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THE SEVERE THUNDERSTORM OUTBREAK OF JULY 6, 1983 IN SOUTHEAST IDAHO, WESTERN WYOMING AND SOUTHWEST MONTANA

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ABSTRACT

Late in the afternoon on July 6, 1983 a squall line developed in southeast Idaho, the southwest corner of Montana and northern Utah. The line of thunderstorms accelerated northeast through southwest Montana and into western Wyoming the rest of the afternoon and early evening before dissipating east of the Continental Divide. The thunderstorms generated wind gusts estimated to 100 mph, did up to 1 1/2 million dollars of damage, and left one person dead and two injured.

The following is a case study of that event, written in the point of view of one who would be responsible for forecasting it.

1. DEVELOPMENT OF SYNOPTIC PATTERN

On the two days prior to July 6th a Pacific cold front, associated with an intense closed upper low off Vancouver Island, advanced east into the Pacific Northwest states. The front developed wave-like characteristics as it moved inland. On the morning of the 5th cold air advection was occurring through the base of the offshore upper lows (Figs. 1 and 2).

By the morning of the 6th a negatively-tilted upper trough was approaching the coast of California, offering a mechanism for the reintensification and movement of the Pacific Northwest cold front. The upper ridge was now east of the Continental Divide (Fig. 3a). The cold front extended from central British Columbia to just west of Spokane, WA (GEG), then to a sea level low in west-central Idaho and south through west-central Nevada. A warm front associated with the long wave upper ridge was east of the Intermountain Region. A developing cold front extended from a sea level low in north-central Montana to the low in west-central Idaho (Fig. 3b).

Daytime maximum temperatures ahead of the Pacific front had been warming by about 10° Fahrenheit (F) each day, having reached 100°F at Salt Lake City (SLC) on the afternoon of the 5th. In the 24 hours prior to 12Z July 6th, thunderstorms had deposited moisture from southwest Idaho to southern Montana. This was reflected in the high surface dewpoints (45°F plus) through the area.

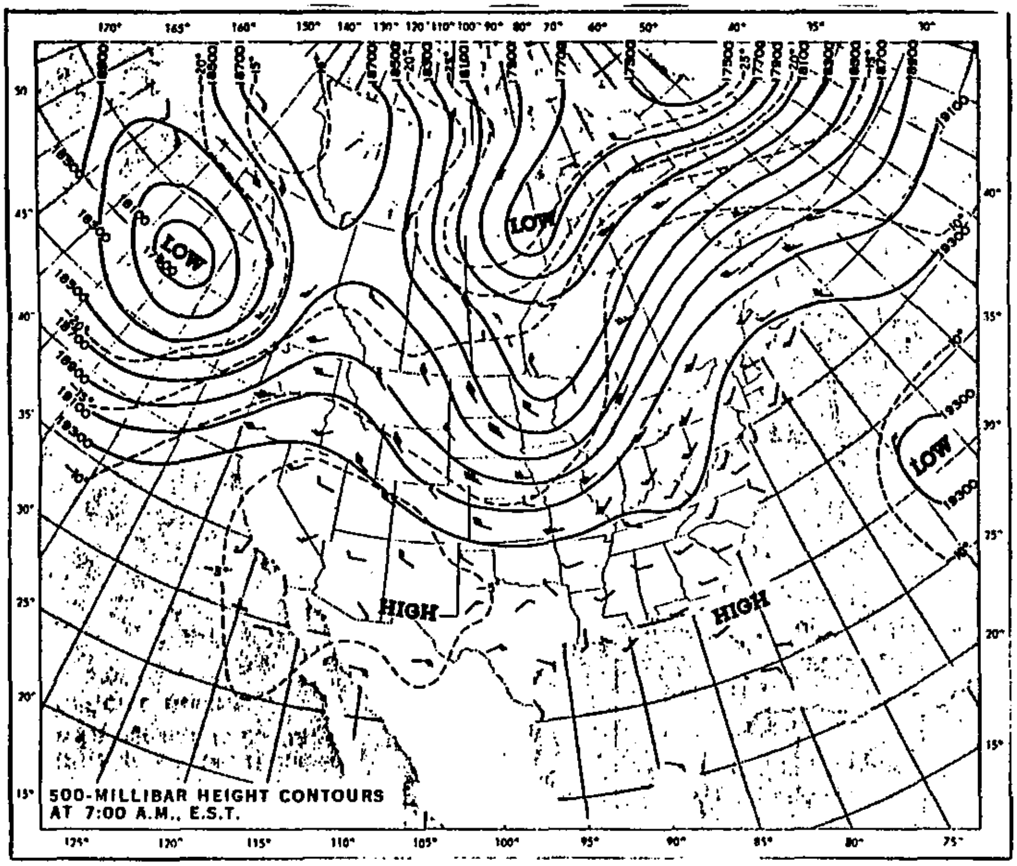

Fig. 1. 500 mb Chart for 12Z July 4, 1983.

