

THE HALLOWEEN BLIZZARD OF 1979

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ABSTRACT

In late October and early November of 1979 a blizzard of intense proportions swept across the Great Plains from New Mexico to the Dakotas and western Minnesota. The storm was most intense across eastern Colorado and northwest Kansas, where traffic was halted and commerce came to a standstill.

On the following pages some of the important characteristics of this storm will be discussed. Attention will focus in particular on the important surface and upper-air features, and the relationship of the snowfall pattern to these features. Finally, discussion will center around the performance of the LFM during this storm.

1. INTRODUCTION

Over Halloween 1979 a blizzard of intense proportions swept across the high plains from the Oklahoma Panhandle across eastern Colorado and western Kansas to southwest Nebraska. Snow and wind created considerable havoc in these areas. Snow amounts generally ranged from 3 to 9 inches, but amounts near 1 foot were reported along the Colorado-Kansas border near Goodland, KS.

Additionally, wind gusts over 50 mph whipped the snow into large drifts bringing commerce and traffic to a standstill.

On November 1 the storm spread to the Dakotas and western Minnesota bringing similar (though less severe) problems to those areas.

Some important aspects of this storm will be discussed, along with significant upper-air and surface features. A relationship between the snow pattern and the various upper-air and surface features will be presented. The performance of the LFM during this storm will be discussed next. Finally, some of the

more important findings will be summarized.

2. THE UPPER-AIR CHARTS

A. 300mb Chart

The 300mb chart was characterized by a strong jet maximum to the southwest and south of the digging short-wave trough on the 28th as it approached the Pacific Northwest coast. Initially the jet stream was oriented in an east-west direction. But as the short wave continued to dig and amplify, the jet stream ultimately became oriented in a north-south direction. This occurred just before the upper low turned eastward.

There was also significant cold-air advection at 300 mb through the 29th.

At 12Z on the 29th, a 125kt maximum appeared in the base of the trough near Winslow. This seemed to indicate that the upper system (which now had intensified to a closed low) had bottomed out and that a turn to the east or northeast was imminent. The lack of cold-air advection at the 500mb level west of the low also gave support to this conclusion. But a closer inspection of the upper-air charts revealed several important clues which indicated the upper low had not ceased digging.

A strong jet maximum in excess of 110 kt was still present west of the 300mb low. Additionally, although cold air advection had ceased at the 500mb level, significant cold air advection was present west of the 300mb low. Finally, a large area of significant height falls was present at 500 mb southeast of the low. These features suggested the upper low would continue to move to the southeast.

The strong jet maximum at Winslow was associated with a short wave rotating around the main low center.

The 500mb analysis valid for 00Z on

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the 30th showed that the upper low had continued on a southeasterly track. Based on the wind reports from Denver and Grand Junction, a weak low had formed at 500 mb over north-central Colorado in response to the short wave which rotated out of Arizona during the preceding 12 hours.

As the primary jet maximum rotated to the south and southwest of the upper low, wind speeds increased to the east of the trough on the 30th and 31st. During this time the low turned to the east, then to the north. A 140-knot jet maximum appeared east of the 300mb low on the 31st as the system began its northerly track.

B. 500mb And 700mb Charts.

Fig. 1 depicts the track of the 500mb height fall center; Fig. 2 shows the track of the short wave and low center. Notice that the first significant height falls occurred in Idaho, well ahead of the short-wave trough position at 00Z on the 28th. It is possible that significant falls were located off the Pacific North-

west coast at that time, but of course they were not indicated on the charts. In any event, the height-fall center and short-wave trough were nearly in phase 12 hours later.

Weber (1) has found that 500mb cyclogenesis occurs north of the height-fall center and the tighter contour and thermal gradients. In addition, Weber states "... moderate height falls of (at least) 15 (150 meters) within a 12-hour period indicate that cyclogenesis has occurred or may occur shortly within the 500mb trough. Often, the height fall center will appear hours ahead of actual 500mb cyclogenesis. Generally, the height fall center moves inland over the West Coast with or slightly ahead of the trough. Cyclogenesis will appear to the north and usually within four degrees latitude of the height fall center 12 to 24 hours later" (2).

With few exceptions the 500mb pattern associated with the Halloween Blizzard evolved in accordance with Weber's findings. Cyclogenesis occurred within the area north of the

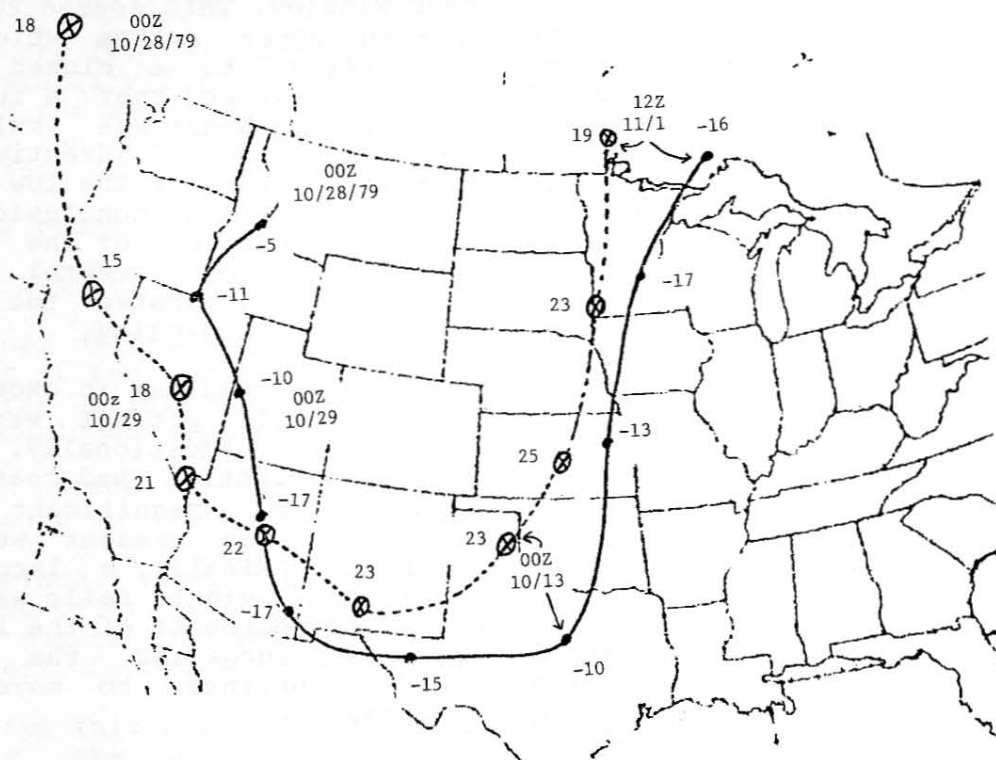


Figure 1. Comparison of the tracks of the 500mb height-fall center (solid line) and the vorticity maximum (dashed). Maximum vorticity and magnitude of the height-fall center are also indicated.

