Western Region Technical Attachment
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A Tornado in January ? - In Utah ?

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THE EVENT

On January 10, 1989, a microscale storm struck a neighborhood in the extreme southeast portion of the Salt Lake Valley. KSL radio called at 9:15 a.m. MST relaying a report they had received about a "tornado" which had just struck at about 11600 South and 1400 East in Sandy, a southern suburb of Salt Lake.

Initial reaction was "this can't be right". The synoptic situation did not appear to support thunderstorm development, let alone a tornado. Tornadoes occur on rare occasions in Utah, but these are usually of the "cold core" type and do little, if any damage. Also, there had never been a tornado reported in Utah during January. However, a few minutes later another call from the radio station indicated there had been damage to 10 houses. We started to pay more attention to the reports. We decided that since the event was so close to the office, we should send a "survey team" out to look at the damage and talk to the folks who reported the event. So the MIC, DMIC, a lead forecaster, and a met intern journeyed out to the area about 11 a.m.

The area is just north of a low range of mountains. To the southwest a break exists in the mountains through which the Jordan River flows into the Salt Lake Valley. This break is referred to locally as the "Point of the Mountain". This location acts to channel winds in the area so that the predominant direction is from the southwest. Indeed, the general winds were southwesterly at 20-30 mph on this day, ahead of an approaching cold front both before and after the event.

The main damage was limited to a small area of about one block with the heaviest damage in less than 1/2 block. There was no damage to areas further south. A second area, about one block north, had a fence uprooted. This second location had a small frail looking shed, within a couple of hundred feet of the fence, which sustained no damage. No additional damage was found farther north. This seemed to indicate that whatever caused the damage touched down only briefly in a small area, possibly skipped about a block and touched down briefly again, then did not propagate any farther. The damage indicated movement from the southeast to northwest, somewhat perpendicular to the predominant southwest flow in the area.

The greatest damage was to the north side of roofs. At the house with the greatest damage, a trap door which "was never opened" had "popped open" by itself. Subsequent inspection by structural engineers led them to believe "the whole roof lifted slightly then settled back onto the house." The resident of another house near the start of the damage path reported that his garage door had been open and although empty garbage cans in the garage were not disturbed (thus suggesting no significant wind in the garage), the door to his freezer (upright) popped open. These factors seemed to indicate damage from not only strong winds but also from sudden pressure change.

The extent of the damage was such that we estimated at least 100 mph winds must have occurred. For instance, a camper which was chained down by four I-bolts set in concrete was blown 40 feet away. A north-south oriented cedar wood fence had asphalt shingles embedded up to about 1/2 inch deep in it on both sides. Boards in this fence appeared to have been broken from both sides. Glass shards from one house were found embedded in the aluminum siding of another house. Shingles from houses to the east, southeast, and west were all mixed together as if there had been a rotating effect.

One section of an east-west oriented fence appeared to have been sheared to the south on one end and to the north on the other. An eight-foot section of the fence was thrown about 20 feet upstream of the prevailing winds and apparent storm movement, while another section was lifted and carried about 1/2 block away and shattered on top of a roof.

An observer across the street from the most damaged house stated he saw debris and snow rotating as the storm moved northward up the street and that this rotating debris appeared to skip up and down. A second resident stated he saw a funnel or cone-shaped debris cloud. Another resident stated she heard a roaring like a train as it moved through and it only lasted about one minute.

All this evidence led the team to believe the area had indeed experienced the touch down of a small rotating vortex, or a small tornado rather than straight-line damage from a microburst.

METEOROLOGICAL DISCUSSION

At 12Z on January 10, a trough was approaching the Salt Lake area from the west northwest (Figures 1a, b, and c). Its associated cold front was moving into southwest Idaho and northwest Nevada at the time. The front was moving at a fast rate (30-40 mph) and moved through the Salt Lake Valley around 22Z (Figures 2a, b,). A 12Z RAOB was taken, but due to equipment malfunction the data was not available to the forecasters until around noon (Figure 3).

Rather typical pre-frontal winds of 15-20 mph were blowing during the morning at the Salt Lake City Airport, but were probably somewhat stronger in the southeast part of the valley, which is also typical. The K and SI analyses for 12Z, the 19Z Convective Outlook and FOUS12 rendered no support for thunderstorm development (Figures 4, 5; Tables 1, 2). The ARTCC radar was not picking up any echoes, but was working at below normal output. Hill AFB FPQ-21 radar (the military version of 74C) was picking up activity to the north and west but detection in the southeast part of the Salt Lake Valley is blocked by ground clutter and terrain. The Hill radar observation at 1635Z (about 25 minutes after the event) had a maximum top of 20,000 feet with most tops around 16,000 feet. However the 1435Z and 1535Z observations, taken while the line of virga was within their area, had tops to 25,000 feet, suggesting moderate convection (Table 3).

Neither ALDS nor observations indicated lightning or thunder reports during the morning. A southwest to northeast line of virga was observed moving across the valley, from the northwest to the southeast. This was appended to the Salt Lake City observations and a forecaster driving to work from the south reported it over the southeast part of the valley about the time of the damaging event (Table 4). This line of virga appears to have been associated with a weak upper level impulse moving across the area which was evident on the satellite imagery (Figures 8 and 9). This impulse was located well ahead of the surface front. Pilot reports taken at the time were advertising moderate to severe icing (up to 1.5 inches) in the middle cloud layers over the valley. This suggests that some convective activity was occurring, though the base of the clouds looked rather flat except for the line of virga.

It is our belief that none of the numerical guidance products, nor any of the local analysis which the forecaster had available, even approached explaining this small-scale, yet damaging event.

