Western Region Technical Attachment
No. 89-27
September 26, 1989

DEW POINT DISCONTINUITY INITIATES SEVERE THUNDERSTORMS IN UTAH

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Introduction

On May 11, 1989, a cold core cut-off low moved into the Great Basin from southern California. An active day of showers and thundershowers was forecast across the region with ample low level moisture in place and temperatures at the 500 mb level already below -20°C. As the day progressed, the atmosphere became more unstable, supporting the likelihood of severe thunderstorms. Although, some isolated thundershower activity occurred between Dugway Proving Ground and the Salt Lake Valley during the early morning, most of the late morning and midday cloud development was suppressed. Then between 1830Z and 1930Z, an area of organized convection developed in the vicinity of and north of Delta, Utah. This area expanded along an apparent axis oriented from west-southwest to east-northeast and moved northward, producing severe weather from near Dugway Proving Ground, extending into the Salt Lake Valley. Severe weather reports included several funnel clouds and a tornado at Hill Air Force Base, a funnel cloud at Dugway Proving Ground, and numerous reports of 3/4 inch or greater diameter hail.

What was the focusing mechanism that produced these thunderstorms? Although this cluster of thunderstorms was likely enhanced over the somewhat higher terrain that stretches from west of Delta toward the southern Salt Lake Valley, there apparently was some type of atmospheric forcing present to initiate the development and then fuel the thunderstorms into the mature stage. The triggering mechanism is believed to be a dew-point discontinuity (strong dew-point gradient) in the boundary layer that provided the necessary surface convergence while positive vorticity advection and upper-level diffluence provided upward vertical motion.

Storm Synopsis

At 12Z on May 11, a moderately cold cut-off low entered the Great Basin from southern California. Temperatures were colder than -20°C at 500 mb across Nevada and most of California with Edwards AFB reporting -25°C (Figure 1). The cut-off low had progressed due east since 00Z, but was forecast by the Nested Grid Model (NGM) to curve slightly north of east during the next 12 hours to a position just south of St. George, Utah. Based on the existence of a 300 mb jet core rotating through the base of the trough at 12Z (Figure 4), this forecast position looked reasonable. A thorough inspection of the 12Z NGM analysis of the 500 mb heights and vorticity field indicated several possible vorticity lobes. Specifically, a vorticity lobe extended from near Las Vegas, Nevada, to Kingman, Arizona, down to Yuma, Arizona, and rotating north (Figure 2a). The 12 hr NGM forecast, valid 00Z Friday (Figure 2b), moved this vorticity lobe through Utah to a position stretching from the low, northward along the Nevada-Utah border, then northeast toward Pocatello. There was positive vorticity advection rotating northward across northern Utah during the optimum surface heating of the midday and afternoon hours.

The 500 mb dew-point analysis indicated large dew-point depressions across southern Nevada, Arizona, and southern California (Figure 1). This was misleading because the 12Z Ely, Nevada sounding (Figure 3b) indicated moisture was in adequate supply from 520 mb down to the surface with 0.439 inches of precipitable water. At Salt Lake City, the precipitable water was greater with 0.654 inches from 500 mb to the surface.

At the 300 mb level at 12Z (Figure 4), a 70 kt southerly jet was moving through Arizona and into southern Utah, with a 90 kt jet core rounding the base of the trough. Analysis of the wind speed and direction at the Nevada stations of Mercury (rawinsonde station located to the northwest of Las Vegas) and Ely, and Salt Lake City indicated cyclonic wind shear and directional diffluence over the region. This area of upward vertical motion associated with the left front quadrant of the jet was forecast over the region for at least the following 6 to 12 hours, during the maximum heating of the day. Therefore, the upper-level dynamics from 500 mb to 300 mb appeared ripe to produce an outbreak of convection.

The lower levels were also primed to produce thunderstorm activity. At the 700 mb level (Figure 5), a large pool of relatively warm dew points (greater than -5°C) existed over the eastern half of Nevada and at least the western half of Utah and possibly northern Arizona. The analysis also depicted a dry slot wrapping around the base of the trough into central Arizona and northward to Grand Junction, Colorado. It is unknown whether this feature played a significant role in the northern Utah thunderstorms. What did appear to play an important role was the moderately strong baroclinic band stretching from central Nevada to south central Arizona (Figure 6). The 700 mb streamline flow and/or entire translation of system northeastward suggested a baroclinic zone passage over central and northern Utah between 18Z and 00Z.

The 850 mb low was located in extreme southeastern Nevada to near the southwest border of Utah (Figure 7), with the axis of the trough line extending north-northeast toward northwest Wyoming. At first glance, the trough axis appeared to be positioned too far west across northern Utah, the 12Z Salt Lake City sounding (Figure 3a) indicated backing winds from the surface to 8000 ft supporting cold advection and, therefore, a frontal passage. However, the temperature profile with the low-level inversion supported a pre-frontal sounding, lending credence to the trough position depicted in Figure 7. In addition, since there was convective activity the previous night, the wind pattern may have been more indicative of old outflow boundaries affecting the Salt Lake Valley rather than a recent cold frontal passage. Therefore, as supported by the temperature profile, the 850 mb trough position across extreme northwestern Utah (northwest of Dugway Proving Ground and Salt Lake City) at 12Z appeared correct. As the day progressed, observations from Lakeside, Utah and Wendover, Utah, (Figure 8), confirmed that a frontal passage had occurred. Both stations reported northerly winds, temperatures about 10°F cooler than either Salt Lake City (not shown) or Dugway Proving Ground, and dew points lower by a few degrees. With the forecast slow movement of the 850 mb trough and surface front toward the east-southeast during the day, the question was exactly where would these boundaries be later that afternoon when the upper-level dynamics were primed and surface heating was at a maximum. The surface observations at both Dugway Proving Ground and Salt Lake City indicated that these sites remained south of the frontal zone through at least 19Z. Then, when the lightning activity increased rapidly to the south of Dugway Proving Ground at 1930Z (Figure 10), some other surface feature obviously provided the low-level convergence, fueling the thunderstorms.

Careful analysis of surface observations to the south of Dugway Proving Ground indicated a very important mesoscale feature. The winds at Delta veered from northwest to north to northeast during the course of the morning and the dew point was steady, holding in the 40s (Figure 8). Then, between 15Z and 17Z, an apparent boundary moved through, as the dew point dropped 10°F and the winds became calm. By 18Z, winds were 120 degrees at 5 kt and the dew point was 34°F. This was characteristically similar to all other stations in southern Utah and southeastern Nevada which also reported a southerly component in their winds and dew points holding in the 30s. This dew-point discontinuity, best seen on the surface analysis (Figure 9), stretching from southeastern Nevada to just north of Delta, is similar to a Southern Plains dryline (in terms of the sharp moisture gradient) which has long been known as a preferred region for thunderstorm development (Schaefer, 1974). Lightning data from the Automatic Lightning Detection System (ALDS), (Figure 10) indicated this was the zone along which the most active cells originated. As the thunderstorms progressed northward, away from the original surface convergence region, there was noticeably less organization to the lightning strike pattern (Figure 11).

Summary

An overview of the situation indicated that neither the surface nor the 850 mb cold front acted as the initiating low level convergence mechanism for the severe thunderstorms. Both features were evidently north of the developmental zone that was between Dugway Proving Ground and Delta. However, the one surface feature which did exist in the proper location was the dew-point discontinuity. This feature passed through Delta between 15Z and 17Z, but did not reach Dugway Proving Ground. Rapid thunderstorm development occurred between Dugway Proving Ground and Delta at about 19Z (Figure 10), along this sharp dew-point gradient. The rest of the atmosphere was primed as well. At the 700 mb level, a baroclinic band was located from central Nevada to northern Arizona at 12Z and was extrapolated to be over north central and western Utah by the afternoon hours. The presence of this baroclinic zone enhanced the convergence in the lower levels of the atmosphere and, therefore, strengthened the net upward vertical motion.