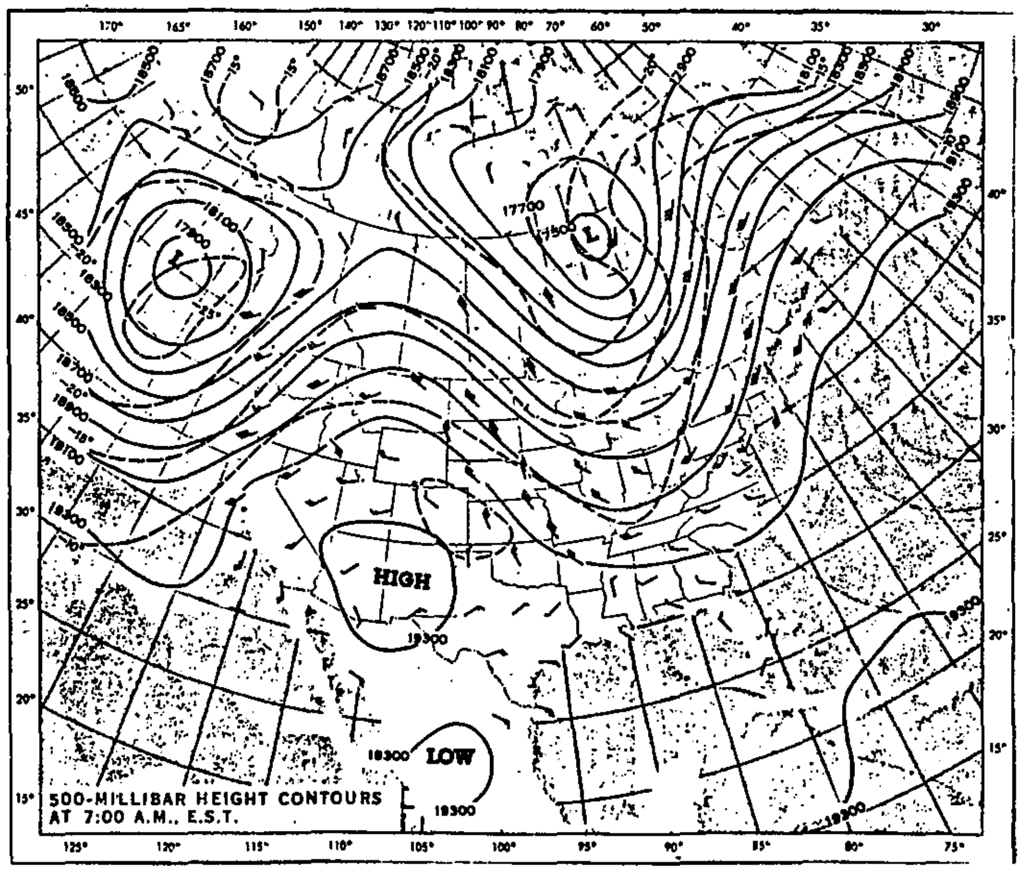

Fig. 2. 500 mb Chart for 12Z July 5, 1983.

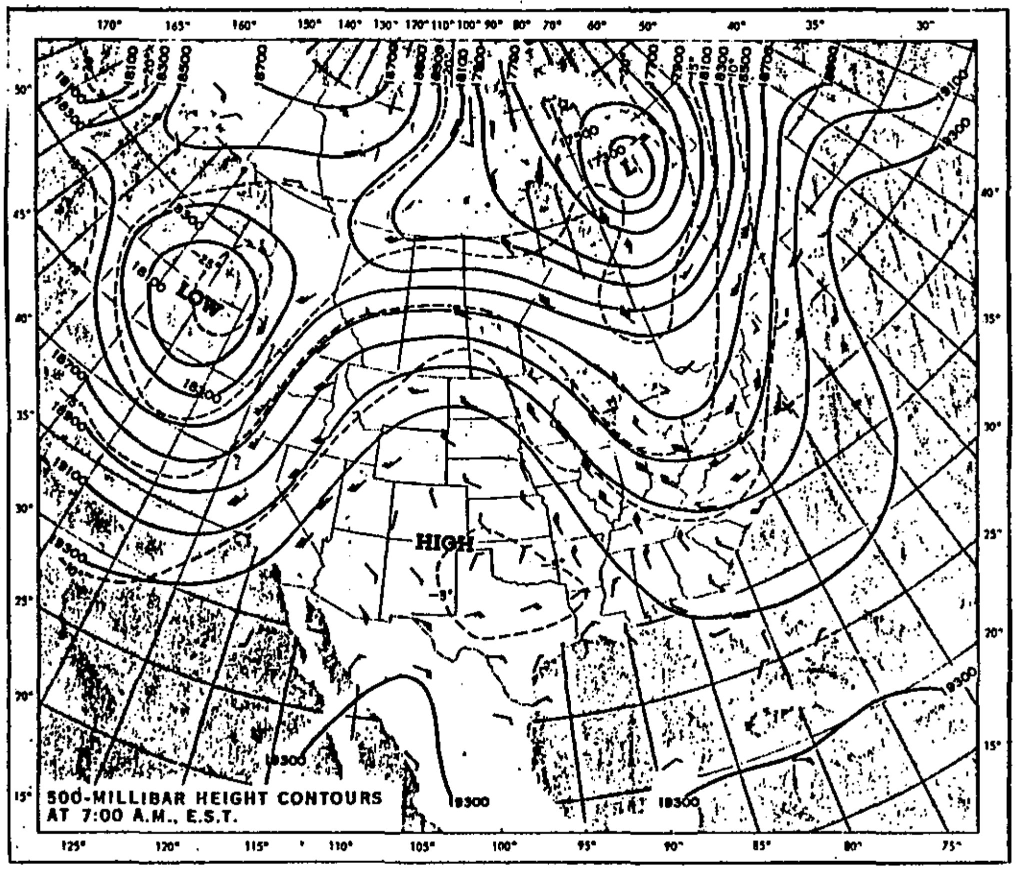

Fig. 3a. 500 mb Chart for 12Z July 6, 1983.