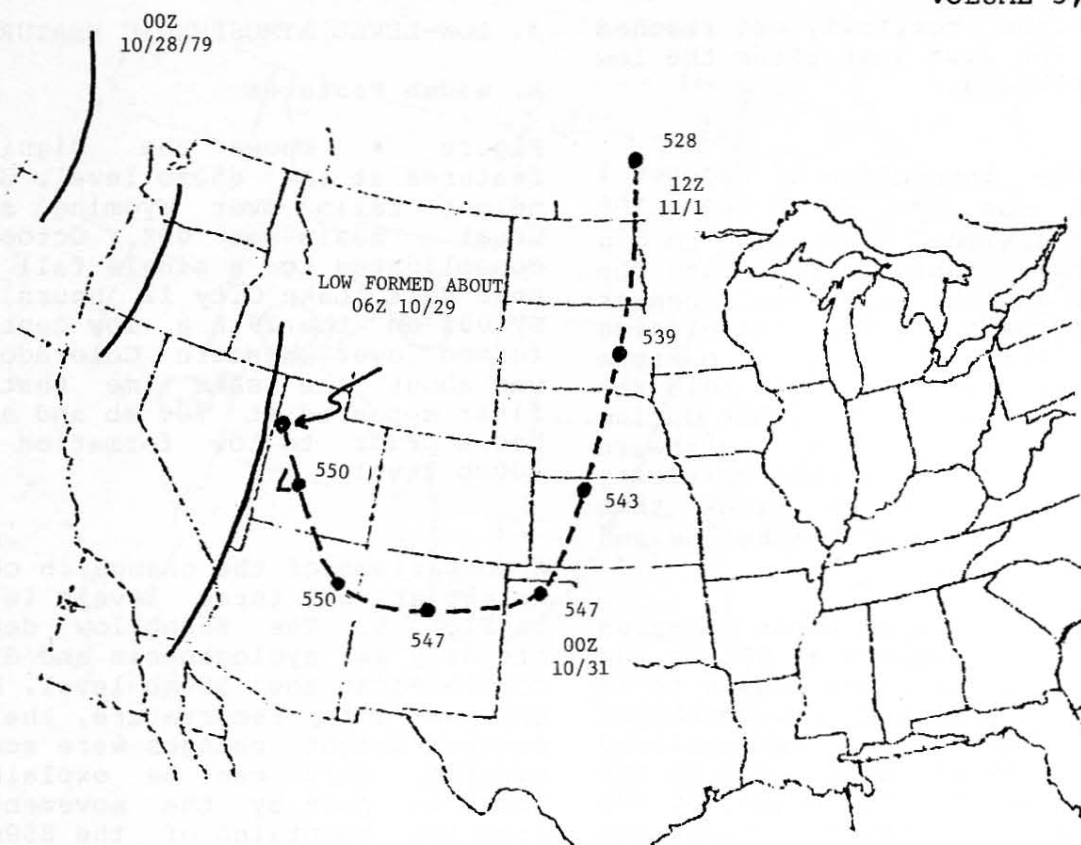


Figure 2. Track of the 500mb short wave trough and low center beginning 00Z October 28. Central height values of the low center are also indicated.

tighter contour and thermal gradients, and within 4 degrees latitude north of the height-fall center. Low development occurred some 30 to 36 hours after the height-fall center first appeared over Idaho. The 500mb pattern on the last analysis before low formation was quite similar to the examples shown by Weber (3), with the contour pattern roughly forming a right angle between the upstream and downstream parts of the trough. Height falls increased in magnitude during cyclogenesis over Utah. Falls of 170m were present over Arizona for a period shortly after a closed low formed.

Studies conducted by Weber indicate that height-fall centers turn easterly when either no change or a decrease in magnitude of the height fall center is observed. He has also found that the magnitude of height-fall centers is usually at a maximum during the period of 500mb low development, and that the magnitude will usually remain unchanged or will decrease while the fall center moves eastward within the bottom of the trough. Finally, he has

found that the magnitude of height-fall centers increases while they move northeasterly (4). A check of Fig. 1 will show that the height-fall center associated with the Halloween Blizzard followed these rules quite well.

Around 00Z on the 31st the low began a turn to the north. In contrast to the earlier trends over Arizona, a significant decrease in height falls occurred over central Texas just prior to the northward turn of the low. At 12Z on the 30th a fall center of 150m was present east of El Paso.

But 12 hours later the fall center decreased to 100m and was located over central Texas. After the northerly track was established, the 500mb low deepened and the height-fall center increased in magnitude.

Figure 1 also shows a comparison of the tracks of the height-fall center and the vorticity maximum beginning with the 00Z October 28 positions. After a decrease in vorticity the first 12 hours, vorticity increased until after the low turned to the

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north. Maximum vorticity was reached at 12Z on the 31st just after the low turned northward.

Upon a close inspection of Figures 1 and 2 it can be seen that the vorticity maximum continued to dig for about 12 hours after both the 500-mb low and the height-fall center turned eastward. During the digging process the vorticity maximum remained to the right of both the 500mb low and fall center. But during the eastward and then northward movement of the storm the vorticity maximum followed a track that approximated the mean of the low and fall-center tracks.

A closed low at 700 mb first appeared over northwest Wyoming at 00Z on the 29th (Fig. 3). This was from 6 to 12 hours before a closed low developed at the 500mb level. The low continued to dig southward until 00Z on the 30th when recurvature began. By 00Z on the 31st a northerly track had been established.

3. LOW-LEVEL ATMOSPHERIC FEATURES

A. 850mb Features

Figure 4 shows the significant features at the 850mb level. General height falls over Wyoming and the Great Basin at 00Z October 28 consolidated to a single fall center near Salt Lake City 12 hours later. By 00Z on the 29th a low center had formed over Western Colorado. This was about the same time that a low first appeared at 700 mb and about 6 hours prior to low formation at the 500mb level.