What appeared to be an inhibitor for good thunderstorm development at Ely's 12Z 500 mb level, i.e., a dew-point depression of 15C, may have acted as a cap, suppressing most convection through the midday hours, until the dynamics and surface heating overcame this negatively buoyant region. This type of dry intrusion, although usually near the 700 mb level, is often present in the Plains States where severe weather is more prevalent. Surface observations at Dugway Proving Ground (Figure 8) supported this idea, as limited vertical development occurred through the midday hours (except over the highest mountains to the east and far west). This was shown clearly on the real-time (ALDS) by the numerous strikes that occurred south of Dugway Proving Ground and north of Delta (Figure 10). By 1932Z, thunder was heard at Dugway Proving Ground and a thunderstorm was in progress at the station by 1955Z. The funnel cloud was sighted at approximately 2015Z, about 10 miles to the southwest of the station. Although hail was not reported at the station, 3/4 inch diameter hail fell to a depth of a couple of inches about 7 miles due west of the station. As the later afternoon and evening progressed, there were numerous reports of hail from across northern Utah and a brief tornado at Hill AFB.

Conclusions

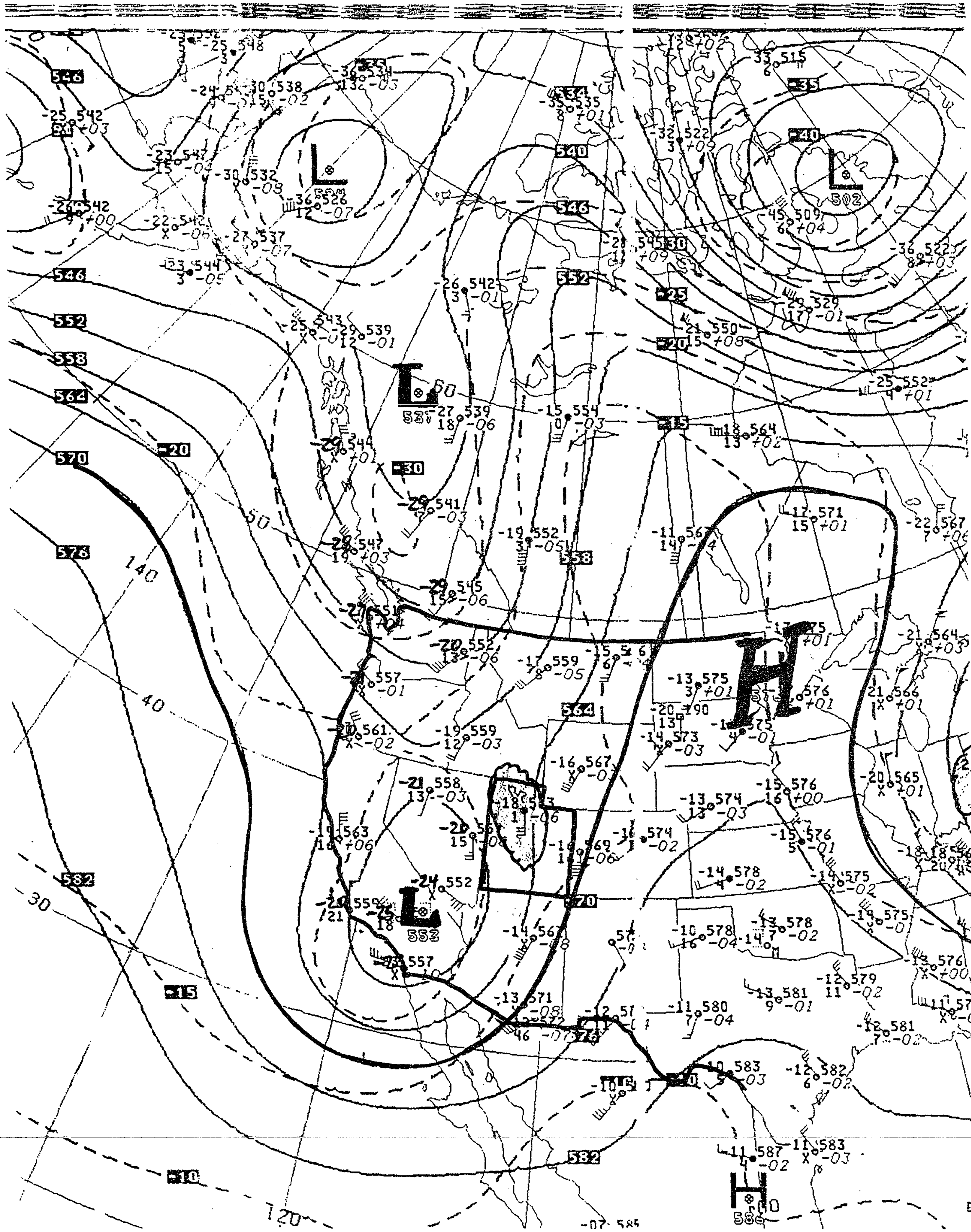
Thunderstorms which develop over the intermountain region during the springtime months are typically associated with cold fronts and with upper level cut-off lows. Extrapolation of these features normally provides a good first guess at where thunderstorm activity will occur during the next 12 hours. However, as described in this case study, other surface features, discontinuities, or boundaries can play an important role in triggering thunderstorm development. These features become increasingly important during the summer months when air mass thunderstorms are prevalent. In this case, the surface convergence was focused around a strong dew-point gradient. This was an especially ripe area for thunderstorm development on this day because its orientation was nearly perpendicular to the flow at the surface and aloft. Once the upper-level dynamics overran this low-level convergence, thunderstorm development was "off to the races". This particular case study points out the importance of surface features which occasionally are either not analyzed correctly or are not analyzed at all.

References

Schaefer, J. T., 1974; The Life Cycle of the Dryline. J. Appl. Meteor., 13, 444-449.

Acknowledgments

The author would like to thank Mr. Dave Smith from the Bureau of Land Management, Boise, Idaho, for supplying the lightning data in raw form (latitude and longitude coordinates). The author also appreciates the efforts of Mr. Don Bullard, Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, and Mr. Jim Bowers, Dr. Elford Astling, and Mrs. Susan Gross all from the Meteorology Division, U.S. Army, Dugway Proving Ground for plotting lightning data, reviewing this paper, offering suggestions, and encouragement in this project. Their efforts combined to produced worthy data and ideas supporting this study.



D155 .. 500MB ANALYSIS HEIGHTS/TEMPERATURE 12Z THU 11 MAY 89

FIGURE 1 - Note SLC is the only reporting station in the Great Basin region and westward with a dewpoint depression of less than 10°.

