnings, watches, statements, logs, and work sheets proved to be an efficient approach. These daily stacks allow quick and easy access to all severe weather-related products.

Additional information can be obtained by calling county emergency preparedness officials, sheriffs and similar sources that may have knowledge about the event. Furthermore, newspaper clippings and photographs that may be useful for identifying unusual storms for inclusion in the outstanding storms section of Storm Data. A WS Form F-61 (Severe Storm Report) may be mailed for information on a particular storm, but a phone call usually provides more complete information in less time.

Check the SELS list of severe weather events (TOPSTATOP in AFOS for Kansas). It lists events taken from statements, warnings, LSR's, observations, and other products. The SELS list is no longer a source of event information for verification. Storm Data is now the only source for such data. The SELS list is used for preliminary verification only. However, it is a good partial record and starting point for examining severe weather events, though.

Of course, nothing else can be as complete as an on-the-spot survey. The most damaging and severe events should be surveyed if at all possible.

A log (in a spiral pad) including each severe weather event has proven to be valuable (see Figure 1). The log gives a complete list of all severe weather events throughout Kansas. This log might also be kept on a word processor, perhaps in a data base that would aid verification.

It is important to document details about a storm as soon as possible after it occurs. Details tend to fade from memory weeks or even days after an event. Just a few notes scratched on a pad can be extremely valuable later.

A list of all warnings issued in Kansas is then prepared. The SELS list (TOPSTATOP) includes warnings, but it sometimes has mistakes. A log like that in Figure 2 may be helpful. It gives a complete list of warnings issued and provides a data base for examining verification, bias in issuing warnings for certain counties, and other statistics. The SELS list of warnings is used for verification, so it is important to assure it is correct. A log of all watches issued within the state (see Figure 3) may also be valuable.

3. Assembling Data

After all the data is gathered, assemble it so it can be used efficiently. In Kansas, each WSO prepares an initial version of Storm Data that includes events in their individual warning area. The severe weather events log and warnings log are used to prepare a list in a Superwriter file that is sent through AFOS to the Kansas weather offices. The storm report list (see Figure 4) shows all events and warnings by warning area. Note also that the list shows preliminary verification statistics. It is a simple matter to compare an event to the warnings list to determine if a warning was in effect at the time of the event. It is also simple to determine if a warning is verified. The figure shows data for September 1987, a relatively simple month. The system seemed to work best when prepared a week at a time. Second and succeeding weeks' entries are added to entries from the first week each month. At the end of the month the file includes all events and warnings for the entire month.

September

*10	D	√ 1839	70mph + GBA	GCK → Sublette → Liberal	
*14	K	√ 1208	1"A	Tonganoxie	
*14	K	√ 1230	70mph	Central Wyandotte Co.	(65th + Riverview)
*14	T	√ 0927	GBA	Baileyville	
*14	T	√ 1125	GBA	Valley Falls	
*14	T	√ 1145	GBA	2 S Oskaloosa	
*14	T	√ 0803	GBA	Bremen	
*15	W	√ 1731	70mph + 3/4"A	Sedan	
*15	W	1752	3/4"A	Cassoday	
* 9 –	C	√ 1550	3/4"A	Lebanon	(Smith
* 9	C	√ 1550	1"A	Burr Oak	
* 9	C	√ 1622	1"A	Mankato	
9	C	√ 1642	1"A	Osborne	
* 9	C	√ 1644	2"A	Downs	(Osborne)
* 9	C	√ 1650	3/4"A	Cawker City	(mitchell)
* 9	C	√ 1719	3/4"A	Glen Elder	(mitchell)
* 9	C	√ 2000?	GBA	8E Salina	
+ * 14	C	√ 0722	1.5"A	NE Washington Co.	New Hanover
+ * 15	C	√ 1904	51kt.	Salina Airport	
+ * 15	T	√ 2000	3/4"A	Manhattan Airport	

Figure 1 Severe weather event log.

FORM CD-26
(12-11-46)

U.S. DEPARTMENT OF COMMERCE

WORKSHEET Warnings Log 1987 Pg 10

Mo.	Day	Typ	Off	Start	End	Counties
9	9	S	C ✓	1831	1930	N Lincoln
	9	S	C ✓	2002	2100	E Saline
9	10	T	D ✓	1839	1940	Finney,Haskell,Seward ✓
	10	S	D ✓	2139	2240	NW Kiowa,E Pratt
	14	S	T ✓	0733	0830	Marshall
	14	S	T ✓	0927	1030	S Nemaha,NE Pottawatomie,Jackson
	14	S	T ✓	1033	1130	Jackson,XX Jefferson,W Atchison
	14	S	T ✓	1130	1230	XXXX Jackson
	14	S	K ✓	1148	XXXX 1245	Leavenworth
	14	S	K ✓	1214	1315	Johnson,Wyandotte
	15	S	W ✓	1722	1820	Chautauqua
	15	S	W ✓	1745	1850	N Montgomery,Wilson
	15	S	W ✓	1800	1900	Chase
	9	S	C ✓	1510	1610	Smith
	9	S	C ✓	1520	1620	Jewell
	9	S	C ✓	1608	1710	E Smith,Jewell
	9	S	C ✓	1641	1740	E Osborne,W Mitchell
	9	S	C ✓	1725	1830	Mitchell,E Osborne

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Figure 2 Log of warnings issued.

FORM CD-26
(12-11-46)

U.S. DEPARTMENT OF COMMERCE

WORKSHEET

Watch Log 1987 Pg 2

No	Day	#&Type	Start	End	Sections	Cancel
6	29	283 S	1430	2100	SW,SC,SE	
7	1	293 T	1530	2100	NW,WC,SW	
	1	296 S	2100	0200	NW,WC,SW	
	2	297 S	0200	0700	SW,SC	
	4	309 S	0315	0800	SW,SC,SE	
	4	311 S	0800	1400	SE	
	5	316 S	0200	0800	C,SW,SC,SE	
	5	317 S	0515	1000	EC,SE	
	5	322 S	1745	2300	EC,SE	1943
	7	339 S	1830	2400	NW,NC,NE,WC,C,EC	
	7	341 S	2330	08/0400	NC,C,EC,ESC,SE	2241
	8	344 S	1900	2400	NW,WC,SW	
	9	350 S	1445	2200	NE,C,EC	1730
	11	368 S	1945	12/0100	NW,NC,WC,C,SW,SC	
	11	369 S	2315	12/0400	NC,NE	
	12	370 S	0100	0600	NC,NE,C,EC,SC,SE	
	12	371 S	[illegible]	0330-0900	NC,NE,C,EC,SC,SE	
	12	376 S	1530	2200	SC,SE	
	14	388 S	1445	2100	SW,SC	
8	6	473 S	1615	2300	NW,NC,NE,WC,C,EC	2030
	7	474 S	1515	2100	NW,NC,NE,WC,C,EC	
	17	490 S	2100	18/03	NC,NE,C,EC,SC,	
	19	494 S	1300	2000	NC,NE,C,EC	
	19	495 S	1645	2200	EC,SE	
	25	501 S	1800	2300	NC,NE,C,EC	2052
9	14	521 S	1015	1500	NE,EC	
	15	525 S	1400	1900	SC,SE,C,NC	
	9	508 S	1500	2100	NC,WC,C,SW,SC	
10	30	540 S	1530	2000	SC	1930