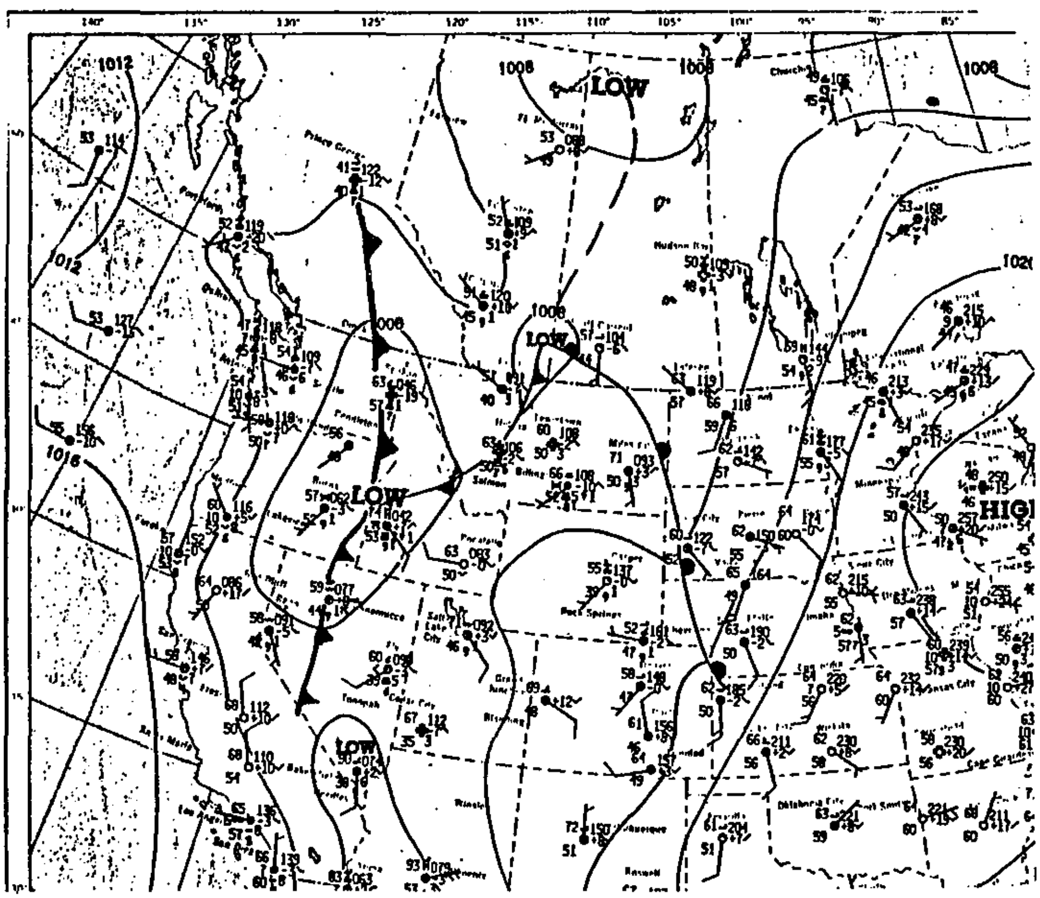

Fig. 3b. Surface/Sea Level Pressure Analysis for 12Z July 6, 1983.

2. MORNING INDICATIONS

A. Soundings and Instability

The morning sounding at SLC possessed the potential for an "Inverted-V" type airmass sounding (Fig. 4). The layers below 700 mb were quite dry, neglecting the surface inversion. Development and advection during the course of the day would deepen the dry layer, satisfying the basic requirement noted in Western Region Technical Attachment 76-14 for very strong thunderstorm winds. Note the similarities to the morning sounding in Fig. 5 (Wakimoto, 1985). From 700 mb upward we will find that there was enough moisture to initiate and sustain high-based thunderstorms. The convective temperature at SLC was estimated to be 98^{o}F, about 5^{o} warmer than the temperature needed to eliminate the surface-based inversion.

Lifted Indices (LI's) through the frontal area and to the east were, for the most part, weakly unstable. The exception was at GEG with an LI of minus 5 (Fig. 6). Miller (1972) has cautioned that LI's are not representative for the "Inverted-V" type airmass because the lower layers are quite dry.

Miller (1972) noted that west of the Rockies Vertical Totals (VT's) of 28 or more were enough to justify thunderstorms. VT's from Boise (BOI) to SLC and northeastward suggested the potential for a scattered coverage of thunderstorms (Fig. 6). Miller has also proposed that a Total Totals (TT's) of 53 is all that is needed for severe thunderstorms with an "Inverted-V" airmass. Total Totals through the area were only slightly below 53 at 12Z on July 6th. Severe Weather Threat Indices (SWEAT) at BOI and Great Falls (GTF) moved the forecast into the realm of severe weather. Both were 300 or higher, indicating the potential for damaging weather. Western Region Technical Attachment 84-14 contains a complete discussion of convective stability indices. Depending on which of Miller's methods used, the maximum gust potential varied from 49 knots to 68 knots, another indication of potentially dangerous weather. It should be cautioned that convective gust potential estimates are often not reliable (Doswell et al., 1982).

Instability is not enough to guarantee severe thunderstorms, much less convection. The available moisture and triggering mechanisms must be investigated.

B. 250 mb Level

At 250 mb a strong jet streak of 90 knots extended from offshore the Pacific Northwest into British Columbia (Fig. 7). The jet speeds and shear over the threat area were moderate and weak, respectively, at 55-65 knots and 15 knots per 90 nm or less. The best diffluence was noted from southeast Idaho through southwest Montana.

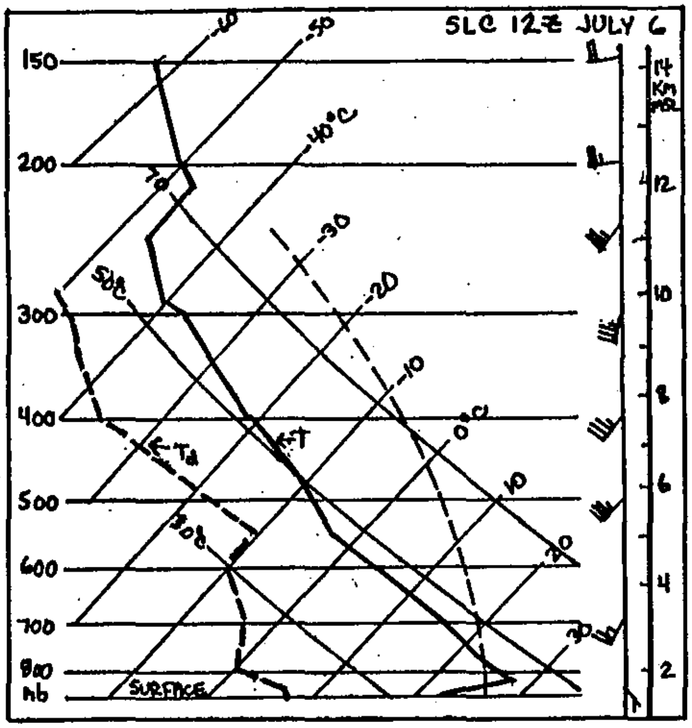

Fig. 4. Skew-T Log-P Plot of Salt Lake City sounding for 12Z July 6, 1983.