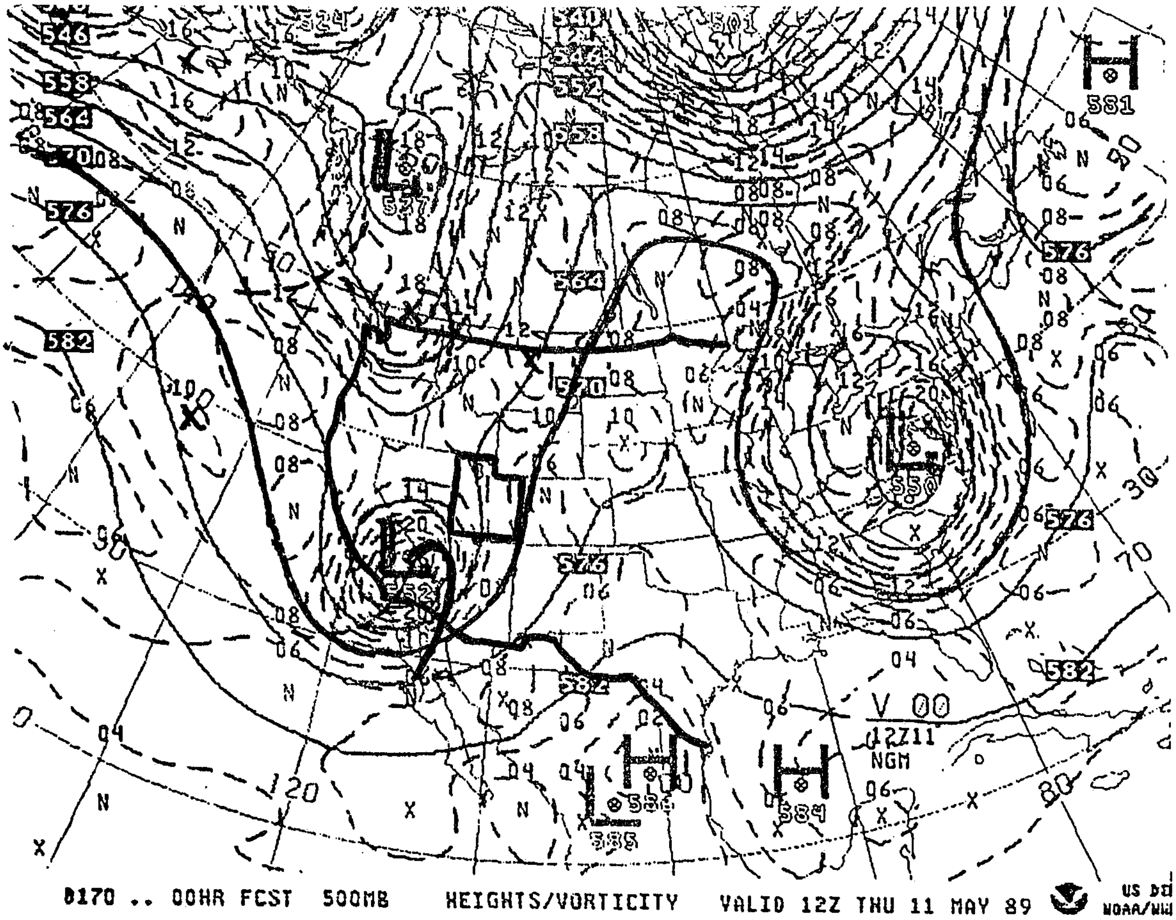


FIGURE 2 (A)

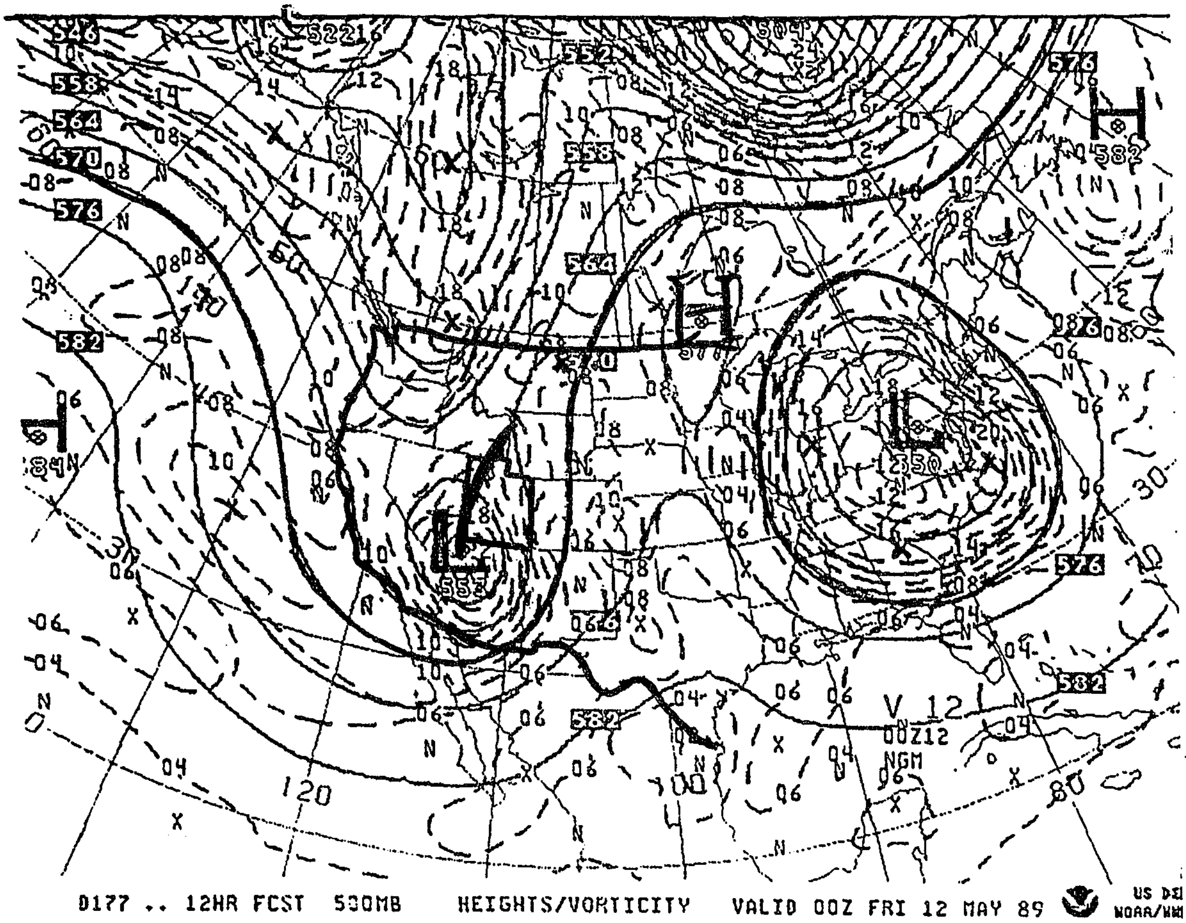


FIGURE 2 (B)