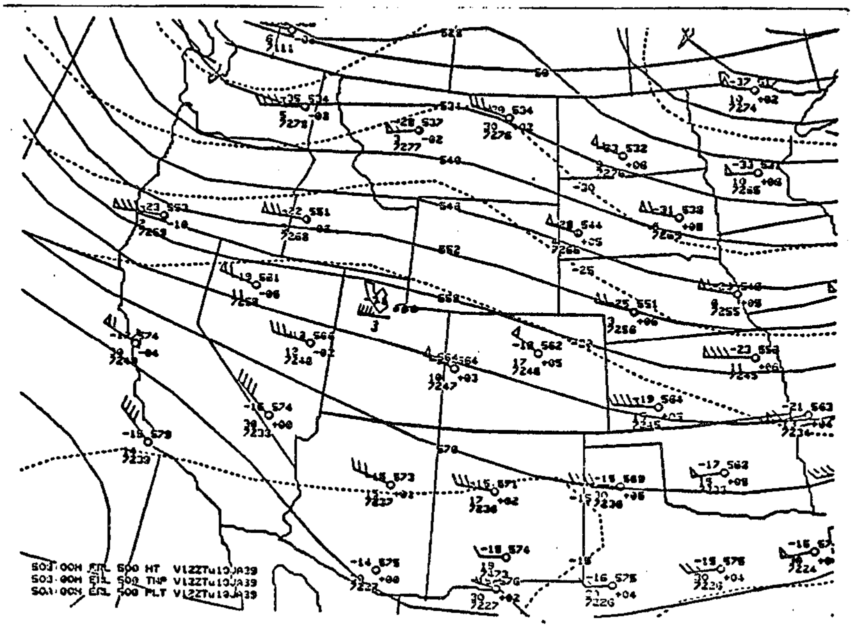
CONCLUSIONS

Forecasters have often noted that the classical supercell theory, which explains development of large tornadoes east of the Rockies, does not fit well with tornadoes in the Great Basin. Most certainly, the tornadoes reported in our area are different animals than the monsters of the Midwest. Western tornadoes typically last only a few minutes and many are associated with weak thunderstorm activity with VIP 1's and 2's rather than 5's. Most of the reports of funnel clouds occur when there is a cold, upper low over the area rather than warm, moist airmass. Most severe wind damage in the West occurs with high-based thunderstorms and the accompanying dry microbursts.

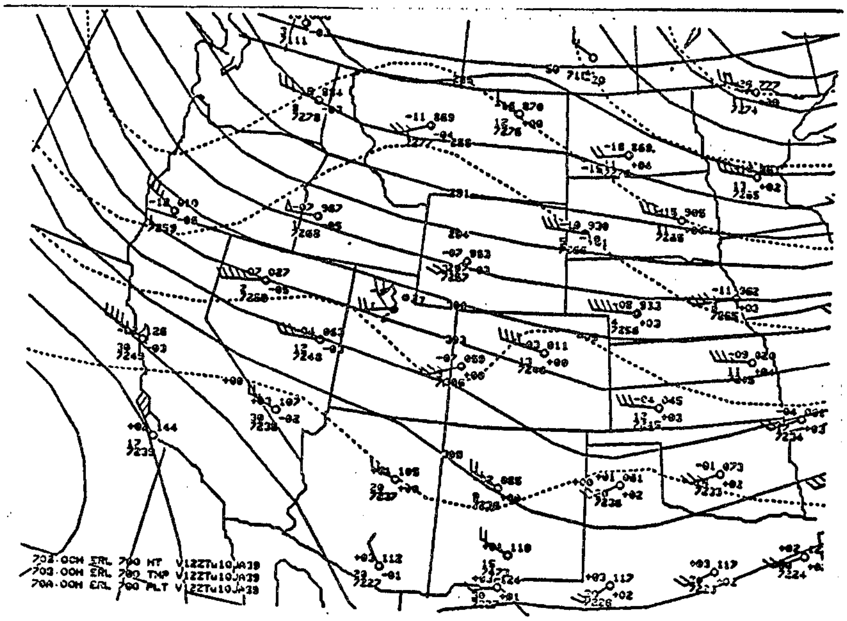
A recent theory developed by Dr. Roger Wakimoto of UCLA and James Wilson of NCAR seems to fit the situations associated with Western tornadoes much better than the classical theory. They have proposed a mechanism whereby small tornadoes can develop without a supercell. They call these non-supercell tornadoes. The theory suggests that along a convergence boundary, shallow shear vortices develop (typically 1 km in depth). Many times, these vortices may be seen as swirling areas of dust. Convergence boundary development is a daily occurrence in our area, with mountain, valley, lake, and other terrain induced wind systems. There are also frequent, dry gust fronts from thunderstorm activity, which can propagate long distances. According to theory, these vortices move along the convergence boundary, and may occasionally move under a developing convective cloud or updraft area. When this happens, the vorticity associated with the surface-based vortex may stretch and increase, resulting in a small tornado without a supercell or mesocyclone. Usually these are relatively weak tornadoes which cause light to moderate damage with winds 73-112 mph. They are also short-lived, typically lasting less than 10 minutes, having short paths and parent clouds which are flat-based in the developing stage. This fits very closely the type of event which was reported in our area at the beginning of this paper.

It is very possible that a weak vortex existed in the area, either as the result of a mechanical or terrain-induced eddy or possibly along a convergence boundary associated with the virga. Then, as the convective cell moved across the vortex, it strengthened significantly for a brief time. If the vortex was mechanically induced, it would have been moving northward in the low level flow while the weak convective line was moving east or southeast. Thus, the duration of the link between vortex and cell would have been very short. This seems to fit the non-supercell tornado theory quite well.

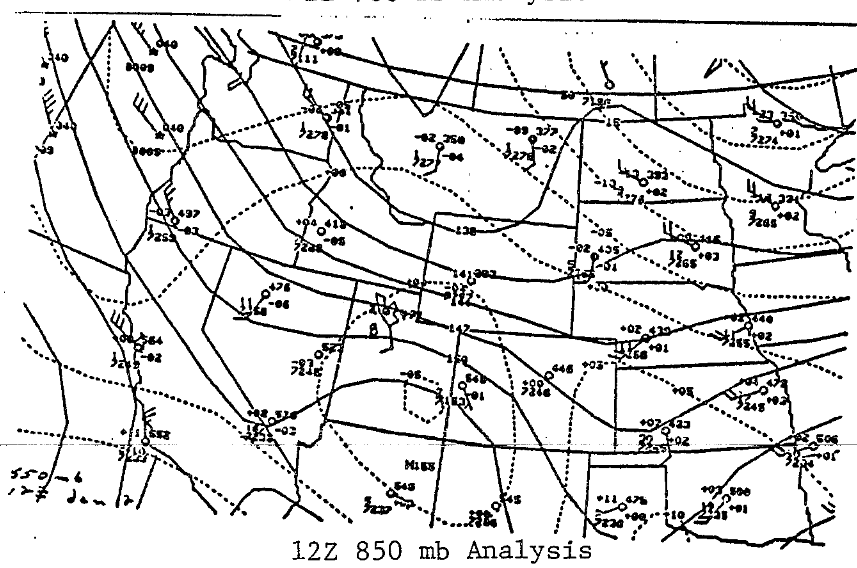
[Editor's Note - The theory referenced in this paper, by Wakimoto and Wilson, is detailed in the videotape, "Tornado Genesis", which was sent to each WSFO in December 1988. As suggested above, this theory fits very well the types of micro/mesoscale wind events that often are unexplained in the western U.S.]