A comparison of the change in central height at all three levels is shown in Fig. 5. The 850mb low deepened steadily as cyclogenesis and digging continued at the 500mb level. During and just after recurvature, the 850mb central height changes were somewhat erratic. This can be explained at least in part by the movement away from the mountains of the 850mb low and the consequent loss of the

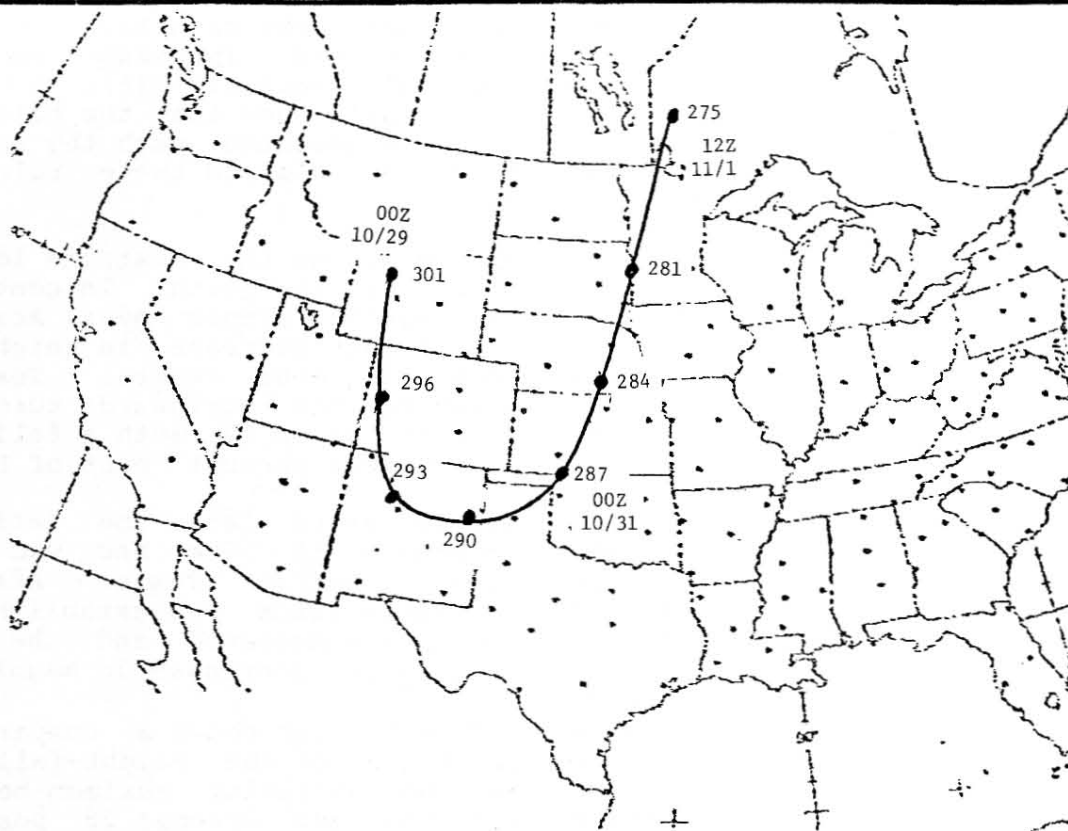


Figure 3. Track of the 700mb low beginning at 00Z October 29. Central height values are also shown.

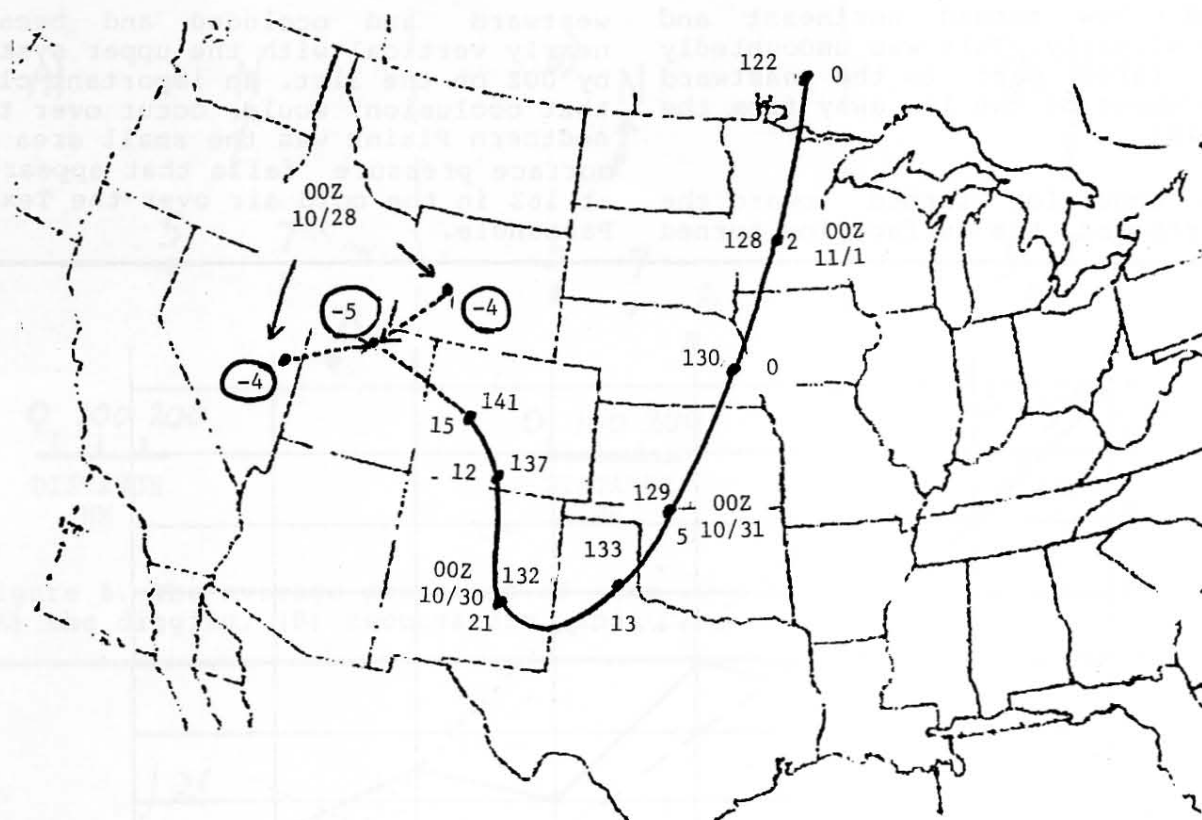


Figure 4. Track of the 850mb low. Central height values and temperature near the low center are also shown.

lee-low effect. During the post-recurvature period, a definite deepening trend became established at all levels as the storm lifted northward through the Great Plains. It is interesting to note that the 700mb low deepened steadily during the entire period and exhibited no fluctuation in central height change as was true at both 850 and 500 mb.