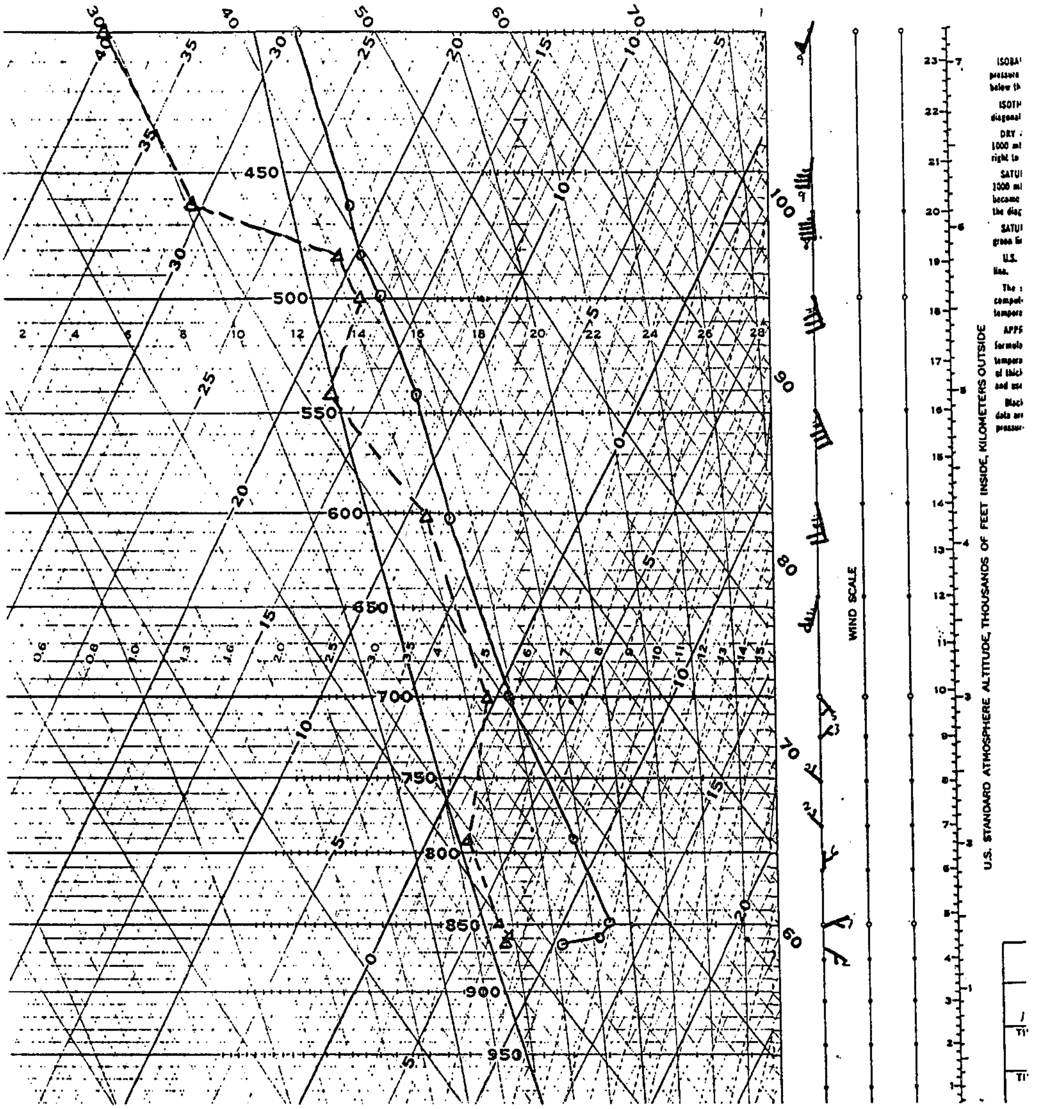


FIGURE - 3 (A)
SLC SOUNDING 12Z MAY 11

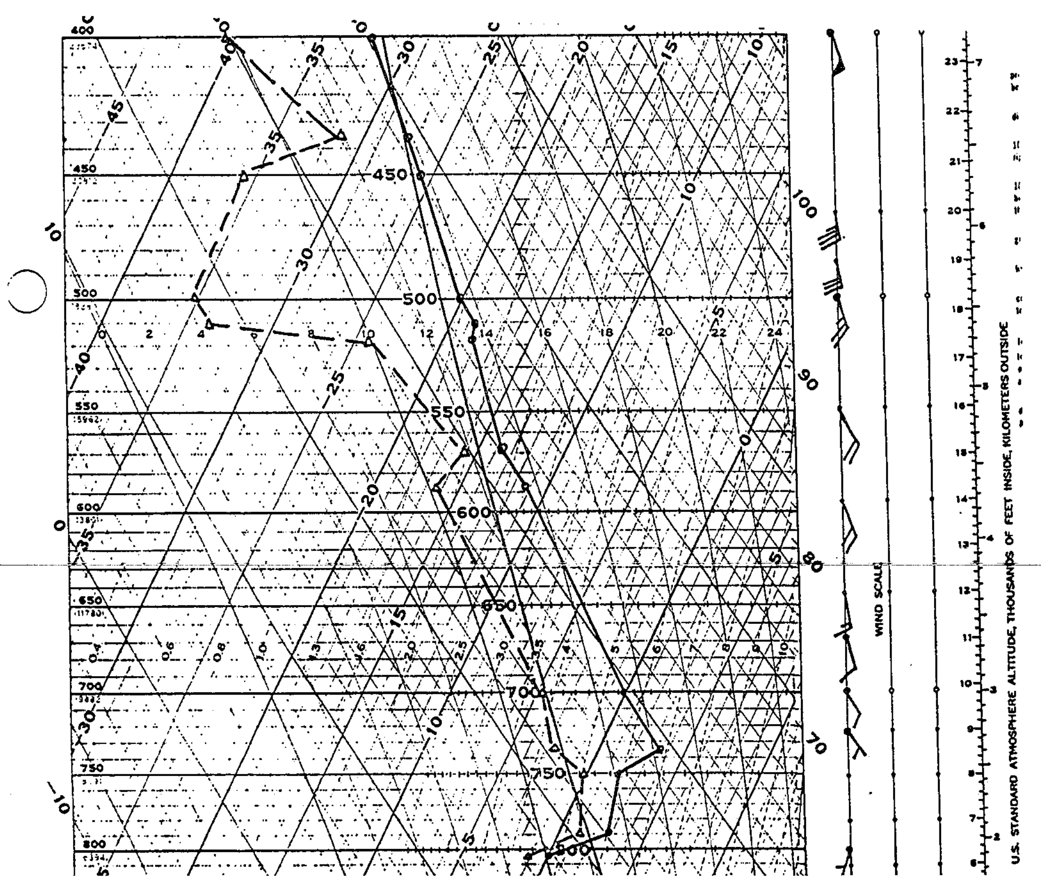