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Figure 3 Log of all watches issued within the state.

```
ZCZC TOPADMTOP SDC
TTAA00 KTOP DDHHMM

///SAVE A COPY FOR THE OIC/// Use PRINT:TOPADMTOP to get all pages.
Summary of Severe Weather Events and warnings for September through
9/23.

Each event should be listed in your Storm Data write up.

  Codes: S=SVR  T=TOR  F=FFW    *=on SELS list (TOPSTATOP)
         s=SVR in effect at time of event
         t=TOR in effect at time of event
         #v= # of counties verified by wind or hail
         #V= # of counties verified by Tornado

CONCORDIA's EVENTS:              WARNINGS:
s09 *1550 3/4"A Lebanon          1v  09 S 1510-1610 Smith
s09 *1550 1"A Burr Oak           1v  09 S 1520-1620 Jewell
s09 *1622 1"A Mankato            1v  09 S 1608-1710 E Smith,Jewell
s09  1642 1"A Osborne            2v  09 S 1641-1740 E Osborne,W Mitchell
s09 *1644 2"A Downs              0v  09 S 1725-1830 Mitchell,E Osborne
s09 *1650 3/4"A Cawker City      0v  09 S 1831-1920 N Lincoln
s09 *1719 3/4"A Glen Elder       0v  09 S 2002-2100 E Saline
 09 *2000 GBA 8E Salina
 14 *0722 1.5"A Nr Hanover
 15 *1904 51kt SLN Arpt


DODGE CITY's EVENTS:             WARNINGS:
 10 *1830 70mph&GBA Garden City 0v  09 T 1839-1940 Finney,Haskell,Seward
 10 *1830 70mph&GBA Sublette    0v  09 S 2139-2240 NW Kiowa,E Pratt
 10 *1830 70mph&GBA Liberal

GOODLAND'S EVENTS:               WARNINGS:
NONE                                 NONE


KANSAS CITY'S EVENTS:            WARNINGS:
s14 *1208 1"A Tonganoxie         1v  14 S 1148-1245 Leavenworth
s14 *1230 70mph KC, Ks           1v  14 S 1214-1315 Johnson,Wyandotte


TOPEKA'S EVENTS:                 WARNINGS:
s14 *0803 GBA Bremen             1v  14 S 0733-0830 Marshall
s14 *0927 GBA Baileyville        1v  14 S 0927-1030 S Nemaha,Jackson
s14 *1125 GBA Valley Falls                          NE Pottawatomie
 14 *1145 GBA 2S Oskaloosa       1v  14 S 1033-1130 Jackson,Jefferson,
 15 *2000 3/4"A MHK Arpt                            W Atchison
                                 0v  14 S 1130-1230 Jackson


WICHITA'S EVENTS:                WARNINGS:
s15 *1731 70mph&3/4"A Sedan      1v  15 S 1722-1820 Chautauqua
 15 *1752 3/4"A Cassoday         0v  15 S 1745-1850 N Montgomery,Wilson
                                 0v  15 S 1800-1900 Chase


NNNN
```

Figure 4 Summary of severe weather events and warnings.

Kansas WSO's use the data on the Storm Data list and add to it any additional information they might have. They then write the initial report of events in their warning area and send it through AFOS back to Topeka. The WPM in Topeka then prepares the final report.

4. Writing the Report

Remember to consider the two main functions of Storm Data when writing the final report. Make sure each event is listed properly with the correct time and date. Check the storm report (Figure 2). Remember, for verification, events within ten minutes and within 15 miles of one another in the same county are considered as a single event. Consequently, if large hail fell at a point in county A and also at a point eight miles away ten minutes later, only the first hail report is used for verification. If, instead, the second event was either more than ten miles away, more than 15 minutes later, or in another county, both events should be included for verification. In any case, all severe weather events must be included in the report, whether they are used for verification or not.

Be sure to include sufficient detail to describe the event adequately. The more significant the storm, the greater the need for accurate detail. Concentrate on those storms that cause great damage, injuries or loss of life. Short, general descriptions are sufficient for relatively insignificant events.

Include each individual event on a separate line prior to the narrative. Only those events listed in that manner should be included for verification. Those found only in the narrative are not normally included for verification.

Follow WSOM's F-42 and C-72 and examples shown in them closely when preparing the report. Indenting the location within a county one space to the right seems to make both the county name and location stand out better.

The report for the Topeka and Kansas City warning areas (since Kansas City has just seven Kansas counties in their warning area, Topeka writes its part of the report) is written first. It is entered in a Superwriter file on the IBM PC and stored on floppy disk. Reports from each WSO are added as they come in. Some events are combined when they cross warning area boundaries. Some other adjustments to the WSO reports are also usually required.

The IBM file used (see Figure 5) is in a format that could also later be printed directly on the WS Form F-8. Line width is set at 72 (the maximum for AFOS) and tabs set at 20, 24, 33, 37, 41, 44, 47, 50, and 53. The final version, including entries from all six warning areas in Kansas, like that in Figure 5 is sent through AFOS to all Kansas WSO's including Kansas City. Each area is then examined for discrepancies.

5. Printing

The final report in the form shown in Figure 5 is then adjusted so it can be printed directly onto WS Form F-8. The only steps required to put it in the proper form are: strip off the header (down through the line of dots on

ZCZC TOPADMTOP SDC
TTAA00 KTOP DDHHMM

///SAVE A COPY FOR THE OIC, use PRINT:TOPADMTOP command to get all pages///

KANSAS_STORM_DATA_FOR_SEPTEMBER_1987

Check entries in your warning area, and let me know if changes need to be made. I plan to type the final version tomorrow morning 10/27.

REMEMBER: Storm Data is the only source for event data for warnings verification. If an event is in the following list it will be included when computing verification statistics. If it is not listed, it will not be included. SELS list of warnings is still the official list. I found no discrepancies in SELS list of September warnings.

....