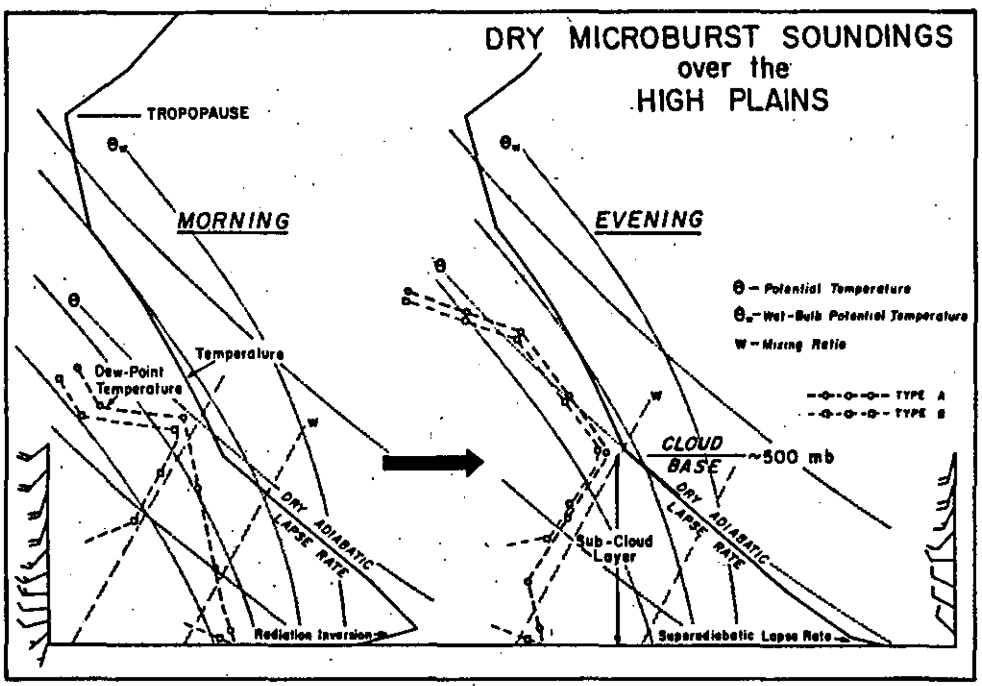

Fig. 5. Model of the characteristics of the morning and evening soundings favorable for dry-microburst activity over the High Plains (from Wakimoto, 1985).

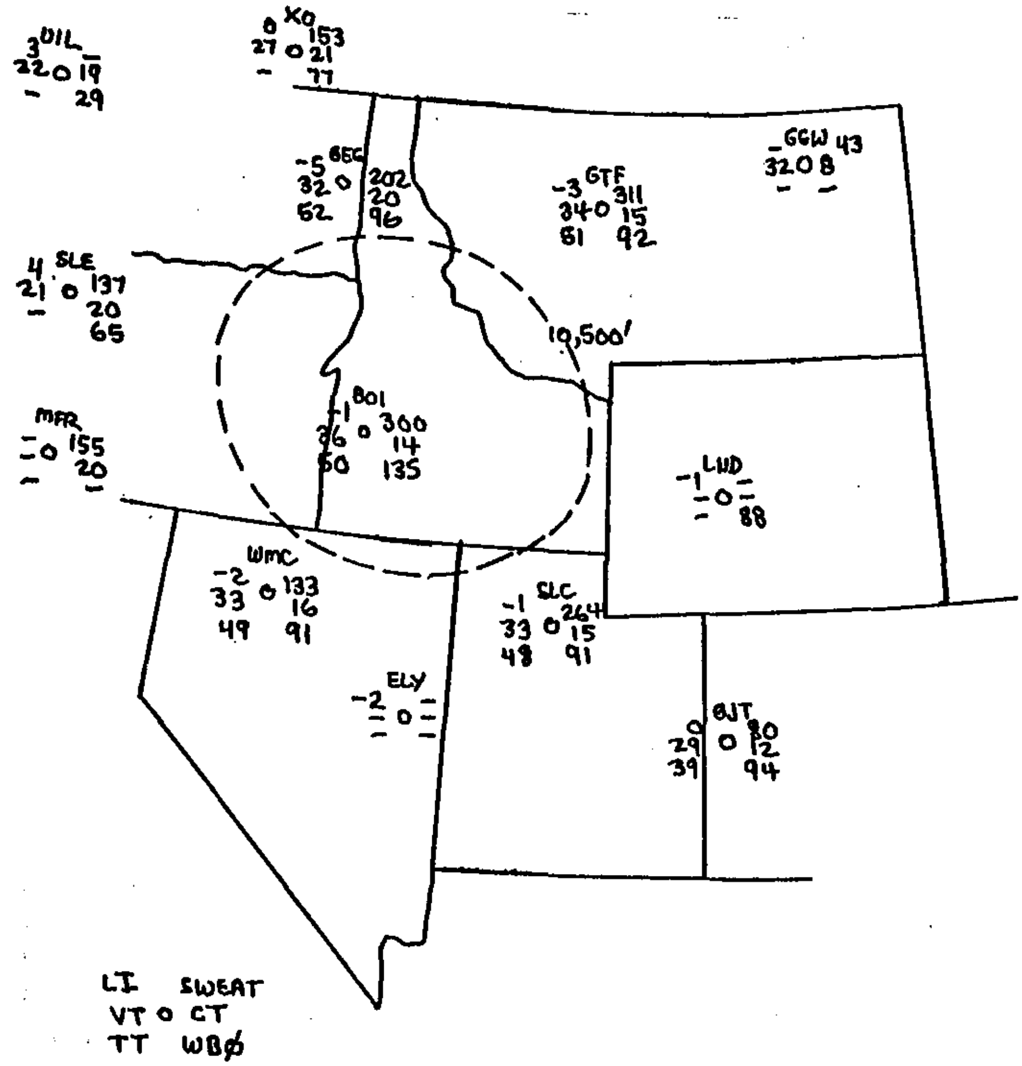

Fig. 6. Convective stability indices (oriented according to plot circle depiction) and Wet Bulb Zero Height (in 100's of ft) for 12Z July 6, 1983.

C. 500 mb Level

The 500 mb minus 10° Celsius (C) isotherm ran from Winnemucca (WMC) to BOI then to GTF, with colder air to the northwest (Fig. 8). Miller (1972) has found this isotherm to mark the potential for any thunderstorms. The author has found this to be a "fuzzy" demarcation, or that at least the storms form in colder air and can move into air where the 500 mb temperature is warmer than minus 10°C.

Miller (1972) has also found that west of the Rockies at 500 mb the minus 17°C isodrosotherm, or warmer, will provide an environment moist enough for thunderstorms. Fig. 8 shows a mid-level moisture band extending from the Desert Southwest through the threat area (using 500 mb as the mid-level since the surface in the region was near the 850 mb level). The shaded area in Fig. 8 shows temperature-isodrosotherm depressions of 6°C or less. A continuous replenishment of 500 mb moisture was assured.