12Z 500 mb Analysis



12Z 700 mb Analysis



12Z 850 mb Analysis

Figure 1 12Z RGL Initial Analysis

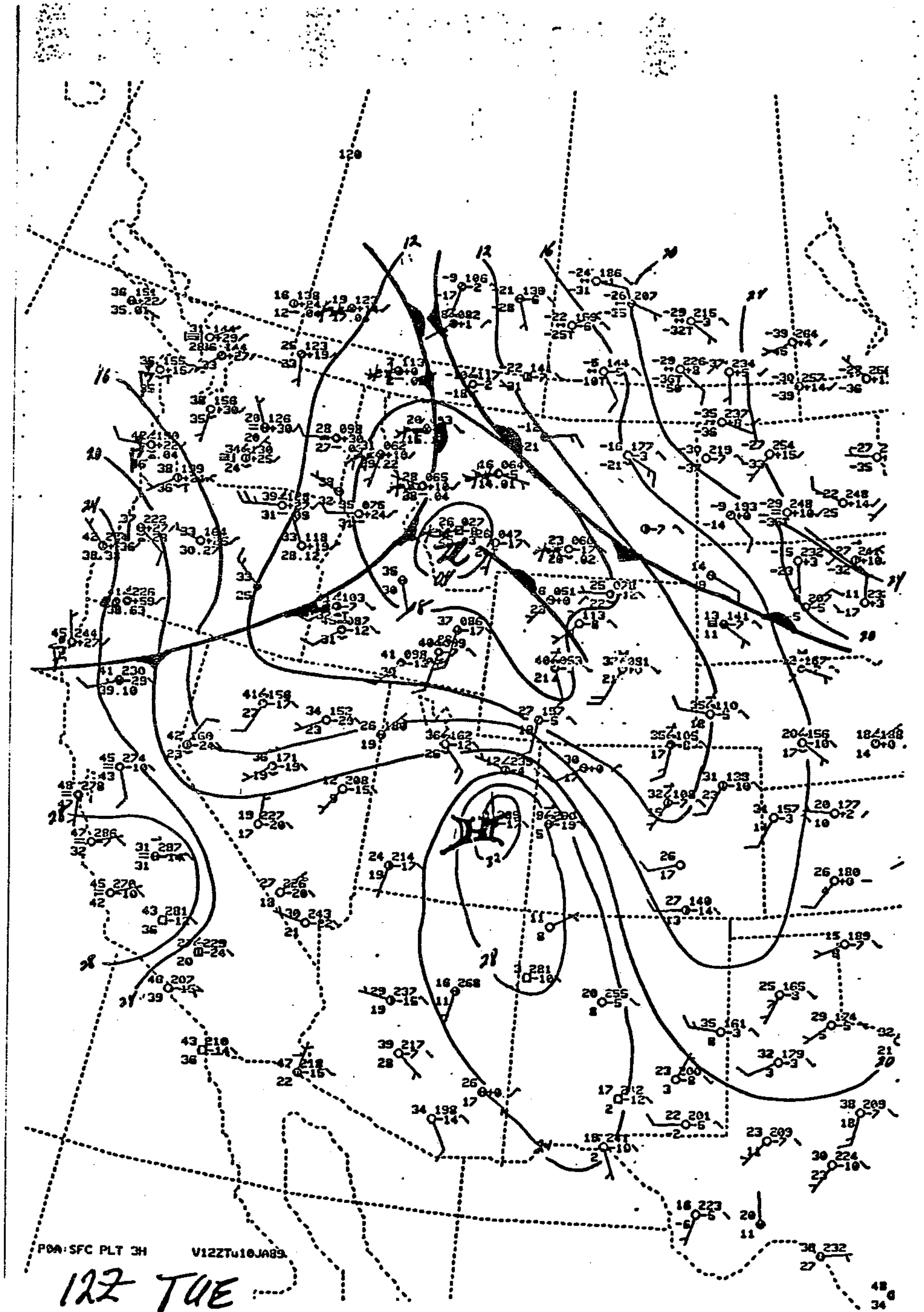