Smith Co							
Lebanon	09	1550CST	0	0	2	4	Hail (.75)
Jewell Co							
Burr Oak	09	1550CST	0	0	2	4	Hail (1.0)
Mankato	09	1622CST	0	0	2	4	Hail (1.0)
Osborne Co							
Osborne	09	1642CST	0	0	2	3	Hail (1.0)
Downs	09	1644CST	0	0	3	3	Hail (2.0)
Mitchell Co							
Cawker City	09	1650CST	0	0	2	3	Hail (.75)
Glen Elder	09	1719CST	0	0	2	3	Hail (.75)
Beloit	09	1738CST	0	0	2	3	Hail (.75)

A cluster of severe thunderstorms moved across Smith and Northern Osborne Counties into Jewell and Mitchell Counties. Large hail damaged milo and corn throughout the storms' path, and it also damaged roofs and cars around Downs.

Saline Co							
8E Salina	09	2000CST	0	0	2	3	Hail (1.75)

A thunderstorm dropped golfball size hail that damaged crops east of Salina.

Kearny Co							
Lakin	10	1815CST	0	0	3	5	Hail (1.75)
Haskell Co							
Sublette	10	1825CST	0	0	3	5	Hail (1.0), TSTM Wind (61)
Seward Co							
Liberal	10	1828CST	0	0	3	4	Hail (.75), TSTM Wind (61)

A line of thunderstorms dropped large hail and produced wind gusts estimated at 70mph in spots from Lakin to Sublette and Liberal. Severe crop damage was done in a strip 8-10 miles wide from 10 miles north of Lakin to Sublette. Hail covered the ground several inches deep in some spots. Hail also killed nearly a thousand ducks northeast of Lakin at Lake McKinney.

Washington Co							
Hanover	14	0706CST	0	0	4	5	Hail (1.5)
Marshall Co							
Bremen	14	0803CST	0	0	4	5	Hail (1.75)
Nemaha Co							
Baileyville	14	0927CST	0	0	4	5	Hail (1.75)
Jefferson Co							
Valley Falls	14	1125CST	0	0	4	3	Hail (1.75)
Oskaloosa	14	1145CST	0	0	4	3	Hail (1.75)
Leavenworth Co							
Tonganoxie	14	1208CST	0	0	3	3	Hail (1.0)
Wyandotte Co							
Kansas City	14	1230CST	0	0	3	0	TSTM Wind (61)

A cluster of severe thunderstorms formed near Washington and moved east through Marysville to Seneca. The storms then turned southeast and moved through Oskaloosa and Kansas City. Golfball size hail fell over a good share of Marshall and Western Nemaha Counties; and again later around Oskaloosa.

The Bremen and Herkimer communities, northwest of Marysville, caught the worst of the storm. Five and a half inches of rain fell in just an hour. Hail stripped crops, broke out windows and damaged roofs. Runoff took out two bridges on rural roads north of Herkimer.

Chautauqua Co							
Sedan	15	1731CST	0	0	2	2	TSTM Wind (61), Hail (.75)

A thunderstorm produced wind gusts estimated at 70 mph and dropped 3/4 inch hail at Sedan.

Butler Co							
Cassoday	15	1752CST	0	0	2	2	Hail (.75)

Three quarter inch hail fell for a short time at Cassoday.

Montgomery Co							
Coffeyville	15	1815CST	0	0	3	0	TSTM Wind Dmg

A wind gust from a thunderstorm tore part of the roof off a youth center in Coffeyville.

Saline Co							
Salina Airport	15	1904CST	0	0	0	0	TSTM Wind (51)

Outflow thunderstorm winds produced a gust measured at 59mph at the Salina Airport. No damage resulted.

Riley Co							
Manhattan Arpt	15	2000CST	0	0	2	0	Hail (.75)

A thunderstorm dropped 3/4 inch hail briefly at the Manhattan Airport. Little damage resulted.

```
Rice Co
 4E Lyons          28  0100CST          0  0  4  0  Lightning
                   Lightning killed 11 head of cattle in a pasture
                   east of Lyons.

                              SPECIAL HAIL SUMMARY

                   Kansas-Oklahoma Hail Loss Service reports indicate
                   hail was especially damaging to crops in the listed
                   counties on the following dates:

                   09  Brown,Ford,Jewell,Smith
                   10  Finney,Haskell,Stevens
                   11  Kearny
                   14  Marshall,Nemaha,Washington
                   15  Edwards,Stafford
                   27  Grant
NNNN
```

Figure 5 Example of Kansas Storm Data report prepared on an IBM PC using Superwriter and sent to Kansas WSO's (including Kansas City) through AFOS.

Figure 5), strip the four n's off the end and change the tabs for proper spacing. The final report must be letter quality, so it is printed on the secretary's NEC Model 2000 printer which has 12 characters per inch and 66 lines per page. The AFOS version is altered as follows: changed line width to 85 and tabs to 22, 27, 36, 43, 50, 55, 61, 67, and 71. The printer is set so it will print the form properly. For the NEC, this means aligning the paper so the print head is on the left edge of the form and on the black line at the top of the form. Next, the print format settings are changed to a page size of 66, a top margin of 10, and a bottom margin of 12. The NEC prints in the proper part of the form, one sheet at a time using those settings. Finally, the form heading is added using a simple Superwriter file with the proper month and spacing to get the F-8 in final form (see Figure 6).

Storm Data is now complete and ready to be mailed. The final Kansas report is sent to 11 separate addresses.

6. Input to Outstanding Storms

The "Outstanding Storm" section was added to the final publication of Storm Data several years ago. It offers the opportunity to document the most significant storms with photographs, maps and other information.

Photographs are obtained from newspapers and other sources. Include copies of the actual newspaper articles that included each photo. A copy of the final published version of Storm Data should be provided to each person who allowed the use of a photo. Draw maps depicting snow depths, isohyets, and tornado tracks to help illustrate the extent of the event. Be as specific as possible.

7. Conclusion

Storm Data is a time consuming and sometimes tedious task. An organized approach can make it more efficient, and sometimes even challenging and fun. The process described above serves well. The author hopes WPM's, MIC's, OIC's and anyone who prepares Storm Data finds some value in it.

8. Acknowledgements

Thanks to Leo Grenier, NSSFC Verification Specialist, for suggesting I document my procedures. Thanks also to Richard P. McNulty, DMIC WSFO Topeka, for his help in organizing and editing.

9. References

National Weather Service Operations Manual F-42, Storm Data and Related Reports.

National Weather Service Operations Manual C-72, National Watch/Warning Verification Program.