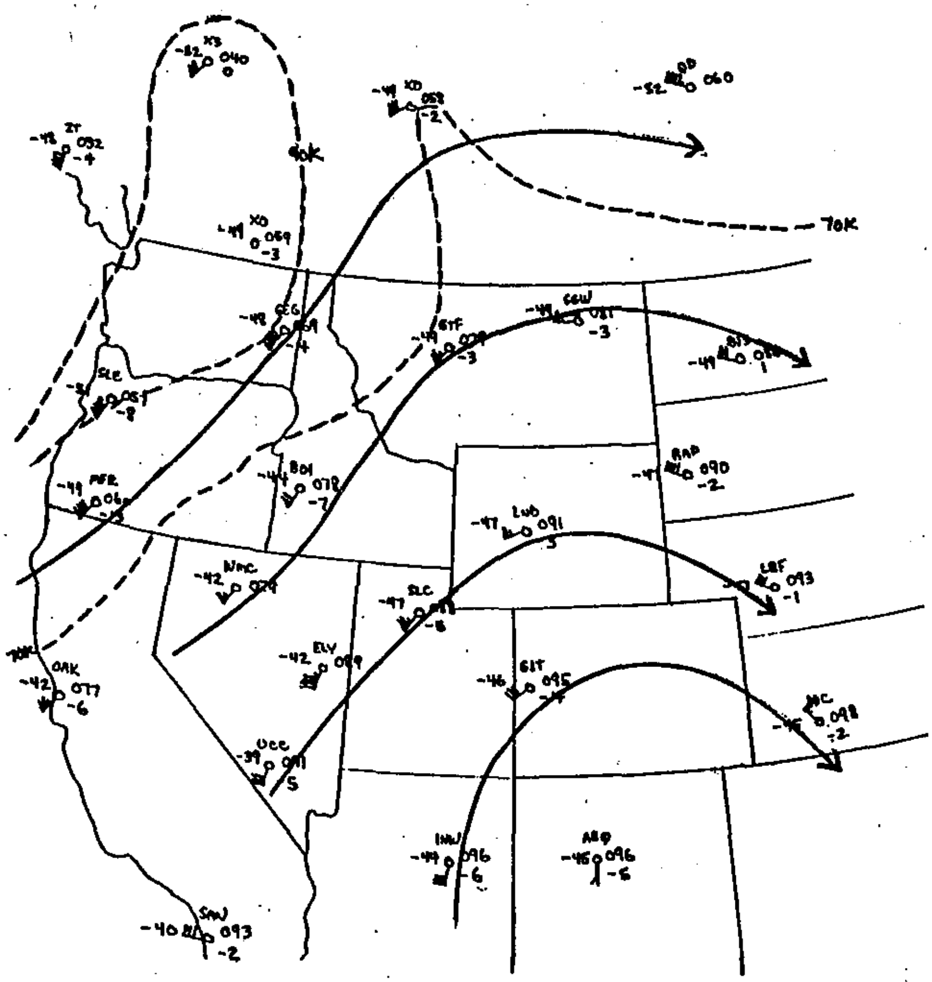

Fig. 7. 250 mb Analysis for 12Z July 6, 1983. Solid lines are streamlines and dashed lines isotachs.

Moderate mid-level wind speeds of 35-45 knots were just southwest of northern Utah and northeast Nevada. Mid-level lateral shear was quite weak, i.e., less than 15 knots per 90 nm. Moderate 500 mb height changes of -30 to -60 geopotential meters were noted, indicating an approaching upper-level disturbance. Even greater height falls at 250 mb (Fig. 7) indicated that the disturbances had a differential strength, i.e., its rate of positive vorticity advection increased with height.

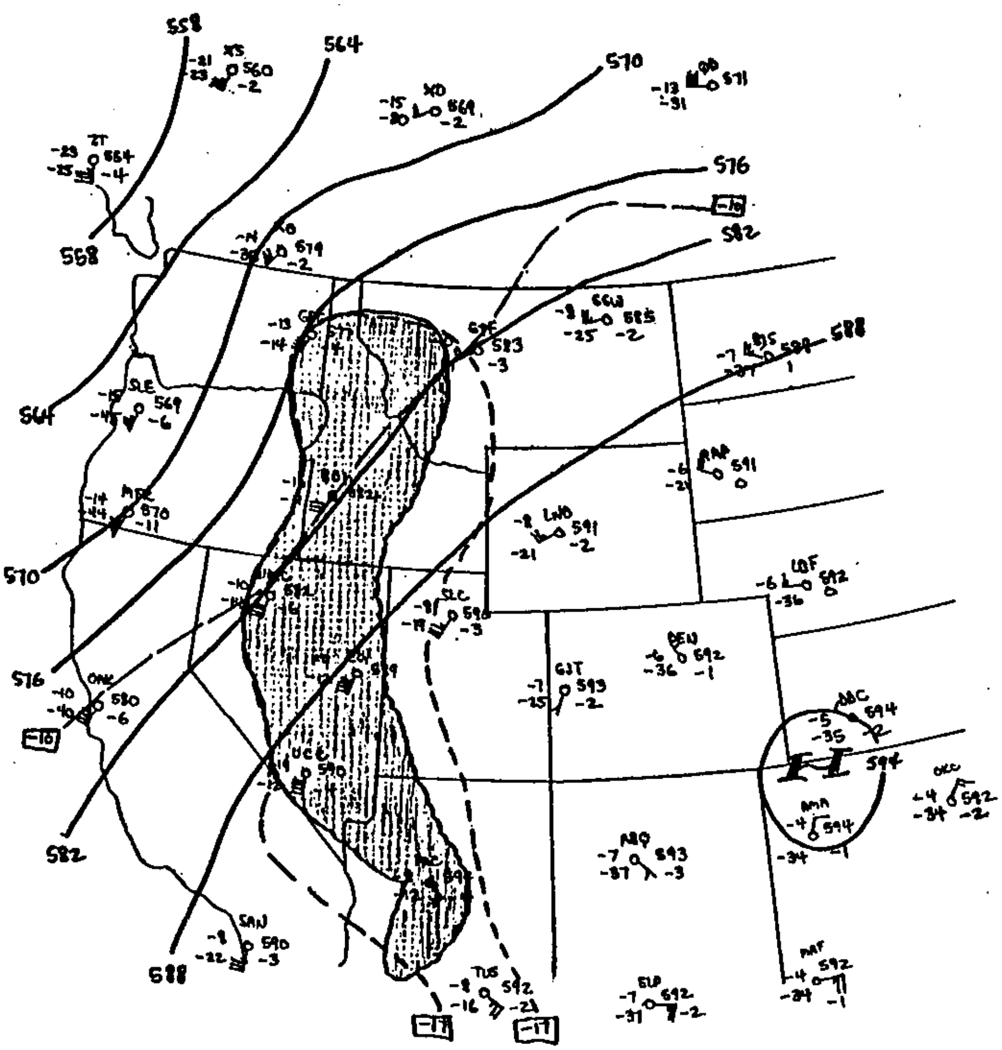

Fig. 8. 500 mb Analysis for 12Z July 6, 1983. Long-dashed line minus 10°C isotherm and short-dashed line minus 17°C isodrosotherm. Shaded area temperature-isodrosotherm depression of 6°C or less.