Figure 2a
12Z Local Surface Analysis

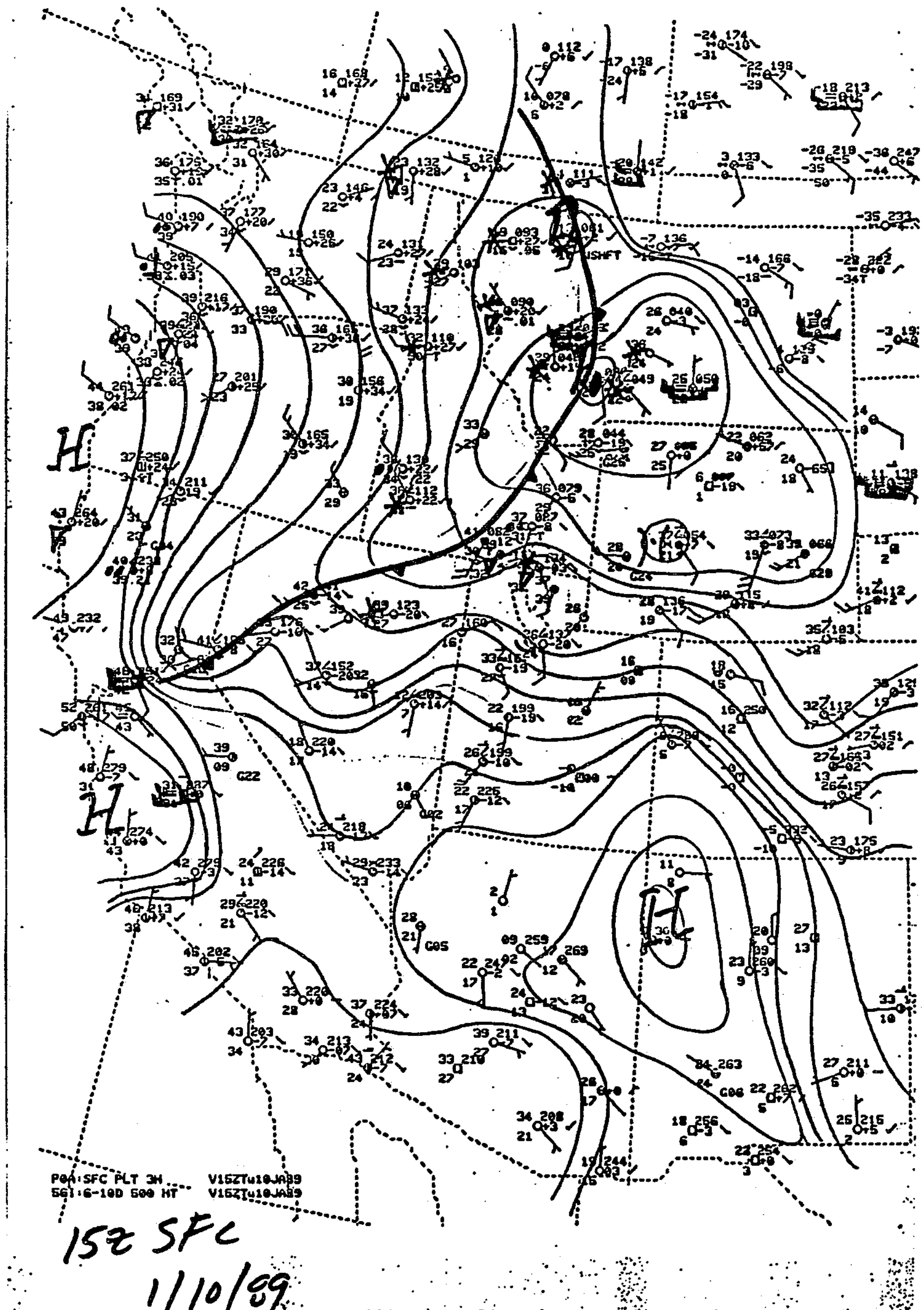
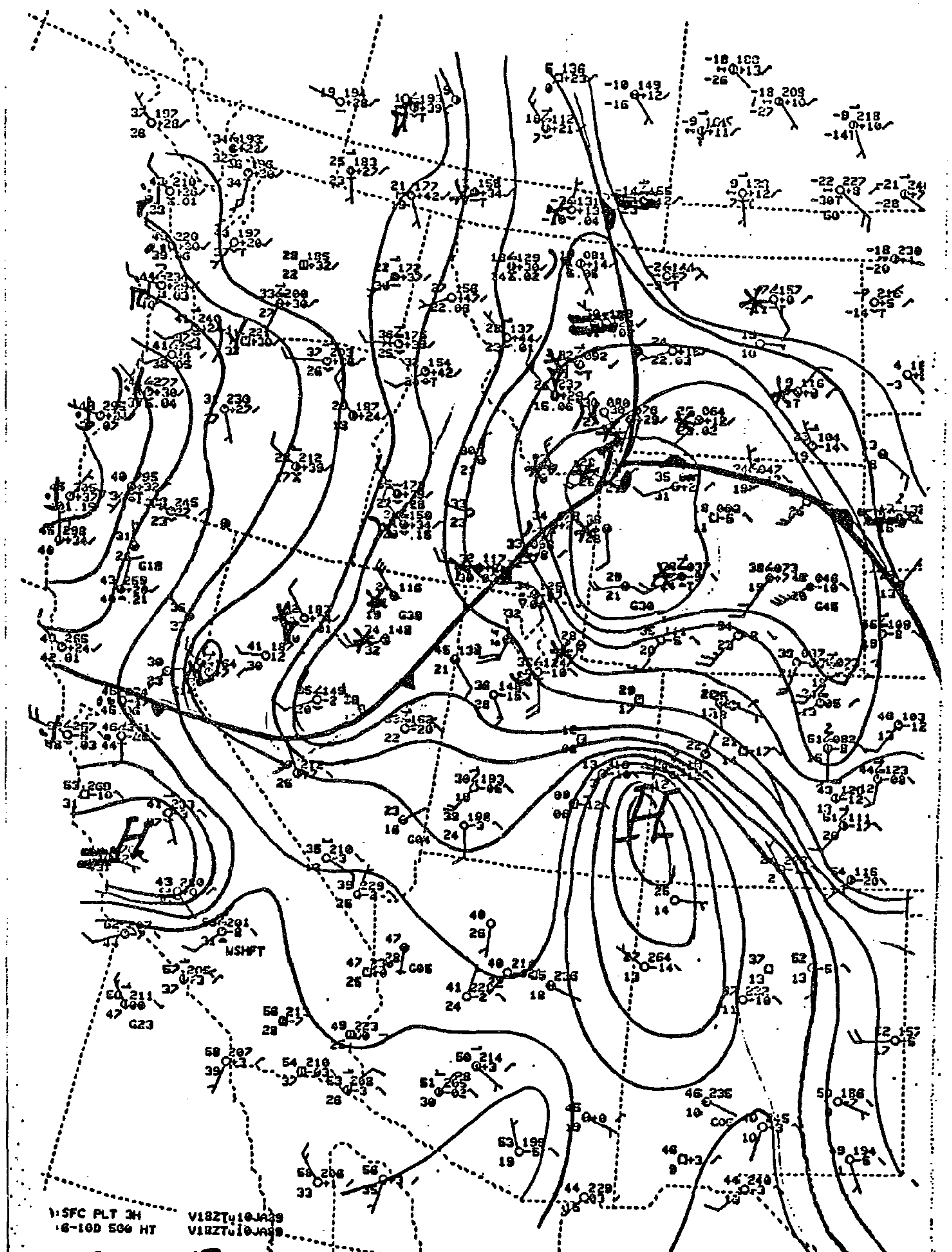