The relationship between the mean positions of the low at all three levels during each of three phases of the storm is presented in Figure 6. An east-to-west slope was present during each phase. During the digging process, the 850mb low was located southeast of the 500mb low. During recurvature the 850mb low moved to the east of the upper system, while the post-recurvature position was slightly north of the upper-low position. Also note that the slope steepened with time as the storm matured.

B. The Surface Low

Significant surface features are

shown in Figure 7. Two lows first appeared at 18Z on the 28th. The easternmost is clearly the lee low, while the low over Utah was the surface reflection of the digging upper system.

The northward shift of the Utah low (and associated looping of the lee low) between 00Z and 12Z of the 29th is interesting in light of the continued digging trend of all significant features in the upper air. It is quite likely that the surface lows were in the process of becoming associated more with the upper low than with the vorticity maximum. This undoubtedly resulted in the northward shift of the surface lows.

By 18Z of the 29th the two lows had combined into a single center over north-central New Mexico, and 6 hours later the low had moved to southeast New Mexico. The surface lows continued to intensify during the entire digging process of the storm system.

As the upper low bottomed out, the

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surface low turned northeast and filled slightly. This was undoubtedly due in large part to the eastward displacement of the low away from the mountains.

As the upper low turned toward the eastnortheast, the surface low turned

westward and occluded and became nearly vertical with the upper system by 00Z on the 31st. An important clue that occlusion would occur over the southern Plains was the small area of surface pressure falls that appeared at 18Z in the cold air over the Texas Panhandle.

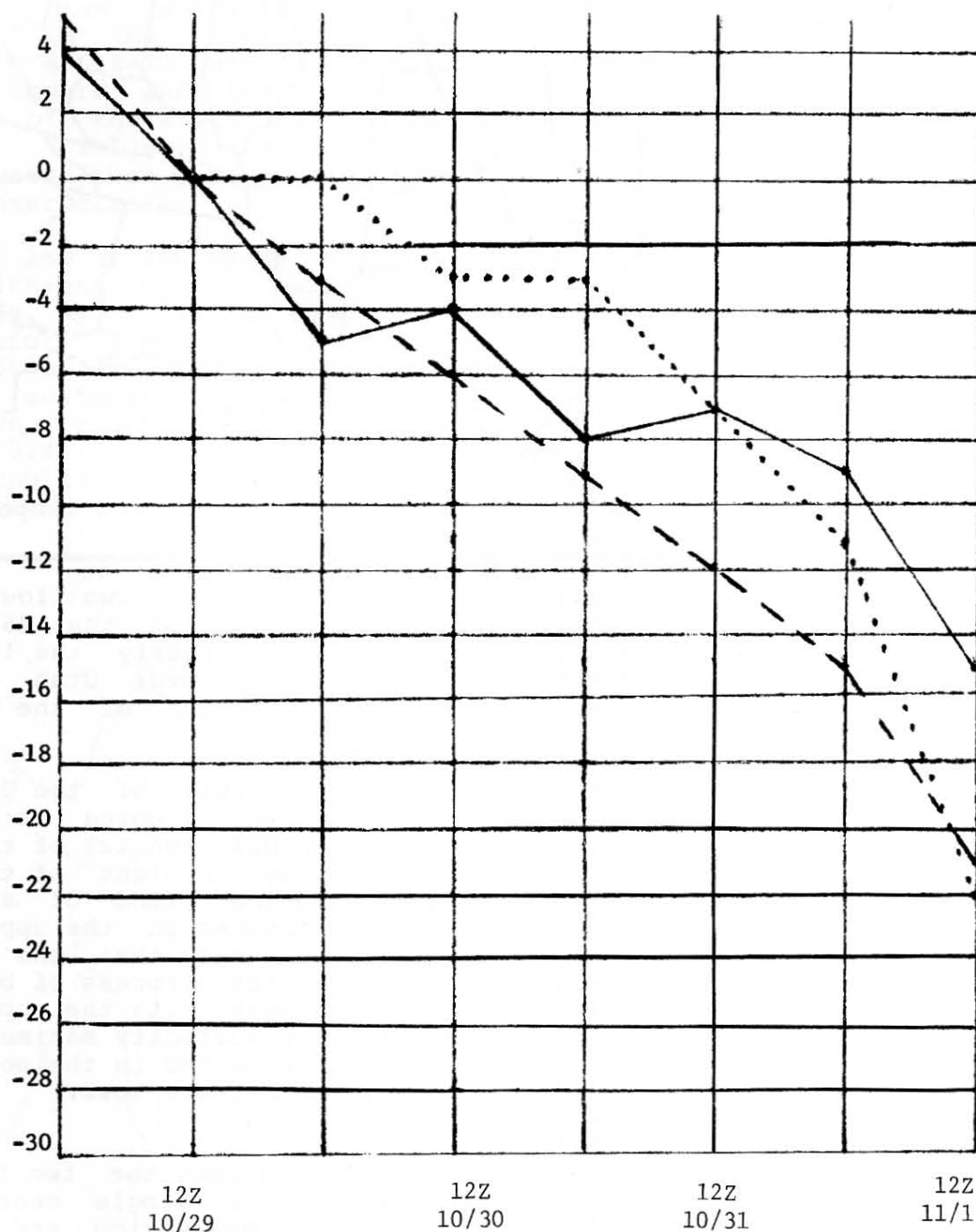


Figure 5. Comparison of the change in central height of the 850mb low (solid), 700mb low (dashed), and 500mb low (dotted). October 29, 12Z, was used as the initial time (zero change), since that was the time when all three lows first appeared simultaneously.