Winds veered from low- to mid-levels upstream of the threat area suggesting destabilizing warm air advection near the surface.

The 500 mb 12Z Limited Fine Mesh (LFM) initialization showed a negatively-tilted trough extending from the closed upper low off Vancouver Island to along the coast of southern California (Fig. 9). By 00Z the LFM forecast the trough to extend from western Washington and Oregon to east of the Sierra Nevadas in California (Fig. 10). Weak vorticity maxima were forecast to be northwest of Havre, MT (HVR) and near Mt. Whitney, CA at 00Z. While at 00Z vorticity values through the threat area were forecast to be barely above planetary ones, moderate to strong positive advection of the vorticity was expected with the southwest upper flow crossing the isopleths of

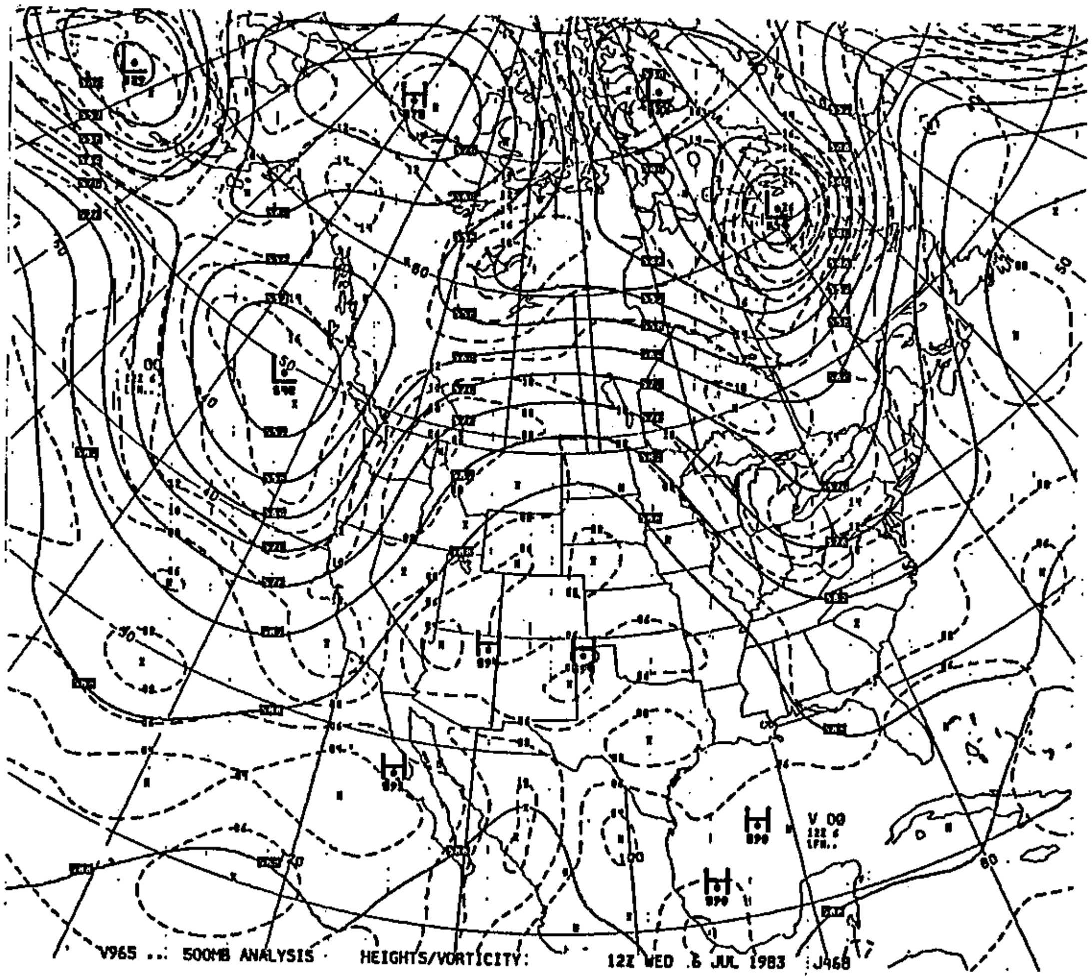

Fig. 9. LFM 500 mb analysis heights/vorticity for 12Z July 6, 1983.

vorticity at an angle of 30 degrees or more. The author chose the LFM for its forecast of positive vorticity advection (PVA) because it would have to be adjusted most to observed and satellite data. This was done to illustrate the point that the models must be used critically and as only one element in a comprehensive understanding of the state of the atmosphere.