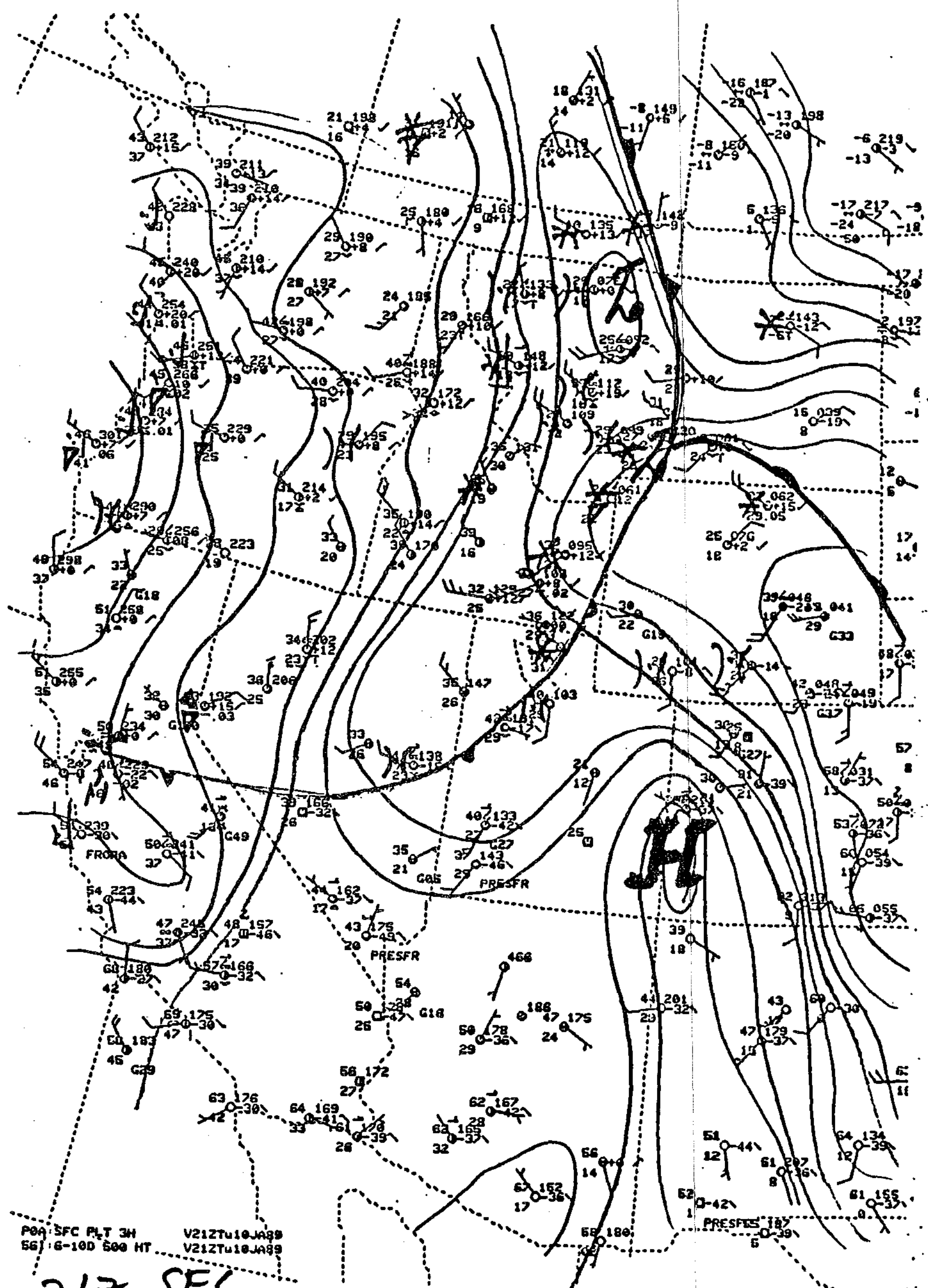
Figure 2b
18Z Local Surface Analysis



18z SFC

18z 1/10/89

Figure 2c
18Z Local Surface Analysis



21z SFC
1/10/89

Figure 2d
21Z Local Surface Analysis

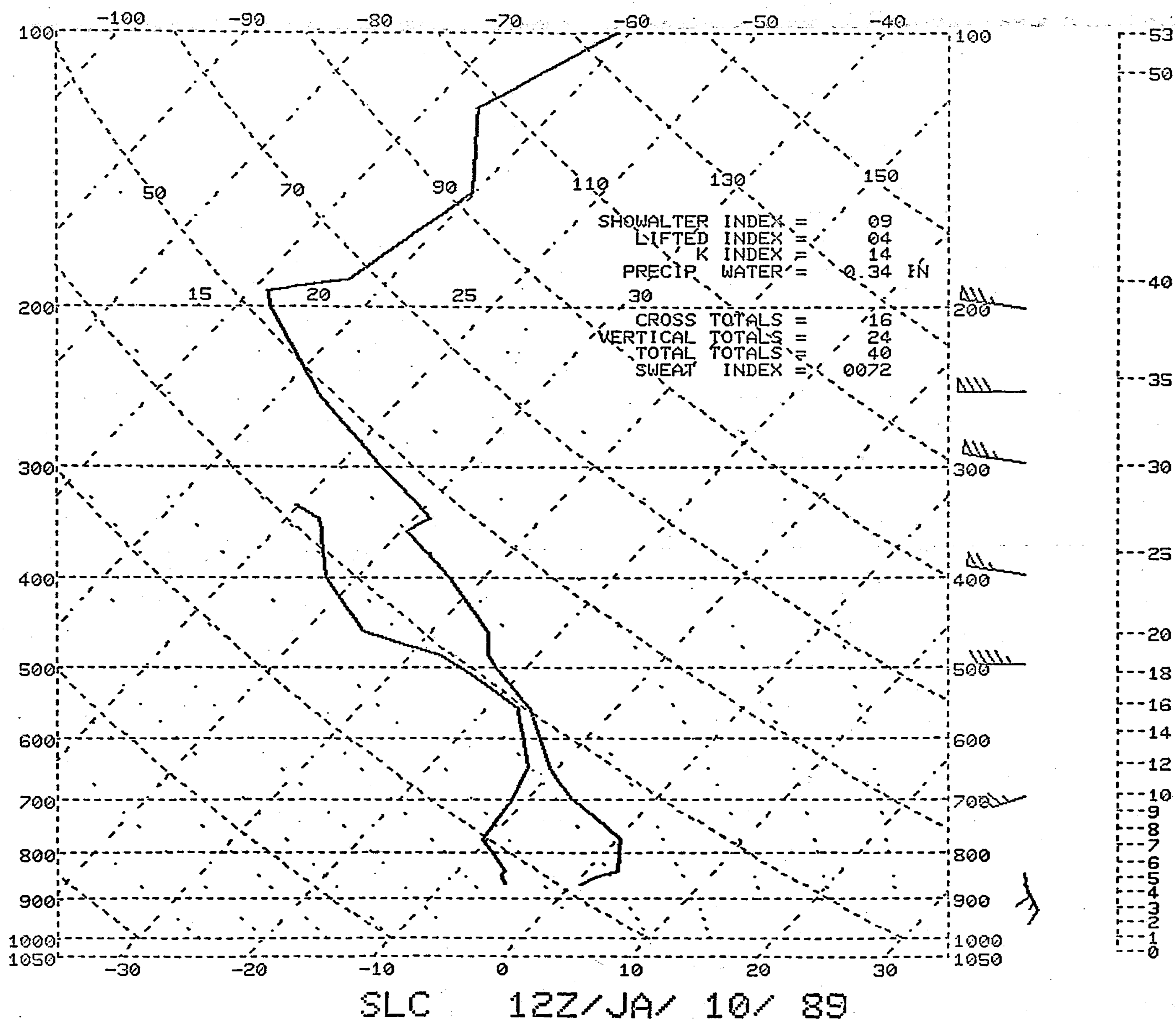