WS FORM F-8 (11-81)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

STORM DATA AND UNUSUAL WEATHER PHENOMENA

STATE KANSAS 14 MONTH AND YEAR SEPTEMBER 1987

PLACE	DATE	TIME	LENGTH OF PATH (MILES)	WIDTH OF PATH (YARDS)	NO. OF PERSONS KILLED	NO. OF PERSONS INJURED	ESTIMATED† DAMAGE PROPERTY	ESTIMATED† DAMAGE CROPS	CHARACTER OF STORM
Smith Co							.5	.25	
Lebanon	09	1550CST			0	0	2	4	Hail (.75)
Jewell Co							.5	.25	
Burr Oak	09	1550CST			0	0	2	4	Hail (1.0)
Mankato	09	1622CST			0	0	2 .5	4 .25	Hail (1.0)
Osborne Co									
Osborne	09	1642CST			0	0	2 .5	3 1	Hail (1.0)
Downs	09	1644CST			0	0	3 .5	3 .3	Hail (2.0)
Mitchell Co									
Cawker City	09	1650CST			0	0	2 .5	3 1	Hail (.75)
Glen Elder	09	1719CST			0	0	2 .5	3 1	Hail (.75)
Beloit	09	1738CST			0	0	2 .5	3 1	Hail (.75)
	A cluster of severe thunderstorms moved across Smith and Northern Osborne Counties into Jewell and Mitchell Counties. Large hail damaged milo and corn throughout the storms' path, and it also damaged roofs and cars around Downs.								
Saline Co									
8E Salina	09	2000CST			0	0	2 .5	3 1	Hail (1.75)
	A thunderstorm dropped golfball size hail that damaged crops east of Salina.								
Kearny Co							.5	50	
Lakin	10	1815CST			0	0	3	5	Hail (1.75)
Haskell Co							.5	50	
Sublette	10	1825CST			0	0	3	5	Hail (1.0), TSTM Wind (61)
Seward Co									
Liberal	10	1828CST			0	0	3 1	4 20	Hail (.75), TSTM Wind (61)
	A line of thunderstorms dropped large hail and produced wind gusts estimated at 70mph in spots from Lakin to Sublette and Liberal. Severe crop damage was done in a strip 8-10 miles wide from 10 miles north of Lakin to Sublette. Hail covered the ground several inches deep in some spots. Hail also killed nearly a thousand ducks northeast of Lakin at Lake McKinney.								
Washington Co							20	100	
Hanover	14	0706CST			0	0	4	5	Hail (1.5)
Marshall Co							30	150	
Bremen	14	0803CST			0	0	4	5	Hail (1.75)

WS FORM F-8
(11-81)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

STORM DATA AND UNUSUAL WEATHER PHENOMENA

STATE KANSAS 14 MONTH AND YEAR SEPTEMBER 1987

PLACE	DATE	TIME	LENGTH OF PATH (MILES)	WIDTH OF PATH (YARDS)	NO. OF PERSONS KILLED	NO. OF PERSONS INJURED	ESTIMATED† DAMAGE PROPERTY	ESTIMATED† DAMAGE CROPS	CHARACTER OF STORM
Herkimer	14	0820CST			0	0	430	560	Hail (1.75)
Nemaha Co									
Baileyville	14	0927CST			0	0	420	550	Hail (1.75)
Jefferson Co									
Valley Falls	14	1125CST			0	0	410	35	Hail (1.75)
Oskaloosa	14	1145CST			0	0	419	35	Hail (1.75)
Leavenworth Co									
Tonganoxie	14	1208CST			0	0	35	33	Hail (1.0)
Wyandotte Co									
Kansas City	14	1230CST			0	0	34	0	TSTM Wind (61)
	A cluster of severe thunderstorms formed near Washington and moved east through Marysville to Seneca. The storms then turned southeast and moved through Oskaloosa and Kansas City. Golfball size hail fell over a good share of Marshall and Western Nemaha Counties; and again later around Oskaloosa.								
	The Bremen and Herkimer communities, northwest of Marysville, caught the worst of the storm. Five and a half inches of rain fell in just an hour. Hail stripped crops, broke out windows and damaged roofs. Runoff took out two bridges on rural roads north of Herkimer.								
Chautauqua Co									
Sedan	15	1731CST			0	0	2	2	TSTM Wind (61), Hail (.75)
	A thunderstorm produced wind gusts estimated at 70 mph and dropped 3/4 inch hail at Sedan.								
Butler Co									
Cassoday	15	1752CST			0	0	2	2	Hail (.75)
	Three quarter inch hail fell for a short time at Cassoday.								
Montgomery Co									
Coffeyville	15	1815CST			0	0	3	0	TSTM Wind Dmg
	A wind gust from a thunderstorm tore part of the roof off a youth center in Coffeyville.								
Saline Co									
Salina Airport	15	1904CST			0	0	0	0	TSTM Wind (51)
	Outflow thunderstorm winds produced a gust measured								

WS FORM F-8
(11-81)

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STORM DATA AND UNUSUAL WEATHER PHENOMENA

STATE KANSAS 14 MONTH AND YEAR SEPTEMBER 1987

PLACE	DATE	TIME	LENGTH OF PATH (MILES)	WIDTH OF PATH (YARDS)	NO. OF PERSONS KILLED	NO. OF PERSONS INJURED	ESTIMATED[†] DAMAGE PROPERTY	ESTIMATED[†] DAMAGE CROPS	CHARACTER OF STORM
[illegible]	at 59mph at the Salina Airport. No damage resulted.								
Riley Co Manhattan Arpt	15	2000CST			0	0	2	0	Hail (.75)
	A thunderstorm dropped 3/4 inch hail briefly at the Manhattan Airport. Little damage resulted.								
Rice Co 4E Lyons	28	0100CST			0	0	4	0	Lightning
	Lightning killed 11 head of cattle in a pasture east of Lyons.								

SPECIAL HAIL SUMMARY

Kansas-Oklahoma Hail Loss Service reports indicate hail was especially damaging to crops in the listed counties on the following dates:

09	Brown, Ford, Jewell, Smith
10	Finney, Haskell, Stevens
11	Kearny
14	Marshall, Nemaha, Washington
15	Edwards, Stafford
27	Grant

Figure 6 Example of final WS Form F-8 prepared using IBM PC Superwriter file.

CRH SSD
CRARP 88-7

CENTRAL REGION APPLIED RESEARCH PAPER 88-7

USE OF LONG-WAVES IN FORECASTING

Carl E. Weinbrecht and Charles Myers
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Des Moines, Iowa

1. Introduction

The following case study illustrates the usefulness of the long wave theory. This concept provides a framework for forecasting. It is one of the first steps of the forecast funnel as proposed by Snellman (1982) and Bullock (1986). This concept gives the forecaster a tool which enables one to choose the proper model in difficult situations. NOTE: For an in-depth discussion of long wave theory see Dunn (1986).

2. Case Study

On the January 28, 1987, an examination of the 24 and 36 hour Regional (RGL) 500 mb progs indicated a strong vorticity maximum of 24 units digging northeast from Utah to central Kansas, then east-northeast into central Illinois (Figs. 1 and 2). The cold air at low levels insured any precipitation that would fall would be in the form of snow. Strong dynamics indicated by the RGL would create significant upward vertical motion, rapidly saturating the layers.