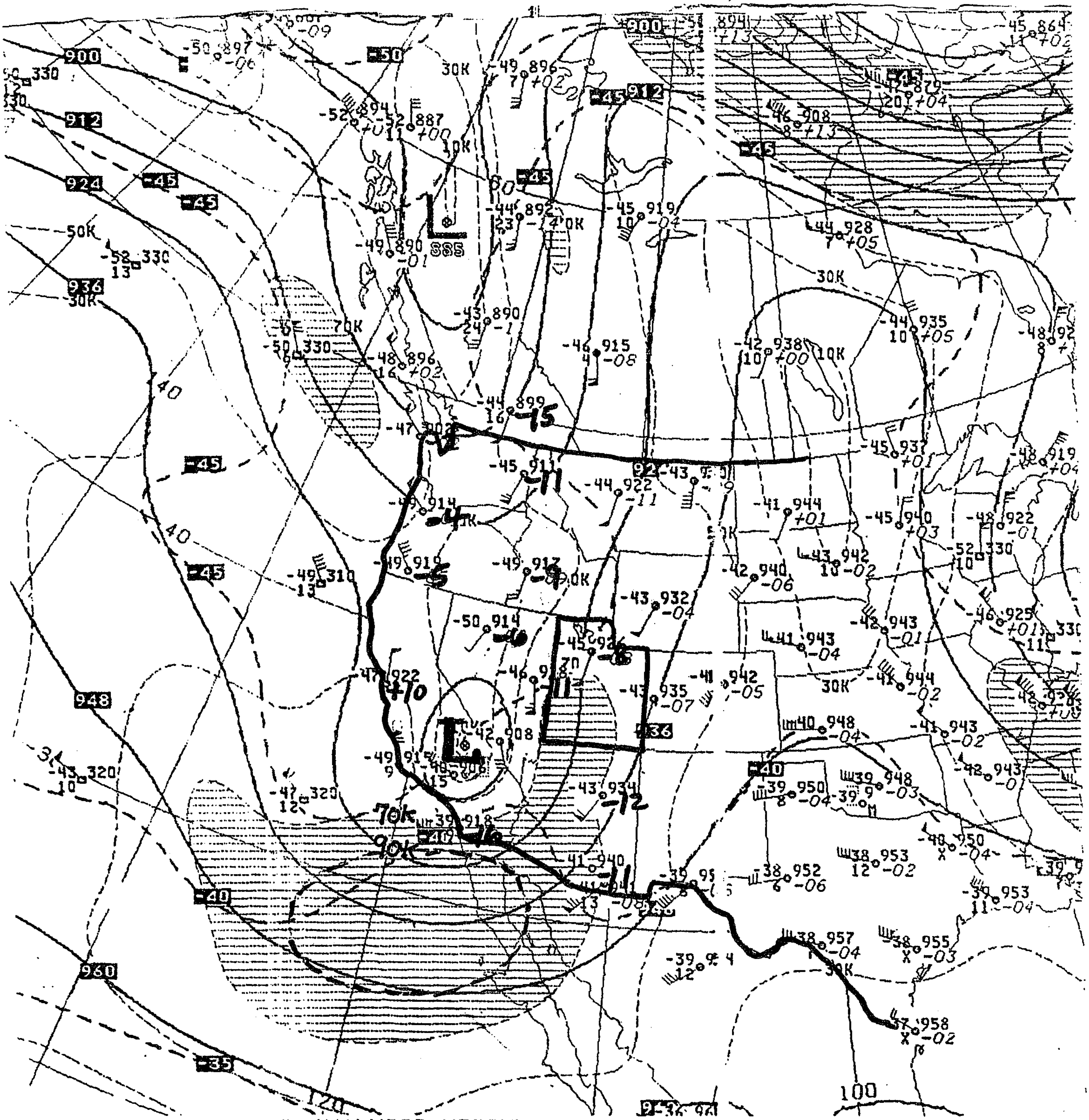
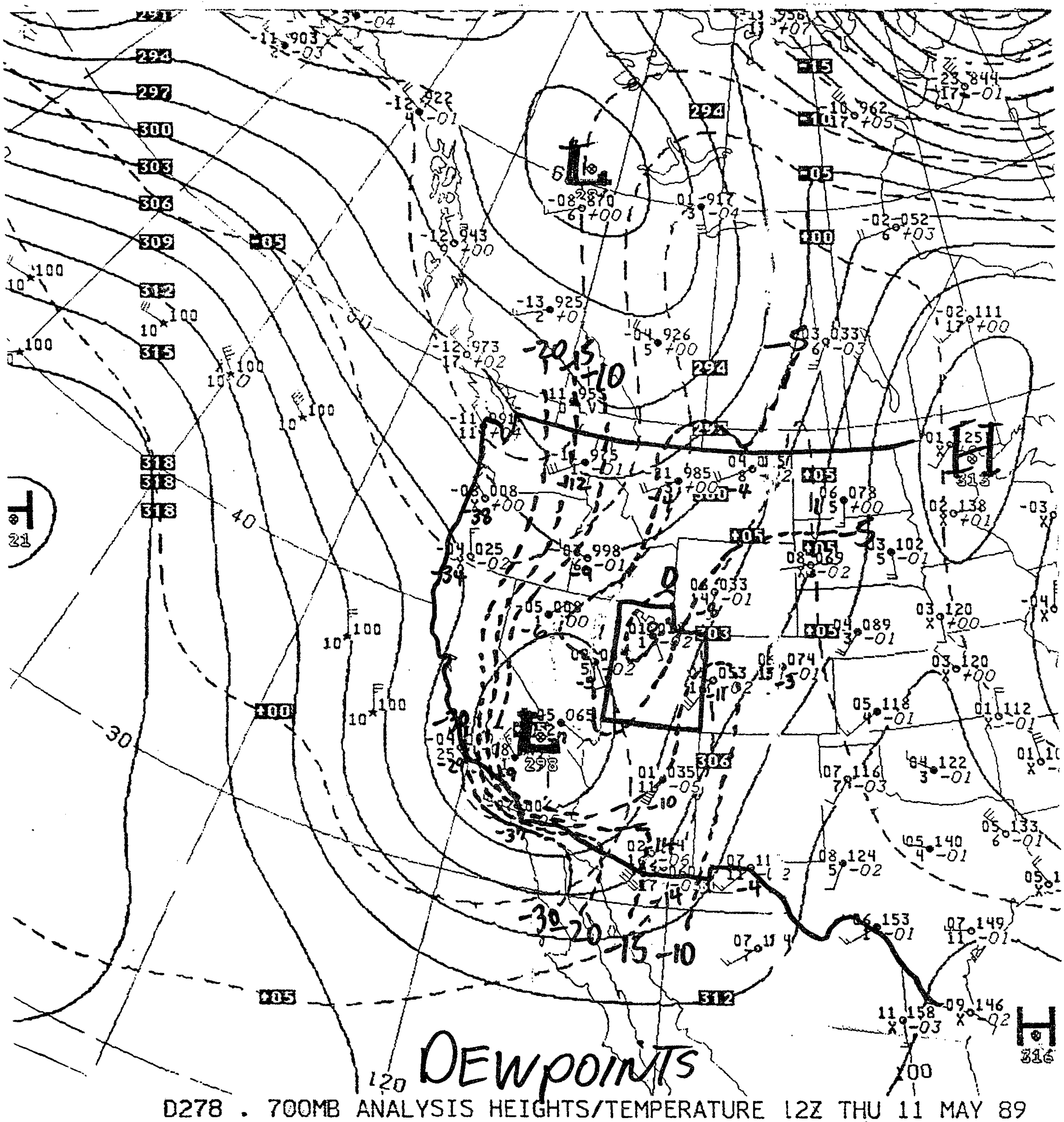