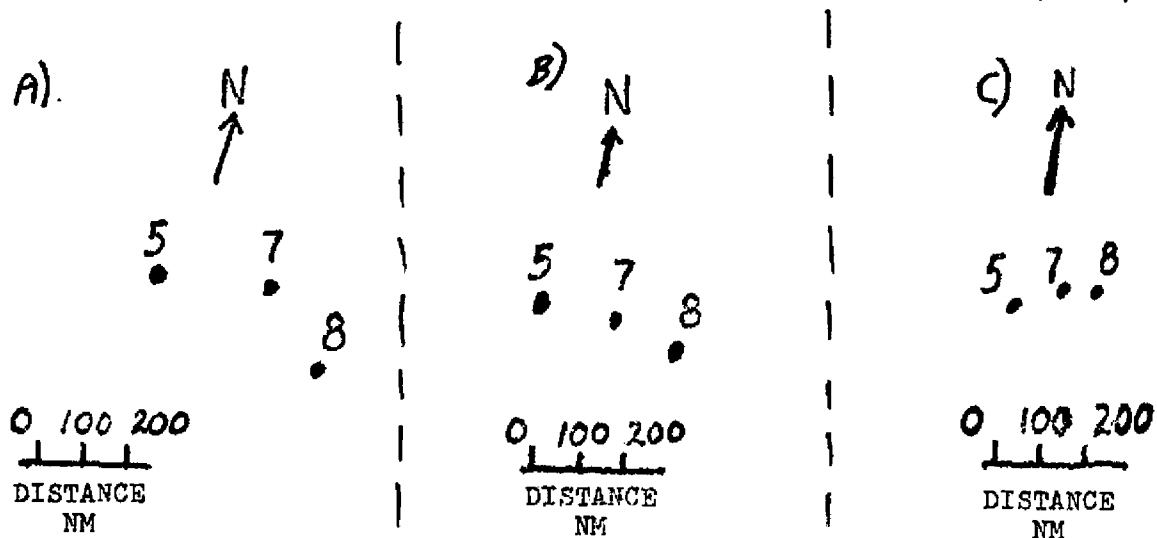


Figure 6. The average positions of the lows at 850, 700, and 500 mb during (A) the digging, (B) recurvature, and (C) post-recurvature periods.

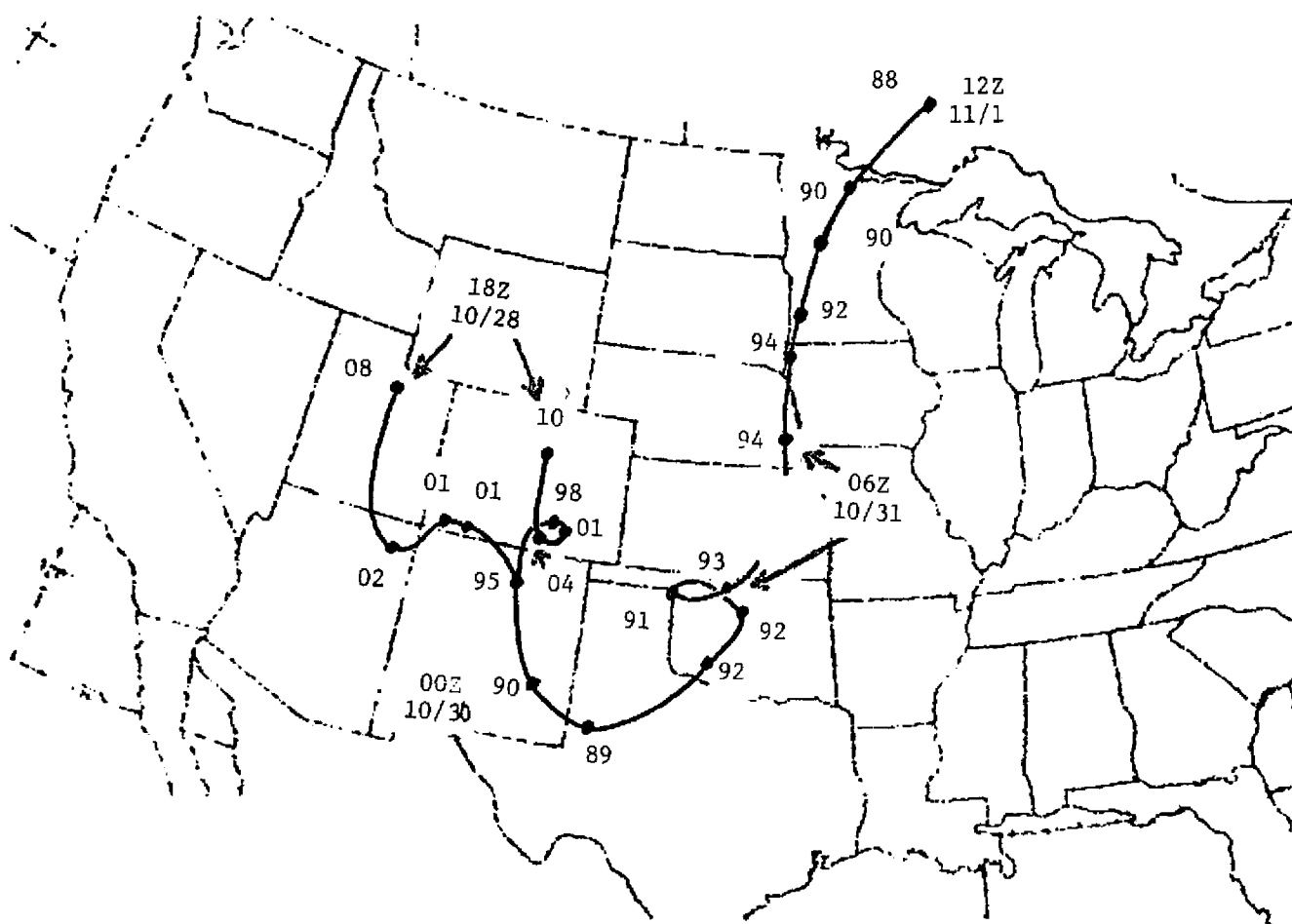


Figure 7. Tracks of the surface lows. Central pressure (mb) is also shown.

By 12Z on the 31st, the low was becoming undiscernable as strong secondary development occurred over southeastern Nebraska. This second low continued to deepen with the upper system and moved into Canada by the morning of November 1.

Heavy amounts of snow were deposited by this storm from New Mexico and western Minnesota as the storm lifted northward through the Plains. The heaviest snow was deposited on southeast Colorado and northwest Kansas as the low occluded over northwestern Oklahoma late in the day of the 30th.

C. The Secondary Surface Development

During the 24 hours ending 12Z on the 30th, excessive rains of 3 to 6 inches fell across northwest Oklahoma

and south-central Kansas. During the next 12 to 18 hours this area expanded to include central Kansas, eastern Nebraska, and northwest Iowa (see Fig. 8). These rains were an indication that a narrow band of strong upward vertical velocity (UVV) had developed through the Central Plains. During this time the storm system was still present over the southern Rockies and southwestern Great Plains well to the southwest of the central Plains UVV field, indicating there were two separate systems at that time.