Goree and Younkin (1966) (hereafter referred to as GY) state that the most favorable locations for more than four inches of snowfall with respect to the 500 mb vorticity center is about 6.5 to 7 degrees latitude downstream and 2.5 degrees to the left of the track of the maximum during the following 12 hours. If the RGL guidance was accepted and GY's criteria used to predict more than four inches in 12 hours, a band would likely develop across much of Iowa stretching into northern Illinois and southern Wisconsin and it would begin early on the 29th in Iowa.

Since the RGL hit the track of a storm that went through northern and central Missouri almost perfectly the previous week and since the RGL's recent performance was fairly good, it would follow that the RGL was the model of choice. At this point, a forecaster would seriously consider issuing a winter storm watch and, in fact, winter storm watches were issued for northern Illinois and southern Wisconsin.

On the other hand, an examination of the Aviation (AVN) model indicated the vorticity maximum was considerably less intense and its track would be farther north. Using GY's method with the AVN guidance, a snow band would be expected to fall over southern Minnesota, extreme northeast Iowa into central Wisconsin. Although snow was likely, the forecast of weak dynamics would suggest that only weak upward vertical motion and consequently less snow would occur (Figs. 4 and 5). A winter storm watch using the AVN solution would not be necessary.

A dilemma now occurs. Which model does one use? A knowledge of the long wave theory provides a clue as to deciding the model of choice. In this case, the long waves were nearly stationary, and would stay nearly stationary through the forecast period. A long wave trough existed along the East Coast with a long wave ridge along the West Coast.

This can be determined by:

A. Animation of the last five days of the Northern Hemisphere 500 mb initial analysis (NMCGPH5AH).

B. Animation of the last five days of the 500 mb 0-5 wave chart (NMCGPH5T5).

C. Animation of the last five days of the height change chart (NMCGPH5AC).

D. Animation of the 500 mb MRF through 132 hours.

To determine which model to use, examine the behavior of each model's short waves forecast checking to see if the short wave follows the long wave theory. In this case, the short wave should slide down the west side of the long wave trough in an orderly manner. The 500 mb short wave trough will intensify at a steady rate before it moves northeast and weakens as the short wave trough moves up the ridge along the East Coast. To determine if the short wave trough is indeed deepening, follow a 500 mb decameter height. Using the 546 decameter height line, one observes that the RGL height does not change in latitude from 24 through 48 hours as the system moves east. The AVN on the other hand has falling 500 mb heights as the short wave moves east (Figs. 3 and 6).

The AVN goes along with long wave theory. The RGL does not. The forecaster should use the AVN model for guidance. Remember, do not follow the individual vorticity centers to see if the trough is deepening, look at the 500 mb heights with time. In this case, the first vorticity center moved northeast and weakened. Later, another vorticity center developed to the southwest of the first vorticity center and moved northeast as the trough deepened.

The AVN indeed was the better model. One to two inches of snow occurred over extreme northern Iowa and southern Minnesota. Three to five inches of snow occurred from extreme northeast Iowa to central Wisconsin.

3. References

Bullock, C. S. 1986: A proposed forecast methodology. National Winter Storm Workshop, Lowry Air Force Base, CO.

Dunn, L. 1986: Large scale diagnosis including blocking. National Winter Storm Workshop, Lowry Air Force Base, CO.

Goree, P. A., and Younkin, R. J., 1966: Synoptic climatology of heavy snowfall over the central and eastern United States. Mon. Wea. Rev., 94, 663-668.

Snellman, L. W. 1982: Impact of AFOS on operational forecasting. Preprints, 9th Conf. on Weather Forecasting and Analysis (Seattle, WA), Amer. Meteor. Soc., 13-16.

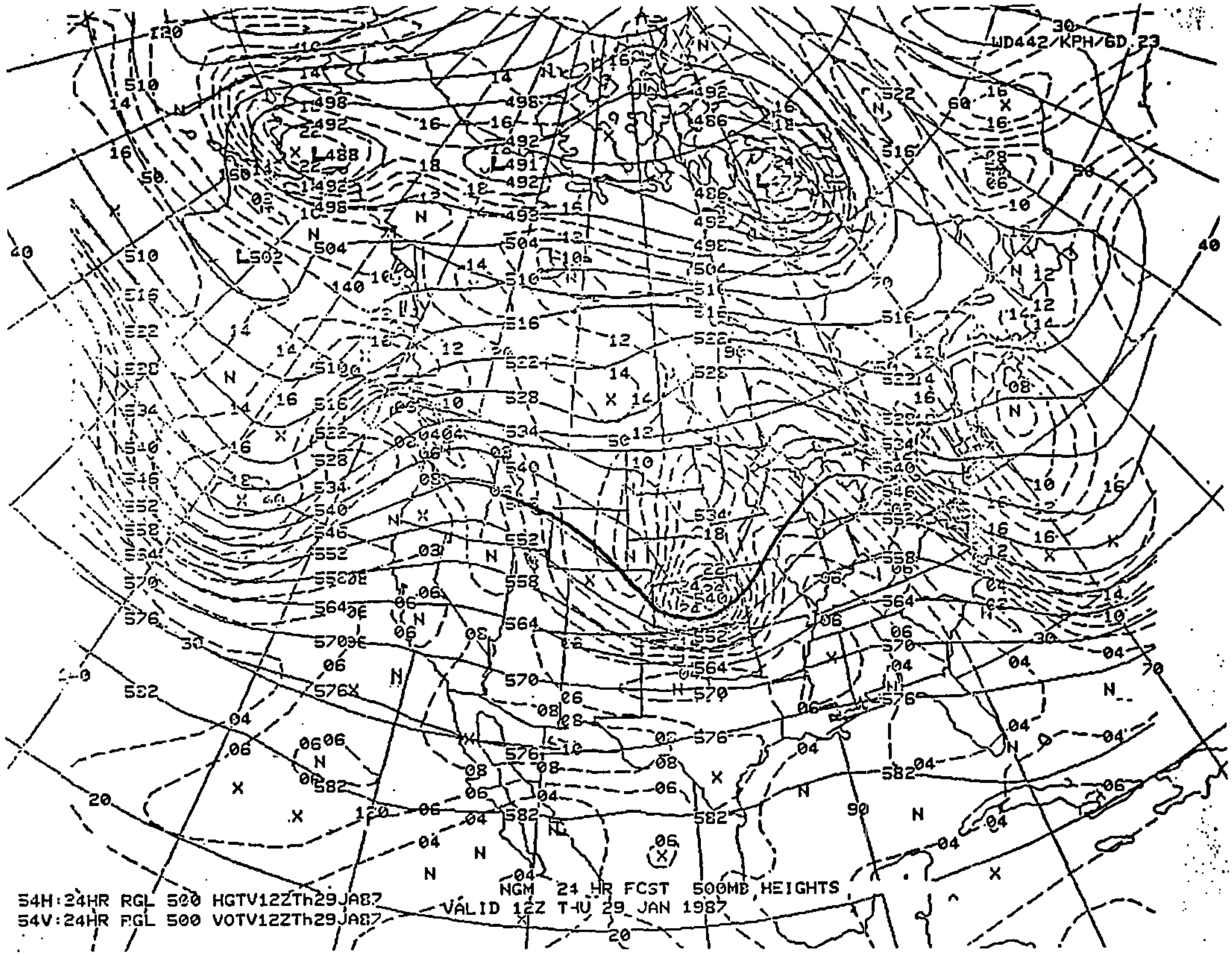

Fig. 1 24 Hour 500 mb height and vorticity forecast valid 12Z, January 29, 1987.