Figure 3
12Z SLC RAOB

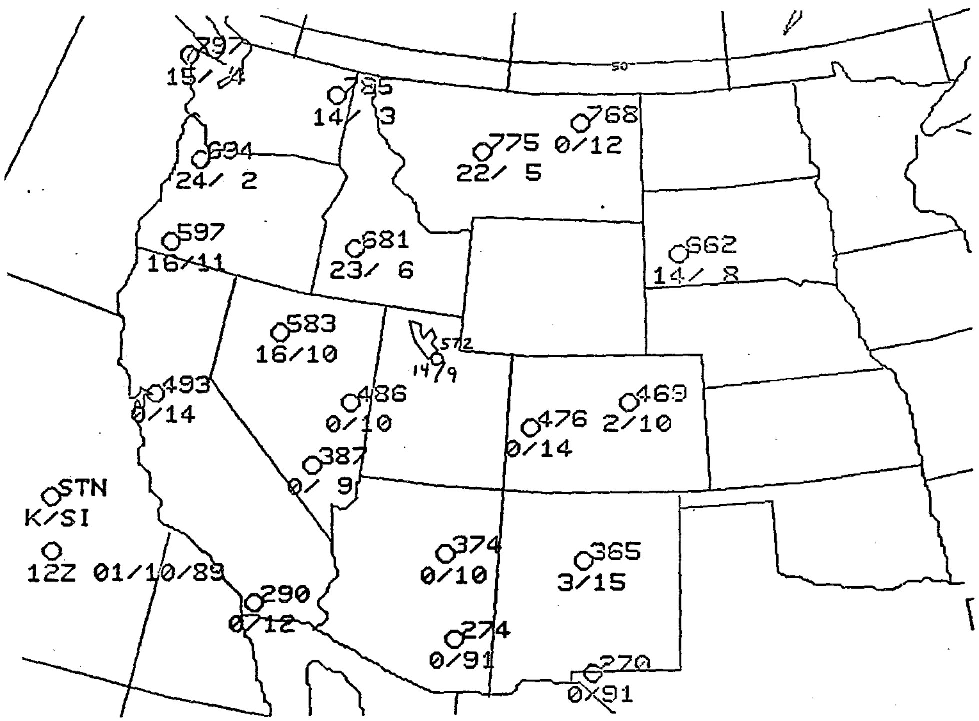


Figure 4
12Z K & Stability Analysis

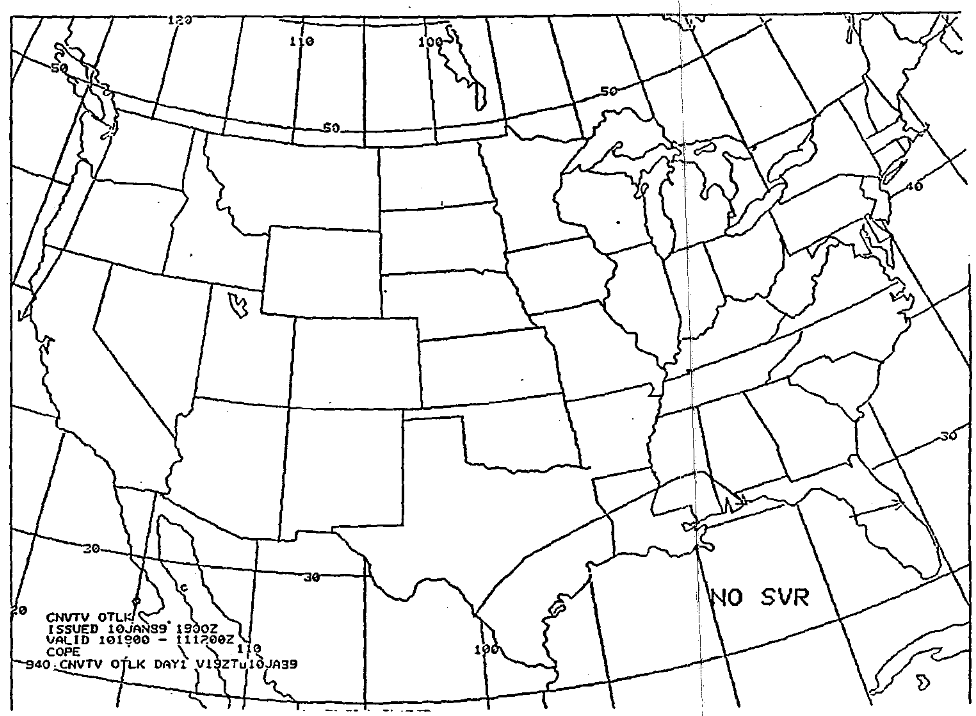


Figure 5
19Z Convective Outlook

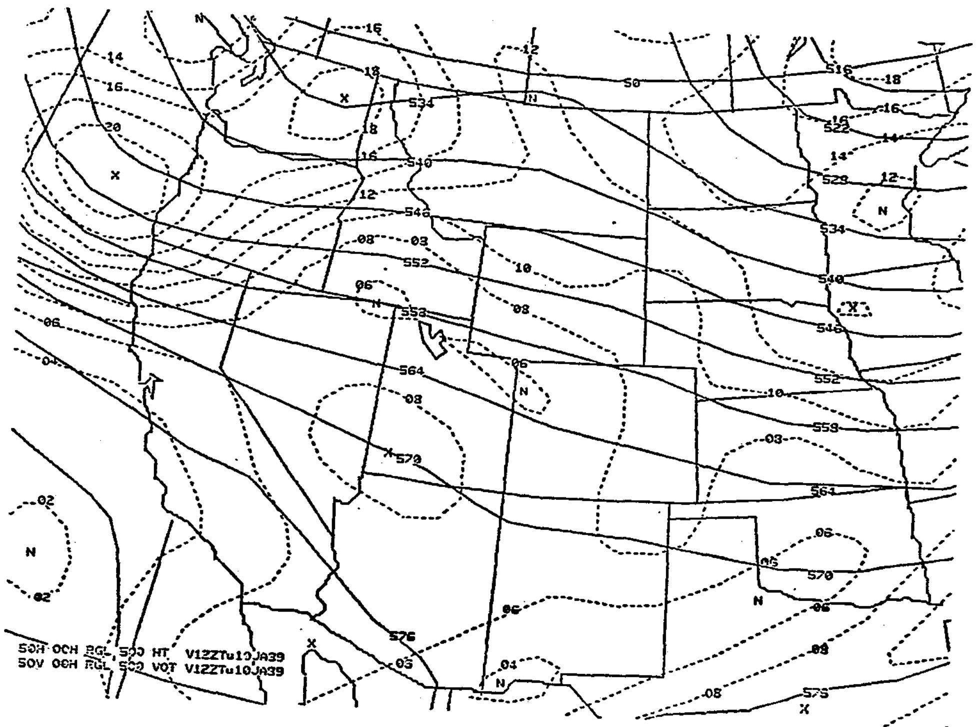