It is significant to note that the UVV field was positioned near and parallel to the actual tracks of both the vorticity maximum and the approaching surface low (compare Figures 1, 7, and 8). Thus, the UVV field was in position to contribute to significant strengthening of the

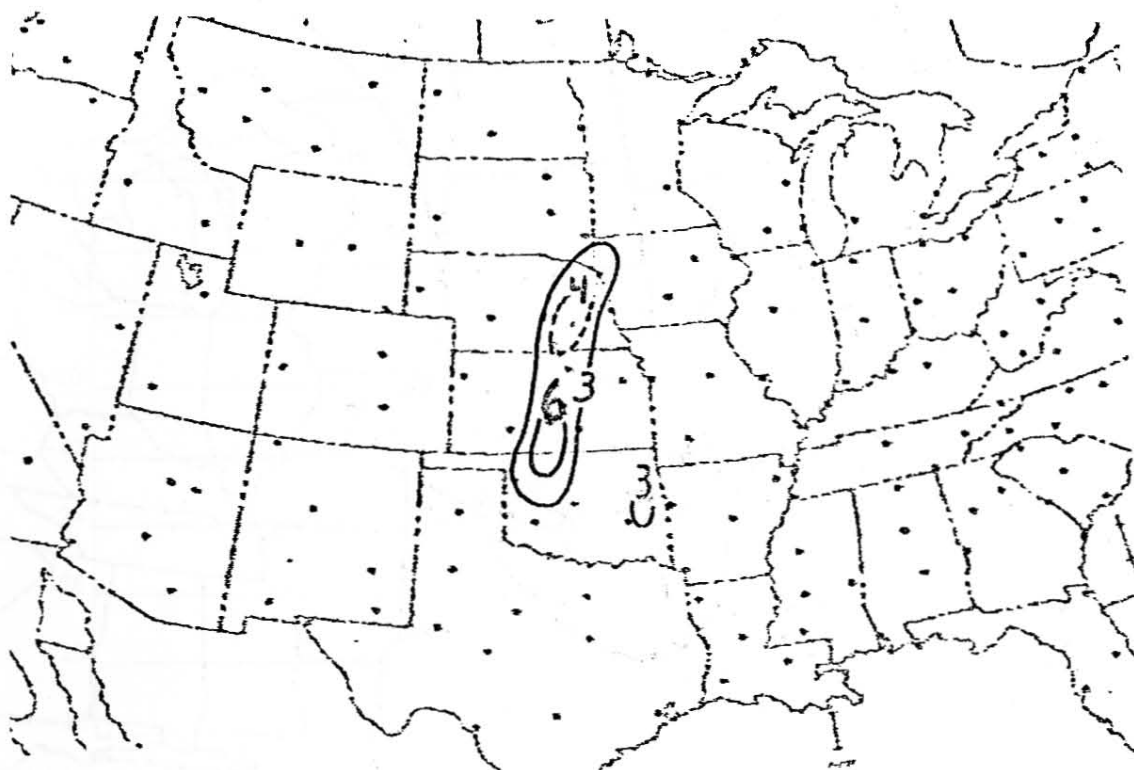


Figure 8. Location of the area of excessive rains which fell during October 29 and 30. The small area over east-central Oklahoma was undoubtedly due to a single thunderstorm.

approaching surface low. But instead, this low turned westward, occluded, and became vertical with the upper system leaving the upward vertical motion field intact. When the strong positive vorticity advection (PVA) ahead of the vorticity maximum overspread the UVV field, strong secondary development commenced downstream from the Oklahoma low.

These developments were quite significant for forecasters. Had secondary development not occurred, the Oklahoma low would have remained the primary surface system. Snow would have been delayed by about 6 to 12 hours across the northern Plains.

Locations of excessive rain areas can be determined during a storm situation by plotting the 6-hourly and even 24-hourly rainfall totals obtained from sequence and synoptic reports. These excessive rain areas indicate the location of strong UVV fields. If the UVV field is elongated parallel to and near the expected future track of the vorticity maximum (and surface low if one exists) and is expected to persist in this position as the vorticity approaches, be alert for one of the following to occur:

a. If no surface low exists, the upward vertical motion field is a favorable location for initial development.

b. If a surface low exists, expect intensification of the low as the vorticity maximum and surface low approach the UVV field.

c. If a surface low exists but is expected to occlude and go vertical with the upper low, expect secondary development as the vorticity maximum approaches the UVV field.

It is important that the UVV field be oriented lengthwise along the tracks of the vorticity maximum and surface low. This will allow sufficient time for the vorticity to act on the vertical motion field.

4. SNOWFALL

Very strong winds made it nearly impossible to obtain accurate measurements of snowfall. Many of the reports indicated highly variable conditions even across short distances. The reports that were obtained were plotted, then smoothed, to get a best estimate of total snowfall. Fig. 9 shows this best estimate.

Nearly a foot of snow fell at Goodland, Kansas, and at Burlington, Colorado, across the border from Goodland. One foot was also reported in the Oklahoma Panhandle near the New Mexico border. But this was an isolated, unofficial report. In any event, greatest amounts were concentrated in a band extending from the northeast corner of New Mexico and the western Oklahoma panhandle to eastern Colorado and northwest Kansas.

The snowfall pattern, including the axis of maximum snow, related best to the track of the 850mb low. The axis of maximum snow was located about 180 nm to the left of the 850mb low track. Poorer correlation was found to be with the tracks of the 500mb vorticity maximum and 500mb height fall center (Table 1). The 700mb and 500mb lows and the vorticity maximum tracked to the right of the snow area just after recurvature. But a tendency toward convergence with the snow band occurred with time (compare Figures 1, 3, and 9). In the later stages of the storm, the upper-air features became incident with the axis of maximum snow. Quite likely this came about as the coldest air moved to near the center of the upper low as the storm matured.