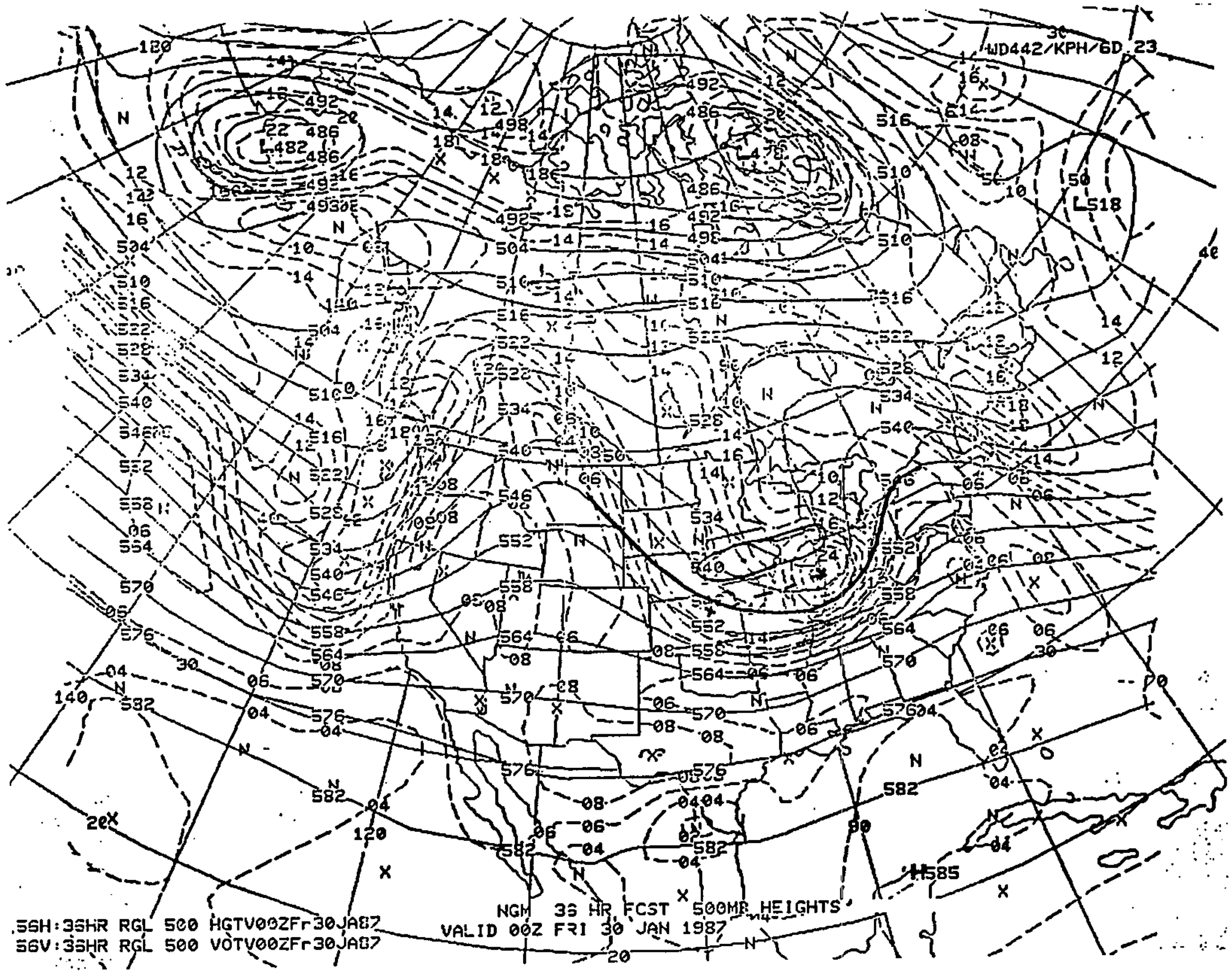

Fig. 2 36 Hour 500 mb height and vorticity forecast valid 00Z, January 30, 1987.