FIGURE - 3 (B)
ELY SOUNDING 12Z MAY 11



D183 .. 300MB ANALYSIS HEIGHTS/ISOTACHS 12Z THU 11 MAY 89

FIGURE 4) Height falls are highlighted and the 90K jet is outlined.



~~FIGURE 5 - Dashed lines~~ equal 5° increments in dew point temperatures. (Note the warm region from southwest Utah to northern Montana).

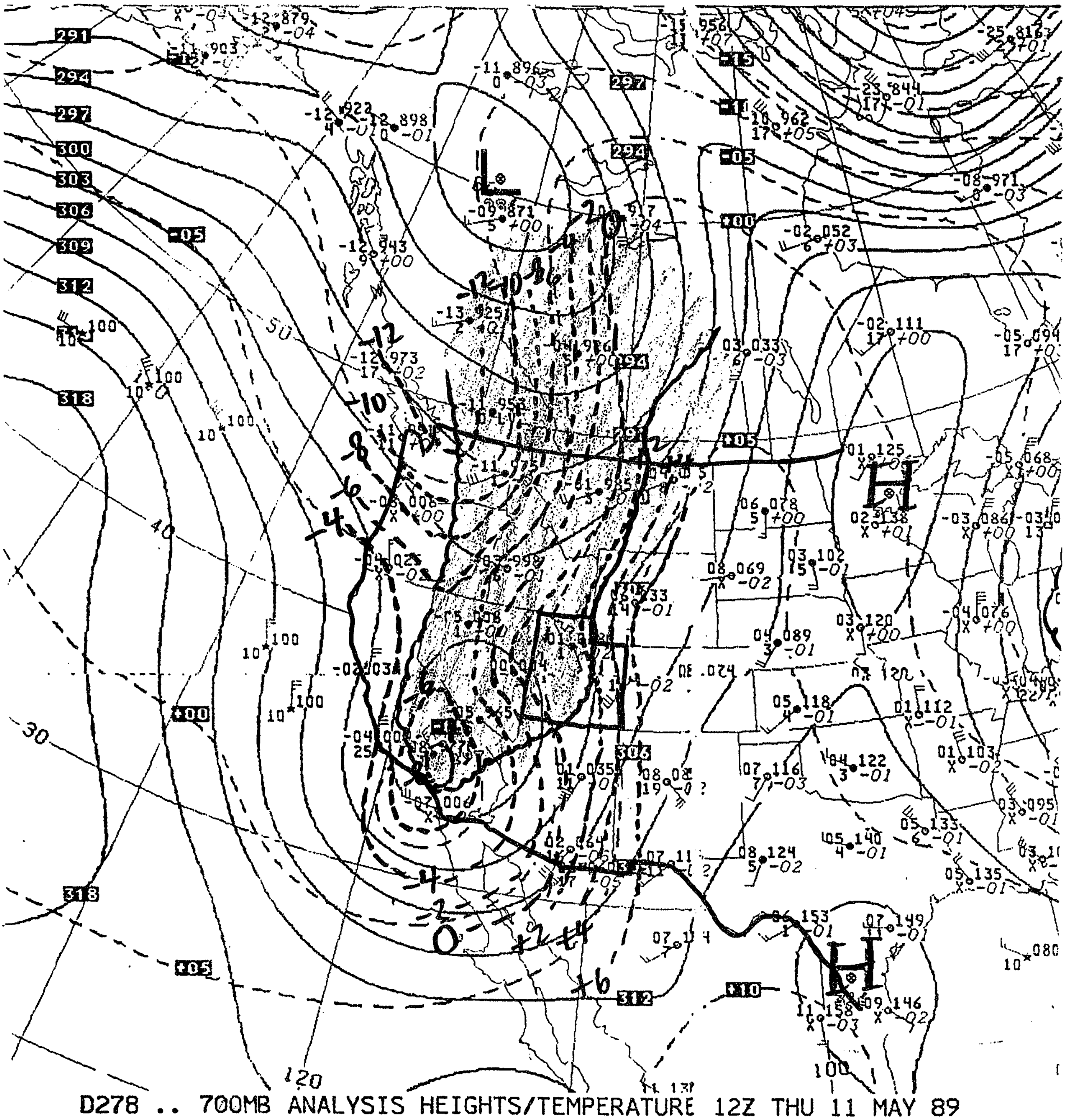


FIGURE 6 - SHADED AREA REPRESENTS WHERE DEWPOINT DEPRESSIONS ARE LESS THAN OR EQUAL TO 5°.
- DASHED LINES ARE 2° ISOTHERMS.

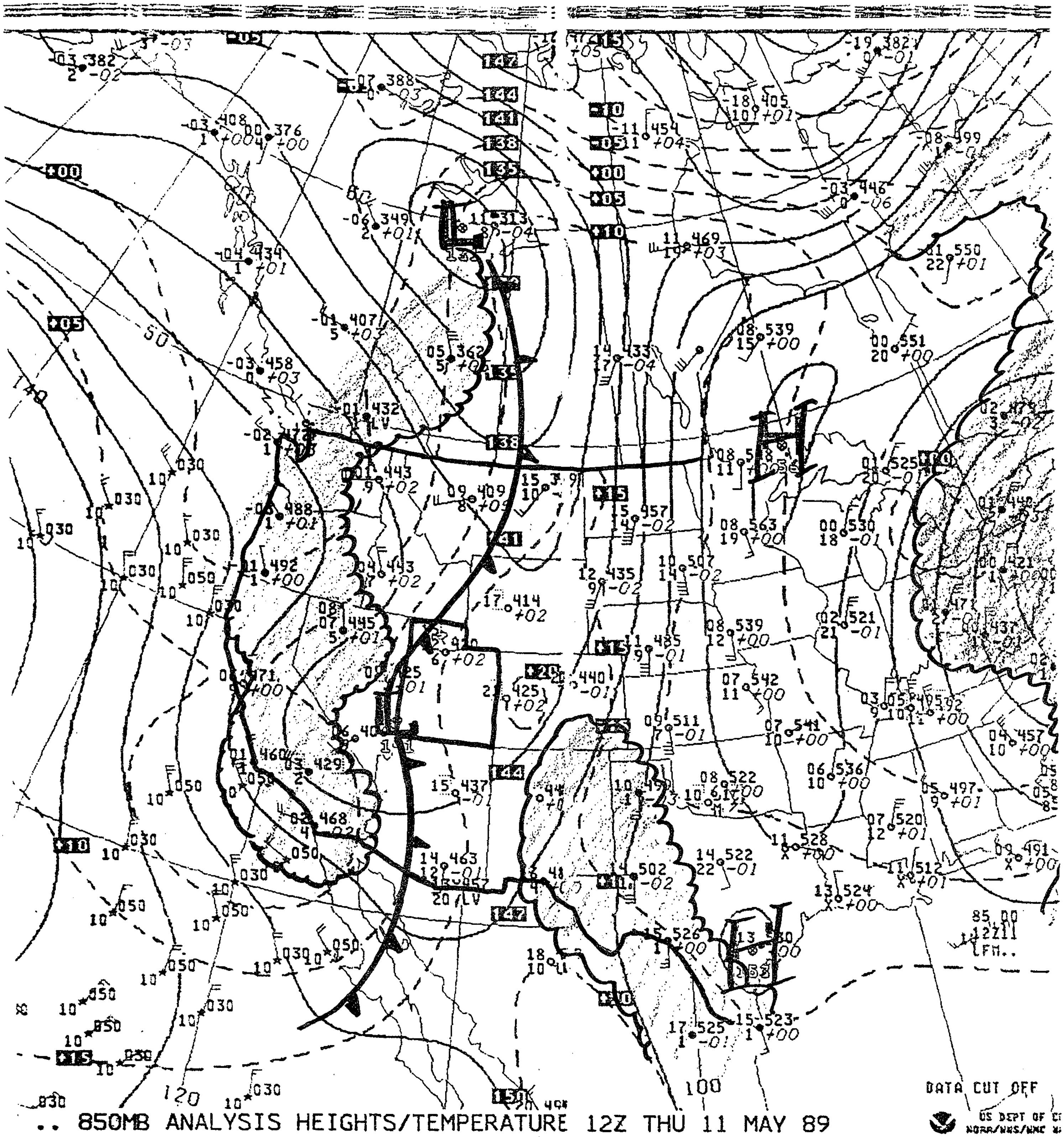


FIGURE 7 - Shaded area represents dewpoint depression of 5° or less.

SURFACE OBSERVATIONS 11-MAY-1989

DELTA, UTAH

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U24 SA 1251 30 SCT E100 BKN 40 047/49/42/3305/M/ SCTD CB AND RWU ALQDS/ 47348=
U24 SA 1345 30 SCT 100 SCT 250 -OVC 40RW- 046/50/44/3512/M/ PCPN HVYR NW=
U24 SA 1448 30 SCT 100 SCT 250 -SCT 50 040/57/44/0410/M/ 80304 /NOSPL=
U24 SA 1550 MISSING
U24 SA 1647 30 SCT 100 SCT 250 SCT 023/63/34/0000/M/ CB RWU S /NOSPL=
U24 SA 1747 E35 BKN 100 BKN 250 OVC 50 016/67/34/1205/M/ CB RWU NE-S/ 71504 47=
U24 SA 1850 MISSING
U24 SA 1950 MISSING
U24 SA 2100 FINO
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LAKESIDE, UTAH

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U16 SA 1355 25 SCT 50 SCT 100 SCT E250 BKN 60 M/52/45/0115G22/E981  /
            CB 25SW-W MOVG N TCU E VIRGA E RWU SW FIRST=
U16 SA 1455 MISSING
U16 SA 1555 25 SCT 50 SCT E100 BKN 250 BKN 60 M/53/42/0119/E980  /MDT CU
            W AND NW VIRGA E-SE=
U16 SA 1655 25 SCT E70 BKN 100 BKN 250 BKN 60 M/55/42/0119G24/977  /CB
            DSNT NE AND 25SE-S MOVG N OCNL LTGCG VIRGA AND RWU E-S=
U16 SA 1755 25 SCT E70 BKN 100 BKN 250 BKN 60TRW- M/57/39/0114/E978  /
            T OVHD-E-S MOVG N OCNL LTGICCG CIG RGD=
U16 SA 1855 MISSING
U16 SA 1955 MISSING
U16 SA 2055 25 SCT 50 SCT 70 SCT E250 BKN 30 M/58/44/3513G20/E974  /CB
            DSNT NW-NE AND 20SE-SW MOVG N RWU SE-SW
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DUGWAY PROVING GROUND, UTAH