Figure 6
12Z RGL Initial 500 mb Height &
Vorticity Analysis

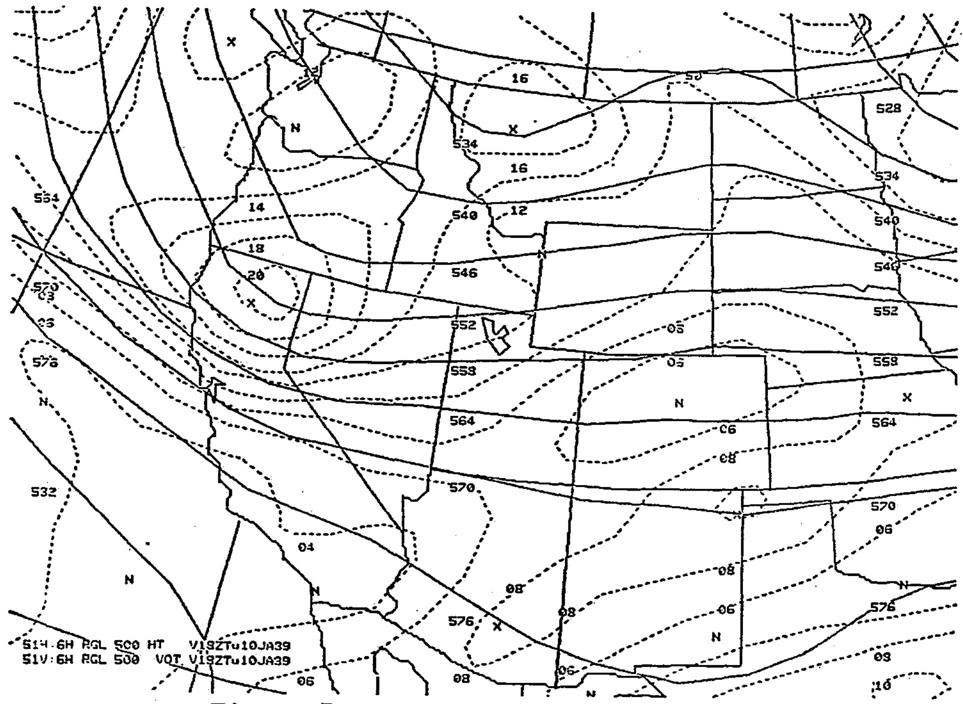


Figure 7
6 Hr RGL Prog 500 mb
Height & Vorticity

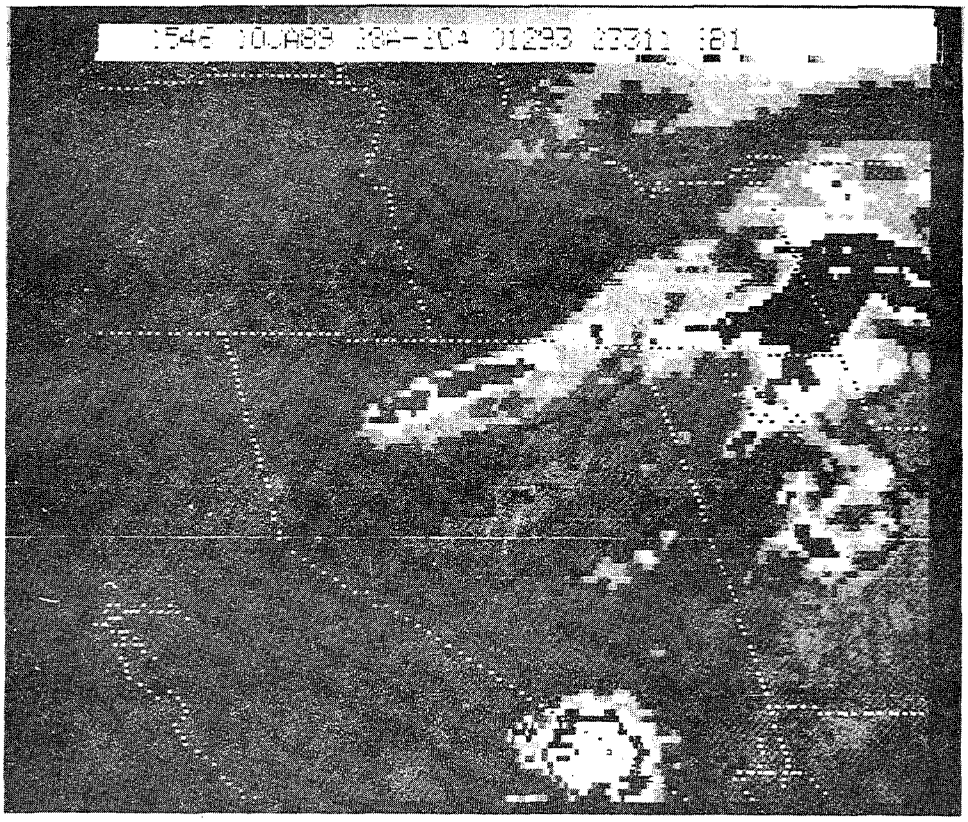
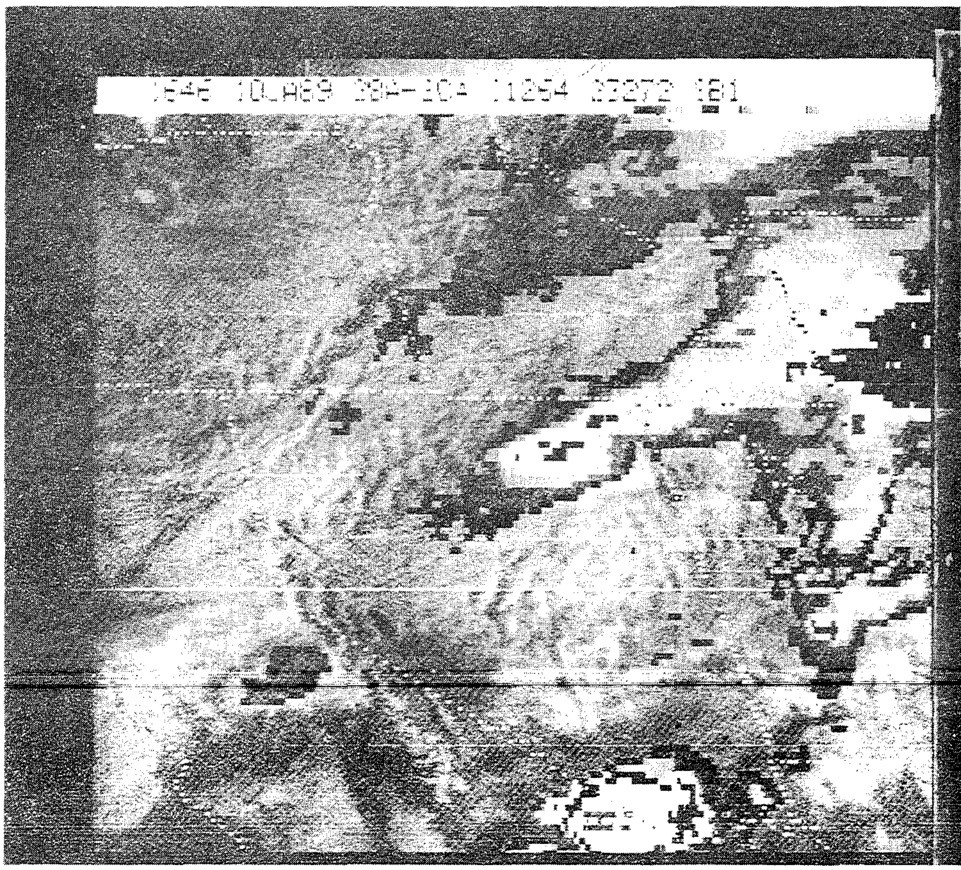