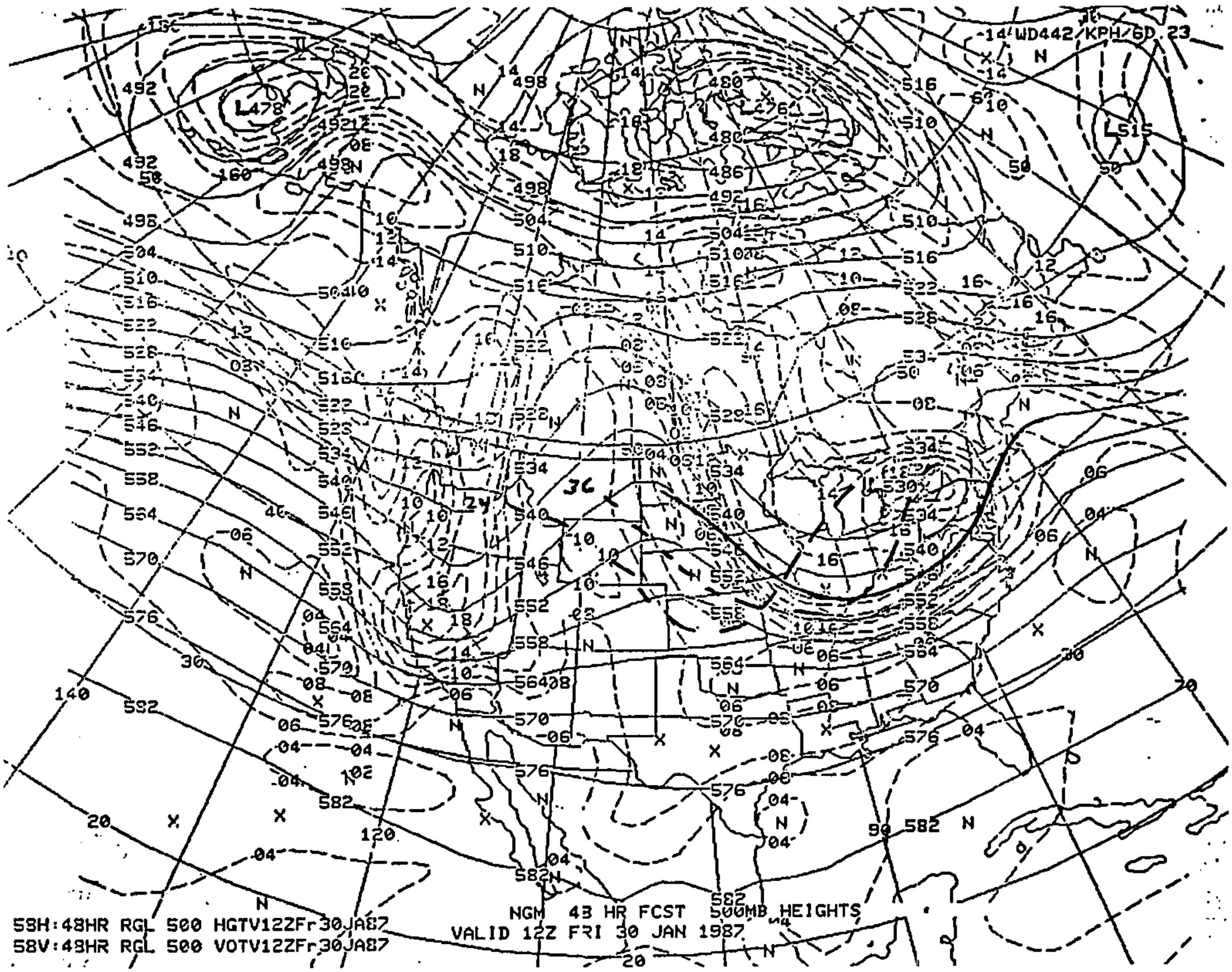

Fig. 3 48 Hour 500 mb height and vorticity forecast valid 12Z, January 30, 1987.

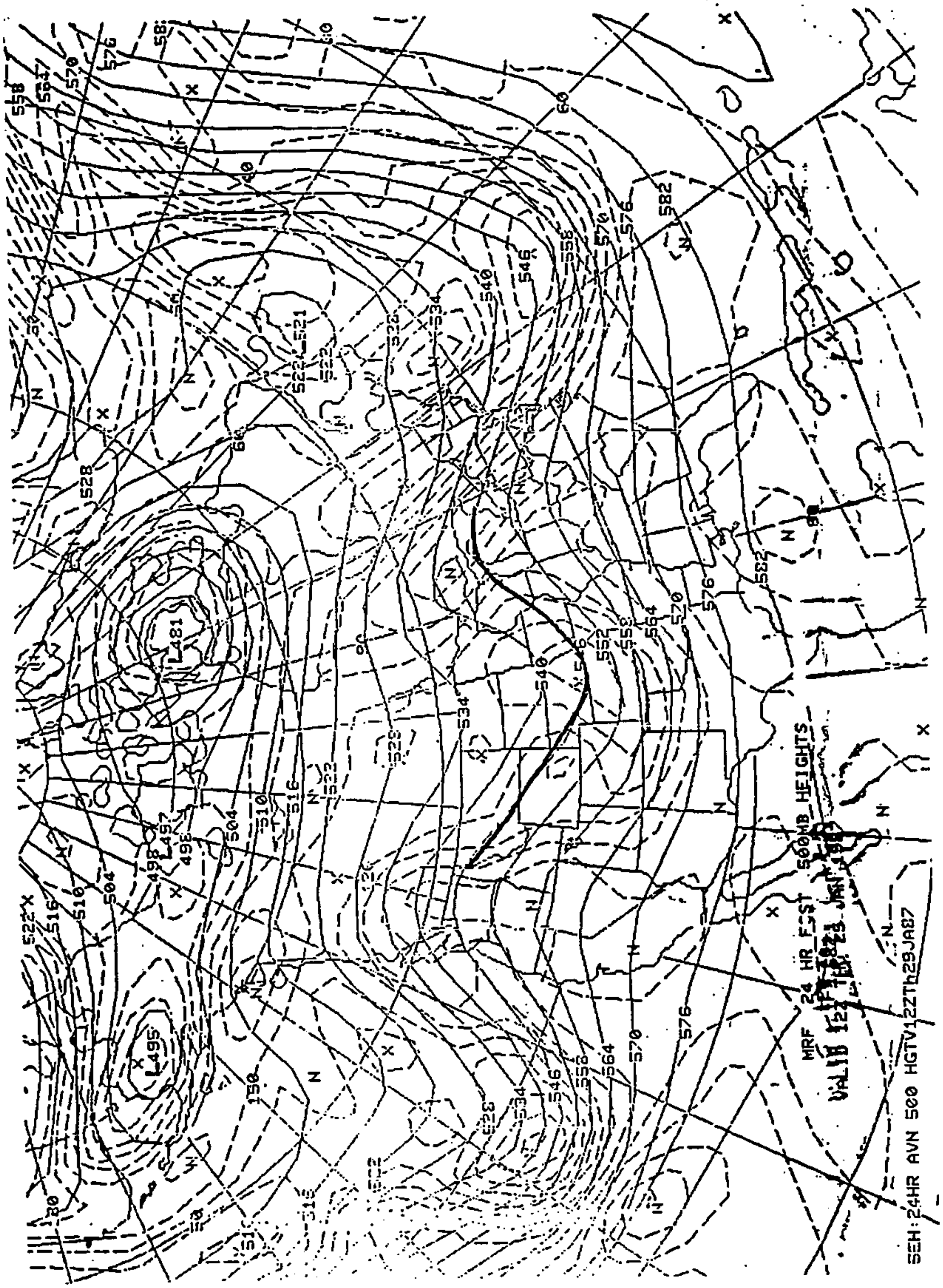

Fig. 4 24 Hour 500 mb height forecast valid 12Z, January 29, 1987.