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DPG SA 1257 60 SCT 90 SCT E140 BKN 250 BKN 50RW- 034/54/44/2203/979/ RB35=
DPG SA 1356 60 SCT 90 SCT 140 SCT 250 SCT 50 036/58/47/3202/979/ VIRGA/RWU
            SW-NW RE15=
DPG SA 1456 60 SCT 90 SCT 140 SCT 250 SCT 50 035/61/48/0902/978/ VIRGA/RWU
            SE AND SW MDT CU NE AND SE-SW / 00200 1278=
DPG SA 1556 35 SCT 60 SCT E90 BKN 140 BKN 250 BKN 50RW- 031/60/46/0803/976/
            CB NE-E MOVG N VIRGA NE-SE RB45=
DPG SA 1656 45 SCT 60 SCT 90 SCT 140 SCT 50 033/66/48/3609/975/ CB N-NE AND
            W MOVG N RWU NE RE04=
DPG SA 1756 30 SCT 60 SCT 90 SCT 50 030/65/45/2804/972/ CB N AND SW-NW
            NOVG N VIRGA/RWU SE AND SW MDT CU SE/ 81700 1970 52=
DPG SA 1855 30 SCT 60 SCT 90 SCT 50 016/70/45/3207G17/968/ CB N-E-S MOVG N=
DPG SA RTD 1955 30 SCT E60 BKN 100 BKN 50TRW- 006/62/44/0217G24/965/ TB32
                OVHD MOVG N OCNL LTGCG CB N-E MOVG N RB44=
DPG SP 2020 FUNNEL CLOUD B2015E2016 10SW DSIPD
DPG RS 2055 20 SCT E45 BKN 100 OVC 25 RW- 055/47/45/2513G21/978 CB ALQDS
            FUNNEL CLOUD B2015E2016 10SW DSIPD TE46=
DPG RS 2155 10 SCT E28 BKN 40 OVC 10 RW- 077/49/46/2404/984 VSBY LOWER
            NE-SW RB07E46 MAX 73 LAST=
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WENDOVER, UTAH

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ENV SA 1248 AUTOB CLR BLO 60 BV8 53/36/3507/978 PK WND 13 054
ENV SA 1348 AUTOB 46 SCT BV8 52/38/2002/980 PK WND 10 054
ENV SA 1448 AUTOB 35 SCT E44 OVC BV6 50/39/2805/982 PK WND 13 054
ENV SA 1549 AUTOB CLR BLO 60 BV5 P 49/40/3506/981 PK WND 08 076
ENV SA 1648 AUTOB CLR BLO 60 BV8 53/40/0703/978 PK WND 13 080
ENV SA 1748 AUTOB 60 SCT BV8 54/40/2904/978 PK WND 17 080
ENV SA 1848 AUTOB CLR BLO 60 BV8 57/43/3509/976 PK WND 17 080
ENV SA 2048 AUTOB CLR BLO 60 BV8 60/40/3309/971 PK WND 15 080
ENV SA 2148 AUTOB E46 BKN 55 BKN BV8 58/40/0705/974 PK WND 11 080
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FIGURE - 8

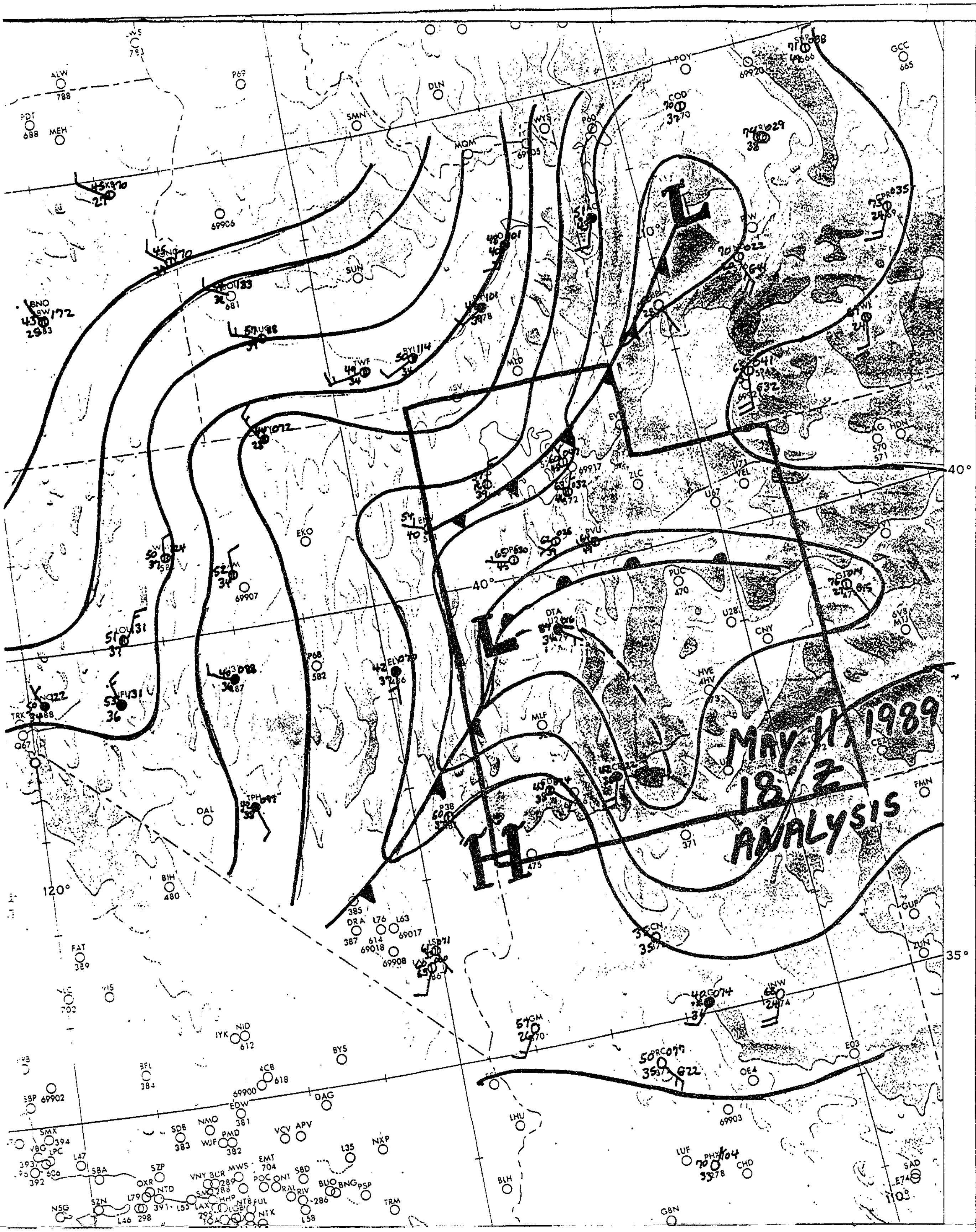
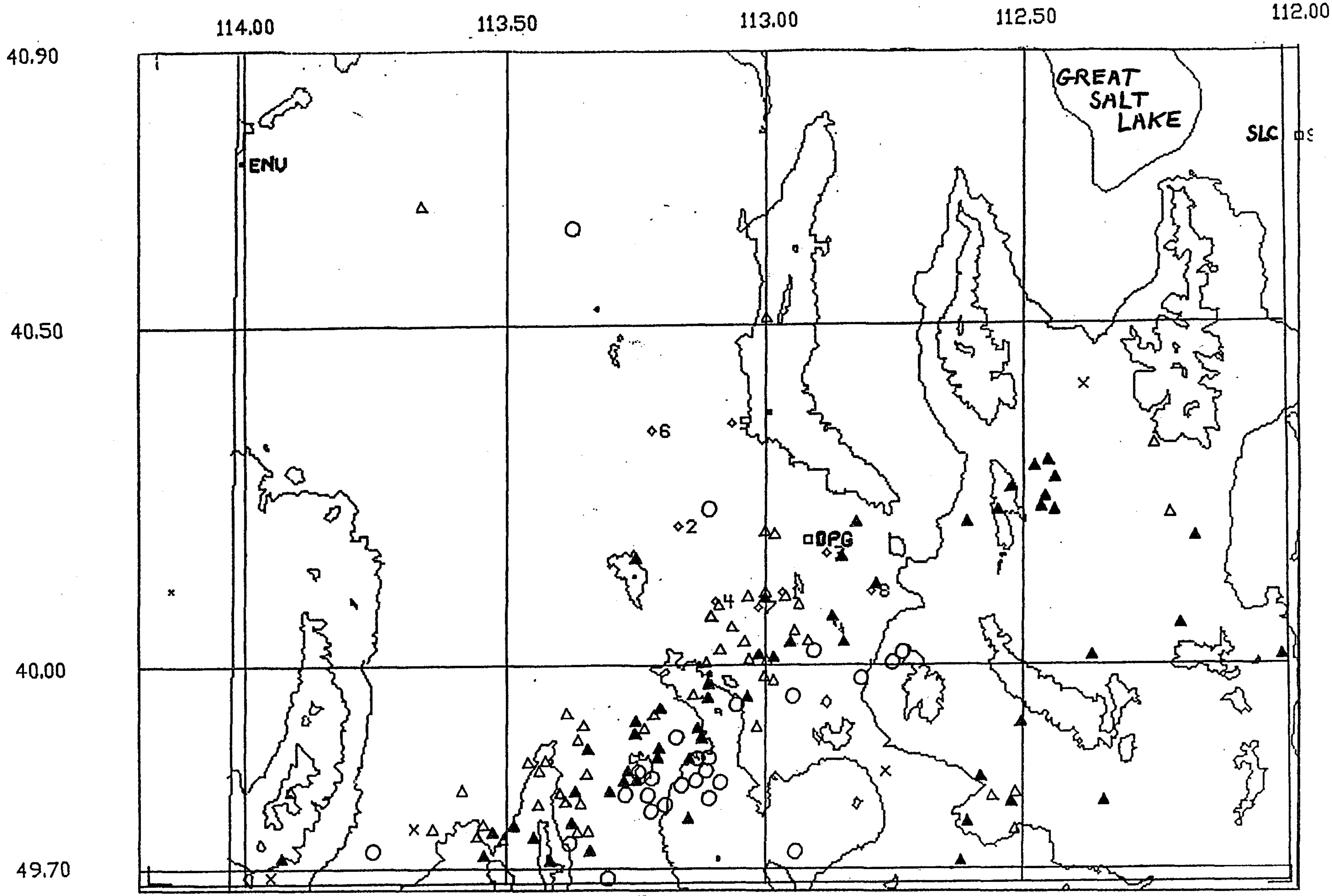