Holton (1979) has qualitatively expressed the content of the Quasi-Geostrophic Omega Equation as:

Rising (Sinking) motion α Rate of increase with height

of ($\pm$) vorticity advection

\+ Warm (Cold) advection

The approaching moderate strength upper trough with associated increasing rate of PVA with height and warm air advection assured good

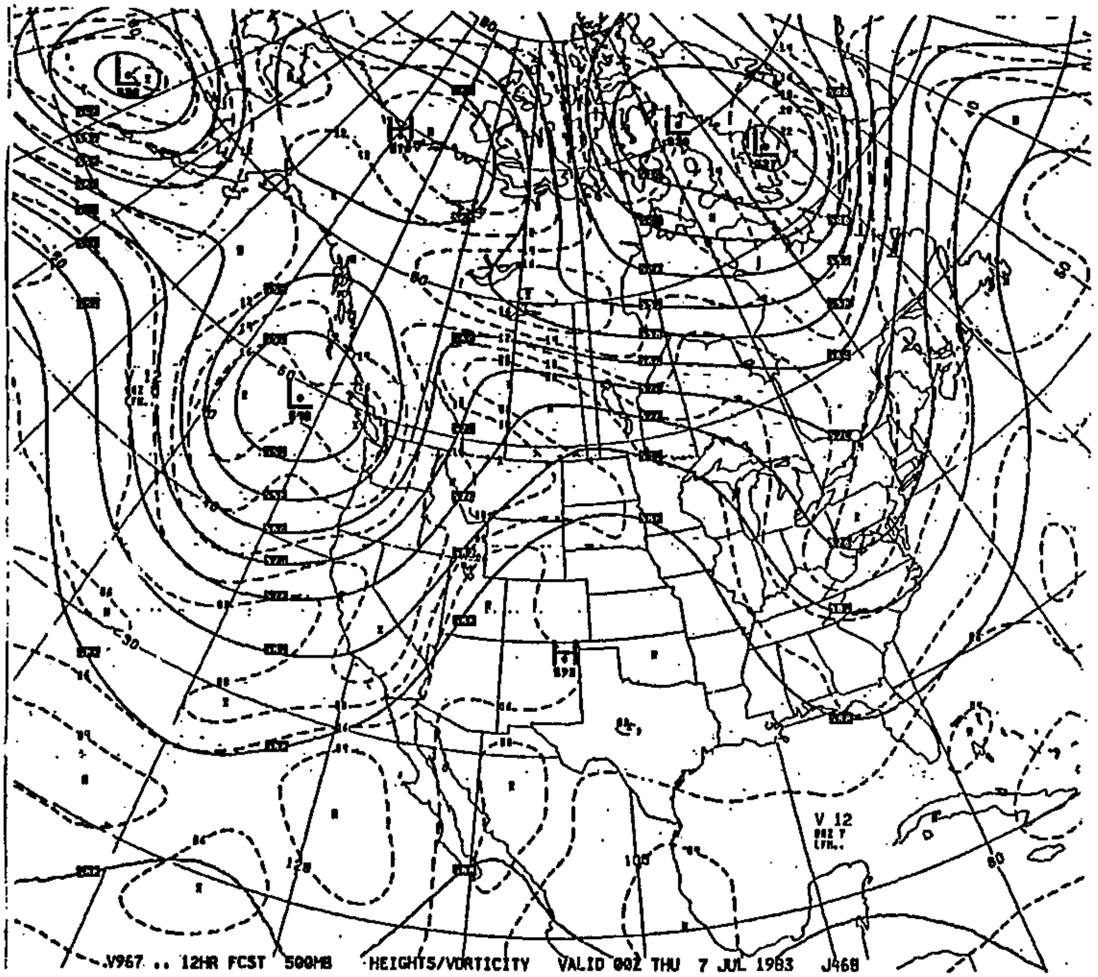

Fig. 10. LFM 12 hr forecast 500 mb heights/vorticity valid 00Z July 7, 1983.

rising motion to sustain deep convection northeast from the Great Basin. An analysis program of Sangster, Central Region Scientific Services Division (personal communication), which computes kinematically-produced vertical velocities at several levels and incorporates terrain effects, was run using the 12Z and 00Z observed surface and upper air data. At 12Z on July 6th these computations showed upward vertical motions in the area of thunderstorm development of 5 microbars per second at 400 mb. By 00Z there were values of 11 in southeast Idaho, 13 in southwest Wyoming, and 14 microbars per second in northeast Utah.

The passage of the upper trough would bring moderate cold air advection and a dry air intrusion at mid-levels.

D. Wet Bulb Zero

The Wet Bulb Zero height, i.e., the height where the wet bulb temperature is zero ^{o}C, was 9000 to 11,000 ft above the surface through northern Utah, southeast Idaho and southwest Montana (Fig. 6).