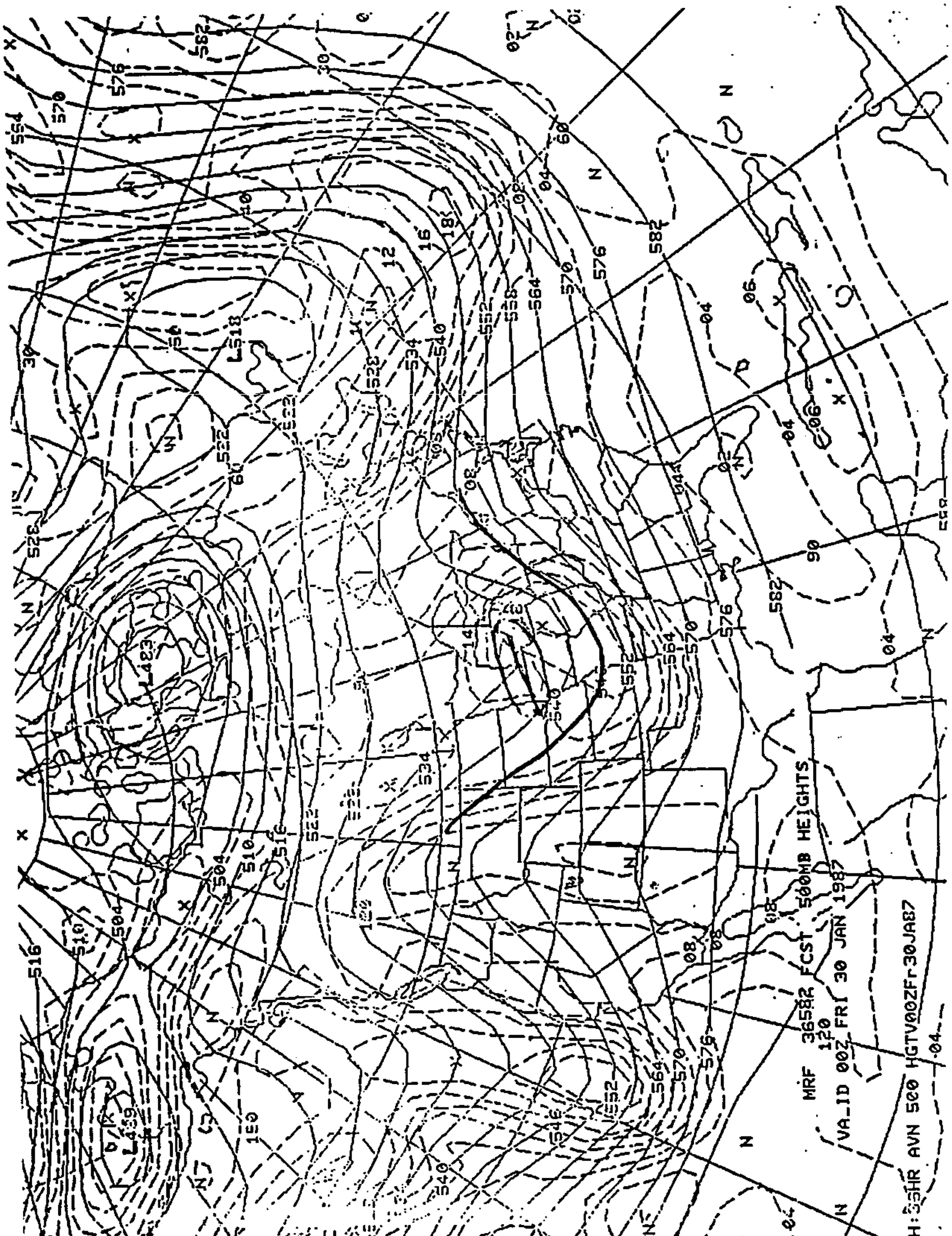

Fig. 5 36 Hour 500 mb height forecast valid 00Z, January 30, 1987.

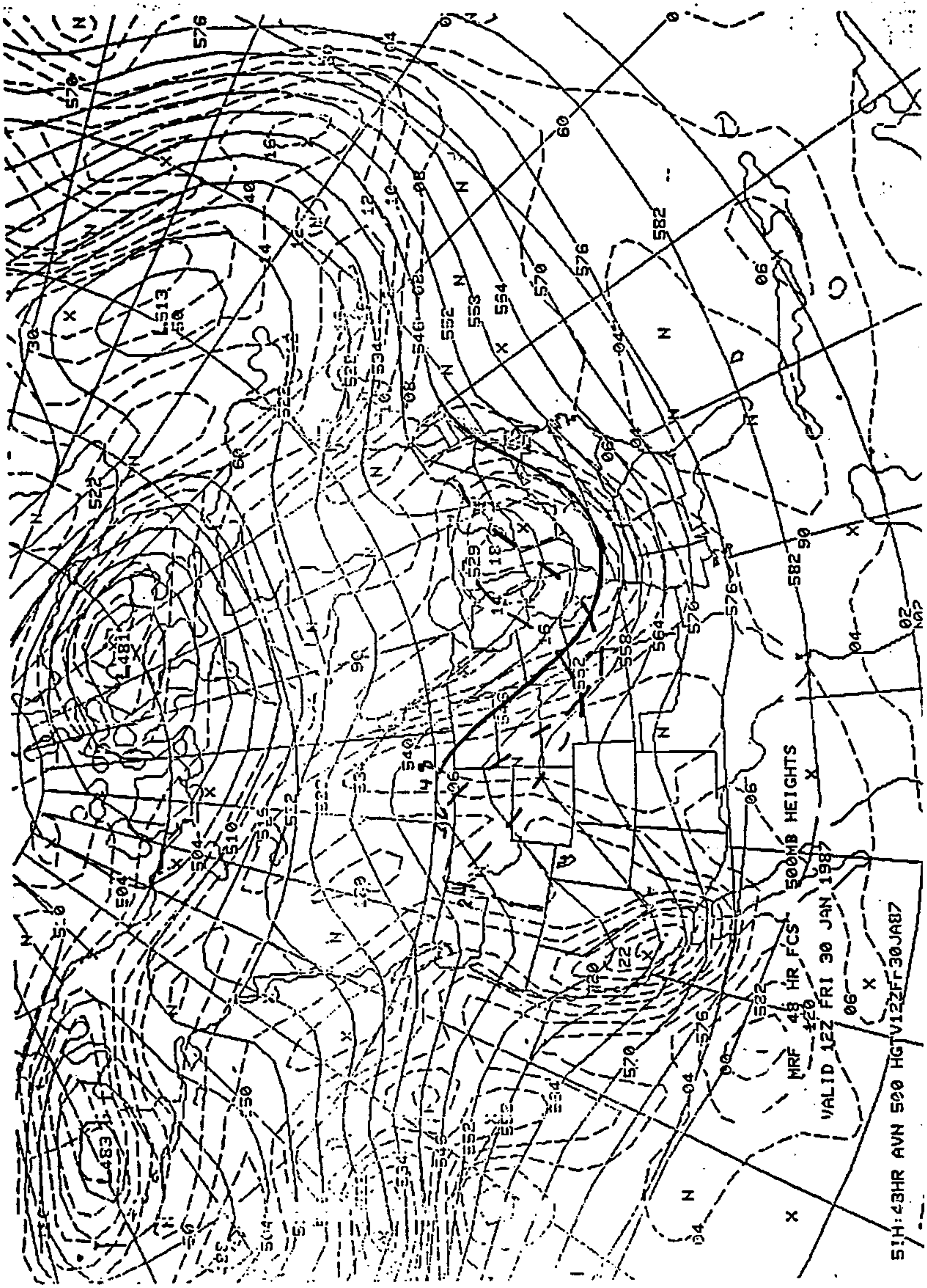

Fig. 6 48 Hour 500 mb height forecast valid 12Z, January 30, 1987.