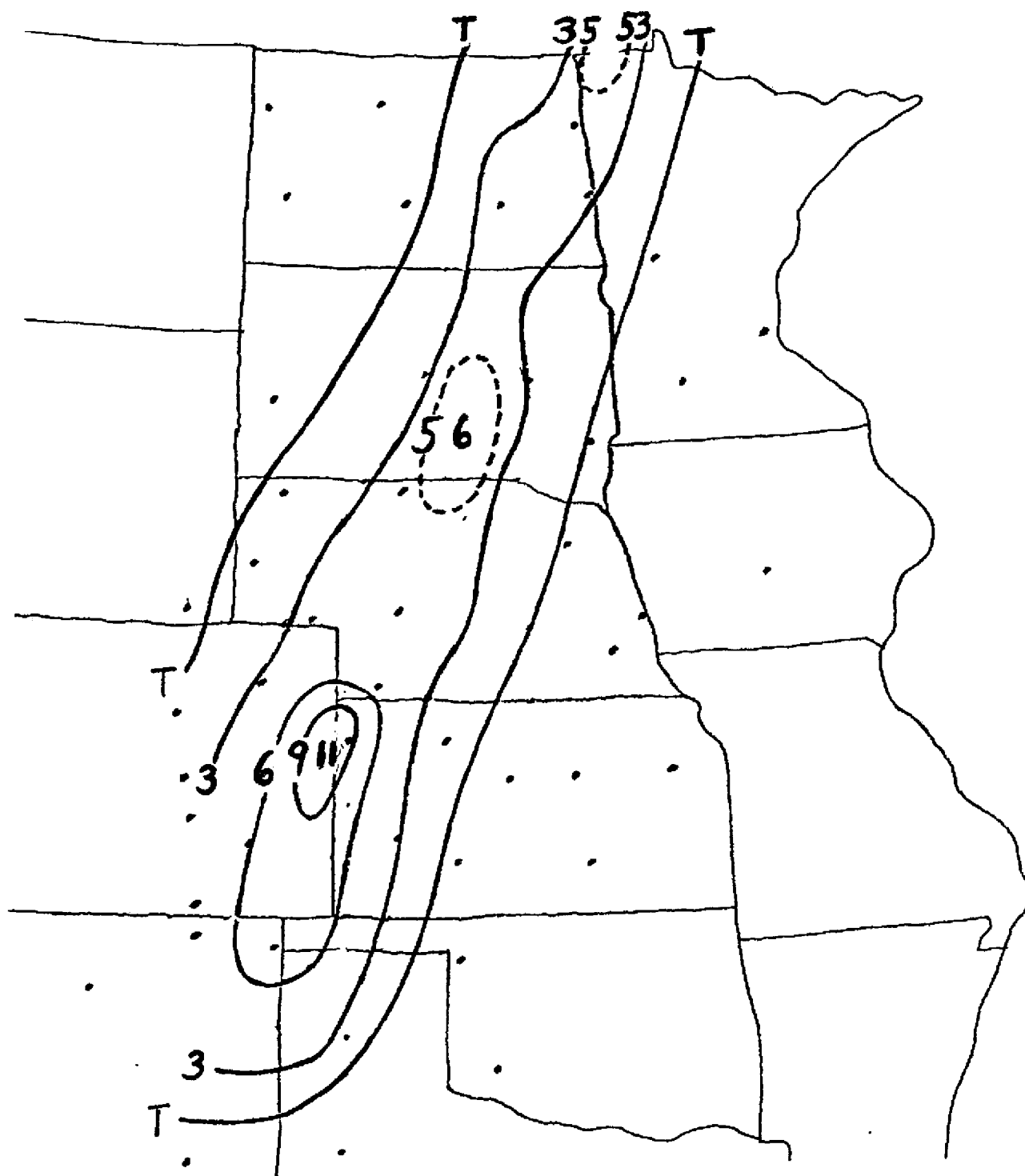


Figure 9. Total estimated snowfall from the Halloween Blizzard.

850 MB LOW	15 NM
700 MB LOW	26 NM
SURFACE LOW	30 NM
500 MB LOW	30 NM
500 MB VORTICITY	38 NM
500 MB HGT FALL CENTER	42 NM

Table 1. The axis of heaviest snow was plotted against the tracks of the various surface and upper-air features to yield a mean distance between the axis of heaviest snow and each of the surface and upper-air tracks. The average of the deviations from each mean was then computed. This table lists the average deviations.

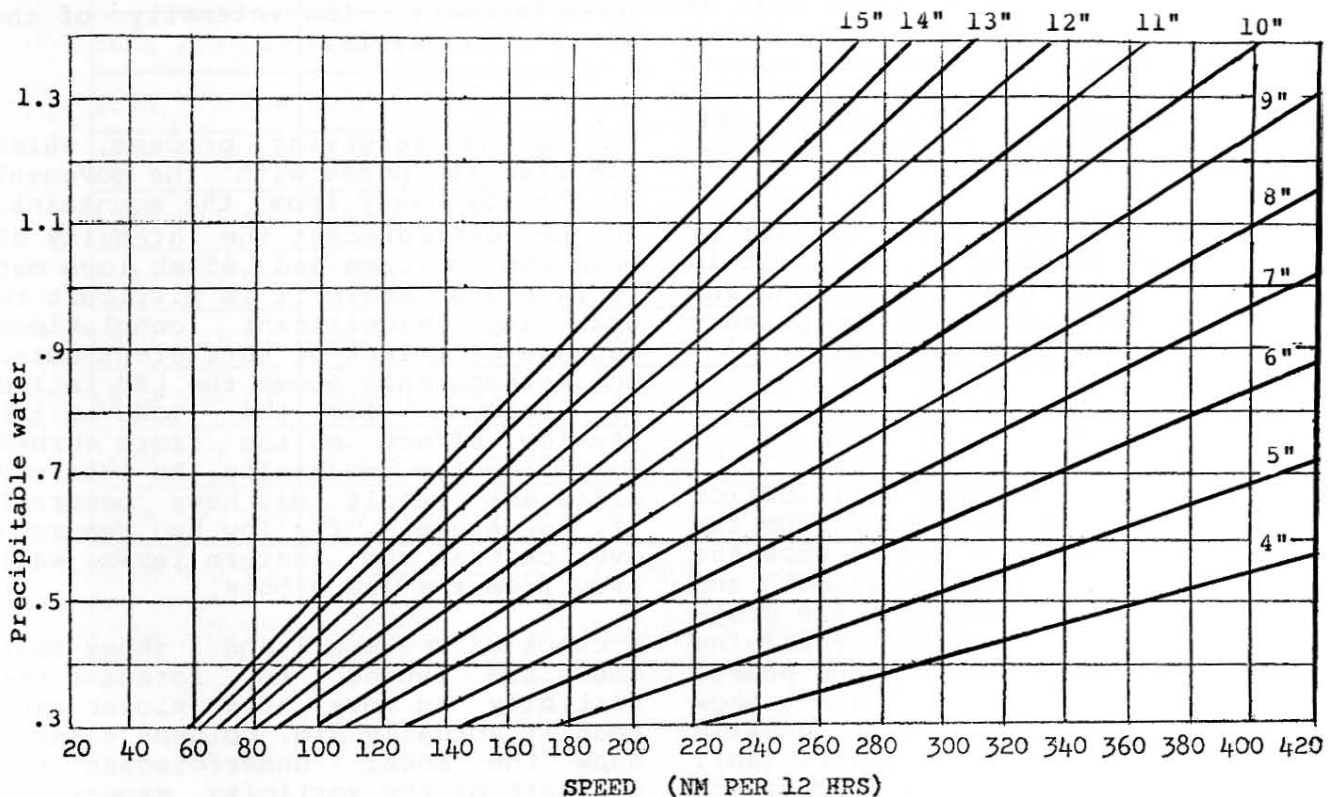


Figure 10. Expected maximum snowfall in the axis of maximum snow as related to the available precipitable water and forward speed of the 850mb low.