Figure 8



NMCFPCSLC									
FOUS12 KWBC 100224									
SLC SCW									
POP06		30	30	40	40	40	40	40	
POP12				50		50		50	30
QPF06		00X/1	00X/1	00X/1	00X/1	00X/1	00X/1		
QPF12				000X/1		100X/1		10XX/1	
TSTM				0		0		0	
POPT	0291/2	0380/2	0265/2	0164/2	0095/2	0097/2	0098/2	0096/2	
POSA				3111/1304/0602/0					
MX/MN				36		26		33	18
TEMP	32 32	33 32	33 34	32 33	33 31	29 29	31 32	30 27	
DEWPT	23 23	22 24	26 27	27 27	28 27	26 25	25 23	21 20	
WIND	1617	1616	1712	1908	3205	0000	3306	3405	
CLDS	0325/4	0226/4	0344/4	0246/4	0237/4	0127/4	1224/4	1333/3	
CIG	000253	000244	000235	001234	011243	011233	011324	001225	
VIS	001118	001008	001117	001116	000117	001117	001116	000117	
C/V	5/6	5/6	5/5	5/4	4/5	4/5	4/4	5/6	
OBVIS	9100/1	9001/1	8101/1	7101/2	81X1/1	81X2/1	72X2/2	81X1/1	

F

Table 1
SLC FOUS 12 from 00Z Data

NMCFPCSLC									
FOUS12 KWBC 101439									
SLC SCW									
POP06		50	50	30	10	10	10	10	
POP12				60		20		20	5
QPF06		00X/1	00X/1	00X/1	00X/1	00X/1			
QPF12				100X/1		00XX/1		000X/1	
TSTM				0		0		0	
POPT	0069/2	0077/2	0097/2	0099/2	0097/2	0096/2	0098/2	0099/2	
POSA				2313/0503/0302/0					
MN/MX				19		29		12	28
TEMP	35 35	32 31	27 25	23 23	27 28	25 20	18 18	17 16	
DEWPT	25 25	25 22	19 17	15 17	20 19	17 14	12 11	10 10	
WIND	1719	0209	3305	3301	3308	3402	3302	0000	
CLDS	0254/4	0127/4	1224/4	4312/2	4312/1	4411/1	6211/1	6212/1	
CIG	001125	001234	000244	000226	001117	000127	000028	001126	
VIS	001117	011116	001117	001117	001118	000118	000118	001118	
C/V	6/6	5/4	5/5	6/6	6/6	6/6	6/6	6/6	
OBVIS	8101/1	7101/1	8101/1	8001/1	81X0/1	81X1/1	81X1/1	81X1/1	

Table 2
SLC FOUS 12 from 12Z Data

```
ALQDS
SLC SA 2050 60 SCT 85 SCT E150 OVC 30 103/40/25/1810/983/ VIRGA AND SWU
ALQDS
SLC SA 1950 60 SCT 85 SCT E150 OVC 30 103/41/25/1915/984/ VIRGA ALQDS
SLC SA 1852 60 SCT 85 SCT E150 OVC 30 115/39/25/1715/987/ VIRGA NW-NE
SLC SA 1750 60 SCT 85 SCT E150 OVC 30 124/38/25/1720/989/ VIRGA NW-NE
810 157/ 90208 28
SLC SA 1652 60 SCT 85 SCT E150 OVC 30 129/38/24/1718/990/ VIRGA NE-SE
SLC SA 1552 60 SCT 95 SCT E150 OVC 30 136/37/25/1412/992/ VIRGA ALQDS
SLC SA 1452 60 SCT 95 SCT E150 OVC 30 137/36/24/1717/992/ VIRGA ALQDS/
520 157/
SLC SA 1352 65 SCT 90 SCT E150 OVC 30 132/38/25/1518/991
SLC SA 1250 65 SCT 85 SCT E150 OVC 30 151/35/25/1514/996
OR
SLC SA 1150 65 SCT M90 BKN 30 162/36/25/1415/999/ 712 1570 90406 32
20001
SLC SA 1150 65 SCT M90 BKN 30 162/36/25/1415/999/ 712 1570 90406 32
SLC SA 1050 65 SCT E100 BKN 20 172/34/24/1209/001/WND SHFTD GRDLY
SLC SA 0952 65 SCT E100 BKN 20 174/36/24/1817/002
SLC SA 0852 65 SCT E100 BKN 20 181/33/23/1510/003/ 824 1570
SLC SA 0752 M65 BKN 100 BKN 20 192/36/23/1517/007/ 98000
SLC SA 0650 M65 BKN 90 BKN 20 197/36/24/1620/009
OR
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Table 4
SLC Surface Obs

```
WBCROBADW
SDUS24 KAWN 101400 RTD02
HIF 1435 COR AREA 4TSW 355/110 110/15 260/125 C2920 MT 250 AT
    262/25=
WBCROBADW
SDUS24 KAWN 101500 RTD02
HIF 1535 AREA 6TSW 355/115 135/40 190/75 295/115 C3020 MT 250
    254/7=
WBCROBADW
SDUS24 KAWN 101600 RTD02
HIF 11635 AREA 6TSW 352/115 153/65 210/55 285/90 C3020 MT 200 AT
    359/33 MOST TOPS BLO 160=
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Table 3
HIF Radar Obs

```
UBUS1 KWBC 101524
 UT 101524
OGD UA /OV OGD/TM 1510 /FL DURGD /TP B727 /TB MDT 110-100
SLC UA /OV SLC270005/TM 1508/FLUKN/TP E120/SK 100 BKN/ TB LGT CHOP
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UBUS1 KWBC 101600
 UT 101600
SLC UUA /OV SLC 230035/TM 1518/FLDURGD/TP B737/IC SVR RIME
    /RM 1 1/2 IN ON WINDSHIELD
SLC UA /OV SLC270030/TM 1528/FL 150/TP B737/IC MDT RIME
SLC UA/OV SLC270030/TM 1528/FL 150/TP B737/IC MDT RIME
SLC UA /OV SLC 5NMR/TM 1532/FL 080-055/TP B737/TB MDT
SLC UUA /OV SLCS60003/TM 1540/FL 055-060/TP C172/TB MDT-SVR
SLC UA /OV SLC 360006/TM 1550/FL085/TP B727/TB MDT
SLC UA /OV FFU/TM 1603/FL200-150/TP LR35/IC LGT-MDT RIME DURGD
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Table 5
Pilot Reports