FIGURE - 9 SURFACE ANALYSIS AT 18Z, MAY 11, 1989



19:00 - 19:15	×	4
19:15 - 19:30	○	26
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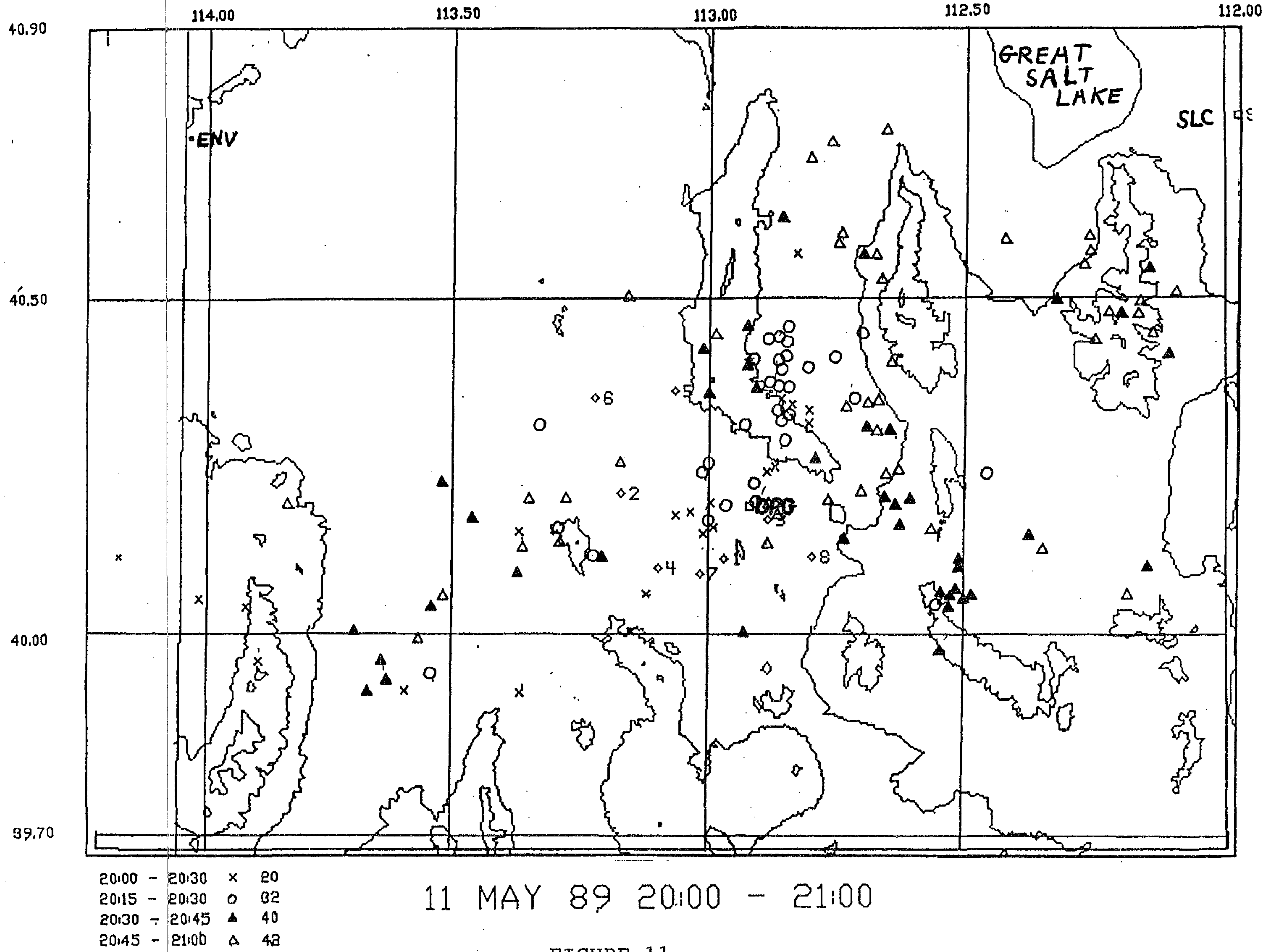
19:45 - 20:00	△	49

11 MAY 89 19:00 - 20:00

FIGURE 10



114.00
113.50
113.00
112.50
112.00
40.90
40.50
40.00
39.70
GREAT SALT LAKE
SLC
ENV
6
2
4
8
20:00 - 20:30 × 20
20:15 - 20:30 o 62
20:30 - 20:45 ▲ 40
20:45 - 21:00 △ 43
11 MAY 89 20:00 - 21:00

FIGURE 11