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Total snow in the axis of maximum snow related reasonably well to the forward speed of the 850mb low and the available precipitable water (5, 6). A graph was developed from this relationship and is shown in Fig. 10. Much of the precipitable water data had to be estimated due to the absence of NMC computer analyses. This should be kept in mind when using the graph in Fig. 10.

Snow fell at very warm thicknesses over the southern Plains. About 09Z on the 30th, a mixture of rain and snow was reported at Dalhart. The LFM analysis of 1000-500mb thickness over the northwest Texas Panhandle at 12Z of the 30th was 5520 meters.

In general, rain changed to snow in the southerly latitudes when 1000-500 thicknesses cooled to about 5490 m. This was true from northeast New Mexico to northwest Kansas. Farther north across the northern Plains, rain did not change to snow until thicknesses cooled to between 5430 and 5460 m. Heaviest snow fell at thicknesses as great as 5460 m through eastern Colorado and western Kansas, while thicknesses around 5400 m accompanied the heavy-snow axis across the northern Plains.

It is unusual for snow to fall at such warm thicknesses, and it is suspected that high elevations and the time of year were the two primary contributing factors to this.

5. VERIFICATION

Table 2 shows the LFM verification for the Halloween Blizzard. From the left, columns 1, 2 and 3 show the difference (in degrees azimuth and nautical miles) between the prognostic position and the verifying position during each of three phases of the storm. Columns 4, 5 and 6 show the difference between the prognostic and verifying central pressures (mb), heights (decameters), and vorticity (units of vorticity) during each of the storm's phases. Values for vorticity are not given in columns 2 and 5 since the lifting-out process

began abruptly when the digging process ended. Columns 7 and 8 give the average overall error.

It can be seen from column 7 that the LFM was too far south in its predicted low position at all levels. Overall the LFM performed best at the 500mb level and poorest at the surface. However, the predicted 850mb and 500mb low positions were quite good through 24 hours.

It is difficult to draw any significant conclusions when considering the digging, recurving, and lifting-out processes individually because the limited amount of data for each process produced highly variable results. But in general it can be seen that the LFM tended to overdo the digging process, although less so at 500 mb than elsewhere. The model was slow on the recurving and lifting-out processes.

Column 8 indicates that the LFM underforecast the intensity of the low at all levels.

During the recurving process, which occurred in phase with the movement of the low away from the mountains, the LFM overforecast the intensity of both the surface and 850mb lows out to 24 hours. Again it is difficult to draw any significant conclusions because of a lack of sufficient data. But perhaps this shows the LFM failed to account for the loss of the lee-low effect as the storm turned away from the mountains. An entirely different result may have occurred if, for example, the low had recurved over central and eastern Texas, well away from the lee slopes.

A check of columns 1 and 3 shows that the LFM tended to forecast the vorticity to move at a slower rate than it actually did. Columns 4 and 5 show the model underforecast the strength of the vorticity, especially beyond 24 hours. Overall the LFM was biased in a southerly direction with the vorticity forecast, and (beyond 24 hours) was too weak.

	PROG POSITION VS. ACTUAL POSITION AVERAGE ERROR			CENTRAL PRESS, HEIGHT, VORT ERROR			MEAN POSITION ERROR	MEAN CENTRAL PRESSURE, HEIGHT, VORTICITY ERROR
	D	R	L	D	R	L		
12HR SFC LOW	030/030	250/140	180/225	3	-4	3	170/080	2
24HR SFC LOW	060/075	250/180	180/165	7	-1	4	170/095	4
36HR SFC LOW	210/210	250/080	170/170	8	6	5	190/175	7
48HR SFC LOW	250/410	230/240	170/150	10	10	12	220/190	11
12HR 850 LOW	040/080	250/070	185/120	2	-4	2	195/040	1
24HR 850 LOW	030/100	240/140	185/130	3	-4	3	195/065	2
36HR 850 LOW	235/300	235/150	170/125	8	4	5	220/140	6
48HR 850 LOW	250/450	250/150	190/250	8	5	9	240/260	8
12HR 700 LOW	050/150	180/030	190/160	1	1	4	165/080	2
24HR 700 LOW	040/345	200/050	200/165	2	-1	6	120/050	2
36HR 700 LOW	240/160	270/080	180/180	8	3	8	210/170	7
48HR 700 LOW	250/430	215/060	190/155	11	9	12	230/170	10
12HR 500 LOW	060/090	190/210	170/075	0	-1	3	140/060	1
24HR 500 LOW	080/060	195/120	175/230	0	-1	7	175/125	3
36HR 500 LOW	005/120	270/030	170/270	5	-1	10	170/100	6
48HR 500 LOW	360/040	250/150	200/120	6	7	12	210/080	9
12HR 500 VOR	320/135	-----	170/155	0	----	1	180/025	0
24HR 500 VOR	010/170	-----	175/230	2	----	1	125/085	1
36HR 500 VOR	295/205	-----	170/260	3	----	2	230/080	3
48HR 500 VOR	270/220	-----	220/170	1	----	3	245/155	2

Table 2. Verification of the various LFM predictions to the actual observations.

6. CONCLUSIONS

Some of the more important findings are summarized here. More testing will need to be done before any definite rules can be established, however.

An important consideration when forecasting in a storm situation is the ability to forecast recurvature of the upper system. The location at 300 mb of jet-stream maxima and areas of significant cold air advection, both with respect to the upper low or trough, can aid in forecasting recurvature.

A narrow band of excessive rainfall is an indication that a field of strong UVV has developed. This has important implications for the future pressure pattern depending on the orientation and location of this UVV field with respect to the expected tracks of the 500mb vorticity maximum and surface low.

When the upper system closes off, the coldest air ultimately moves near the center of the low. This produces a trend toward convergence with time of the track of the upper low and the snowfall pattern.

The snowfall track related best to the track of the 850mb low. Total snowfall in the axis of maximum snow related reasonably well to the forward speed of the 850mb low and the available precipitable water.

Snow fell at very warm thicknesses, particularly in the more southerly latitudes. The time of year and the terrain elevation no doubt had much to do with this.

The LFM performed best at 500 mb although the 850mb and 700mb low predictions were quite good through 24 hours. The model tended to overdo the digging process although less at 500 mb than elsewhere. The LFM consistently underforecast the intensity of the storm.

Vorticity predictions were too slow and too weak.

7. ACKNOWLEDGMENTS

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