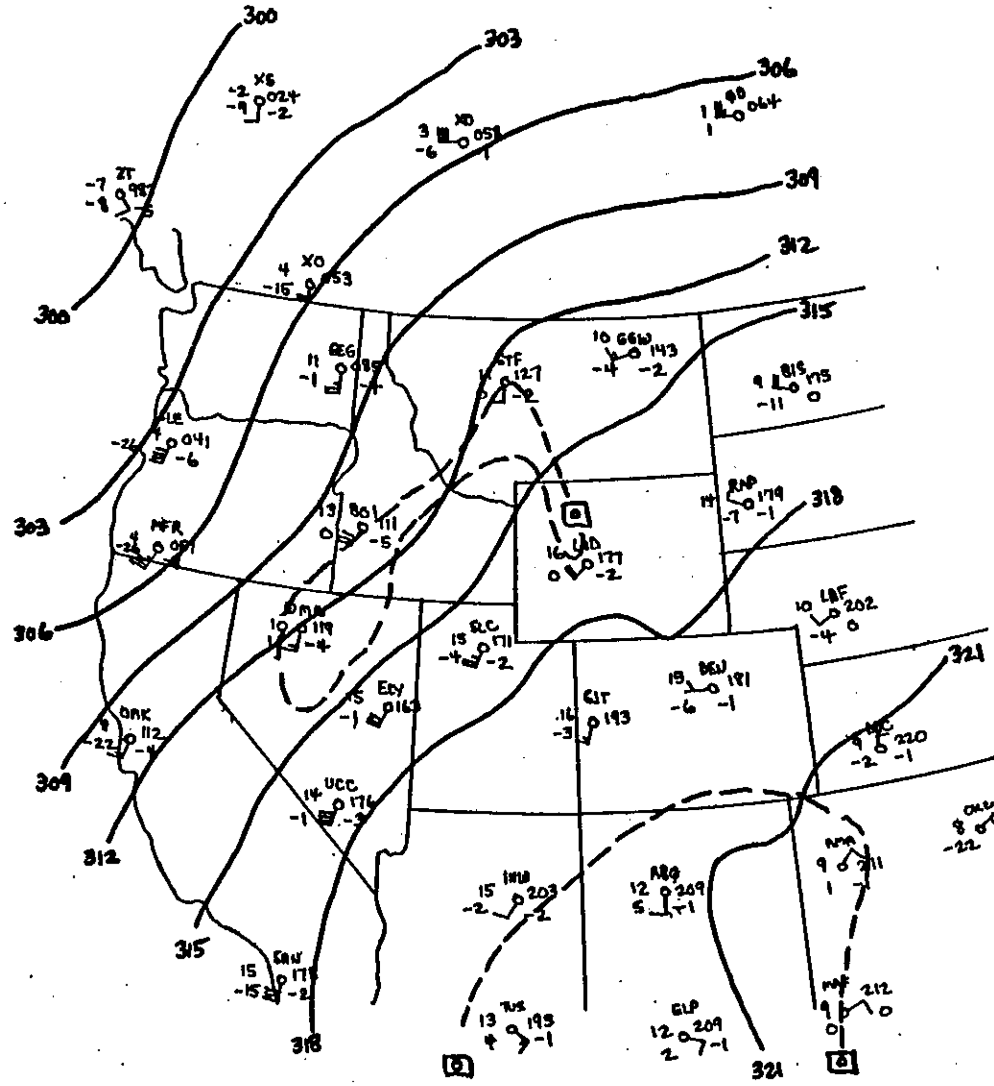

Fig. 11. 700 mb Analysis for 12Z July 6, 1983. Dashed line zero°C isodrosotherm.

Miller (1972) has found that the area between the 10,500 and 7000 ft AGL Wet Bulb Zero isopleths as the most probable limits of severe weather phenomena at the surface.

E. 700 mb Level

The 700 mb 0°C isodrosotherm wound from northwest Wyoming and southwest Montana through central Idaho and into northern Nevada (Fig. 11). West of the Rockies, Miller (1972) has found it a requirement for the occurrence of thunderstorms, similar to the 500 mb minus 17°C isodrosotherm. The horizontal advection pattern indicated that the 0°C line would move downstream of the area. During the day drier rising air upstream and below 700 mb would bring a change. The moist portion of the "Inverted-V" airmass would be maintained, but by late afternoon the moisture originally at 700 mb would be nearer the 600 mb level, enhancing the potential for severe gusts in the subcloud layer.

F. 850 mb Level

The 850 mb level was less than 1000 ft off the surface at SLC on the morning of July 6th.

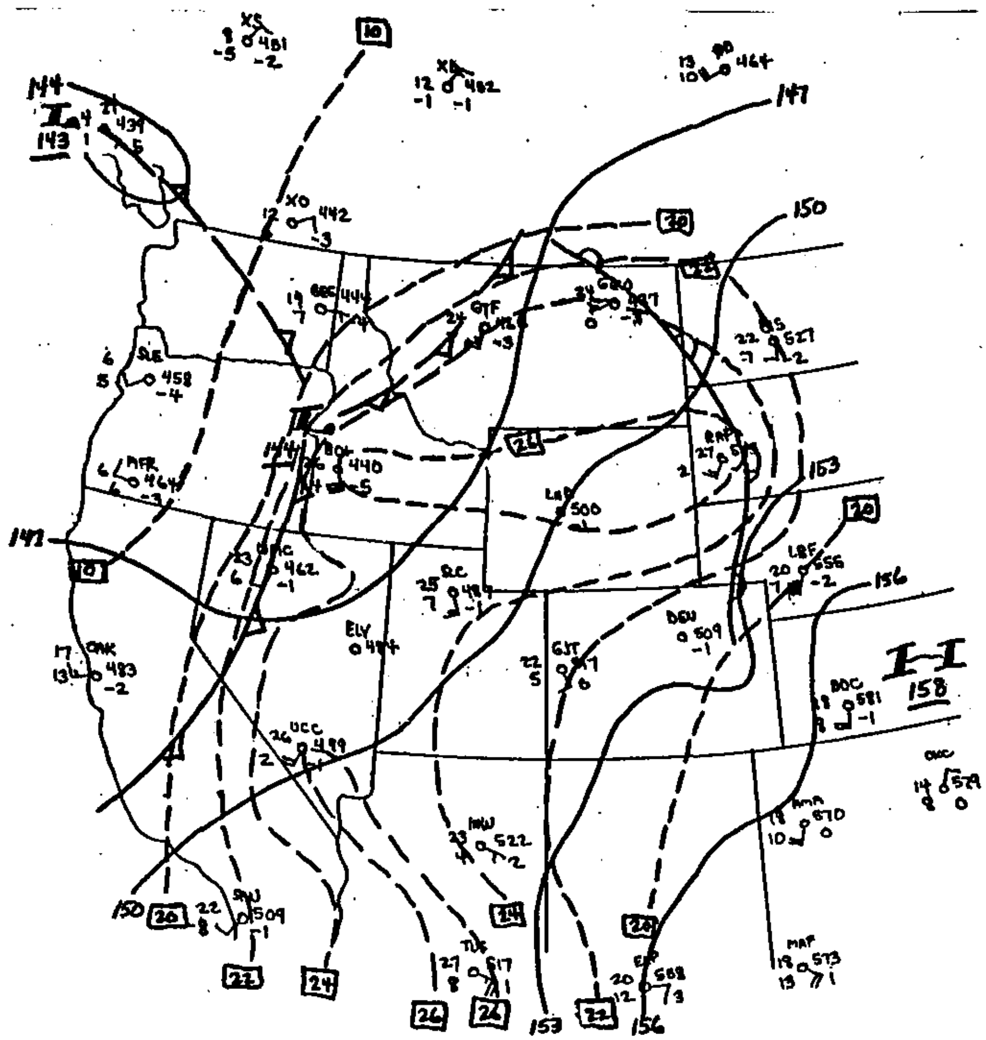

Fig. 12. 850 mb Analysis for 12Z July 6, 1983. Dashed lines isotherms.

In accordance with the type of airmass the 850 mb level was quite dry, and the horizontal advection pattern indicated even more drying. However, due to the proximity of the 850 mb level to the surface, and with high surface dewpoints, the mixing of the planetary boundary layer (PBL) would act to reduce additional drying by advection.

One 850 mb thermal ridge was east-west through southern Idaho and northern Wyoming (Fig. 12). Even more importantly, another near-surface thermal ridge was to the south and west (upstream) of the 700 mb and 500 mb moist ridges. The low-level warm air advection ensured upward vertical motion spreading into the threat area during the day. This also meant thermodynamic destabilization.

A weak near-surface jet of 20 knots was located at the northernmost tip of the 850 mb thermal ridge upstream.

3. EVOLUTION OF CONVECTIVE CYCLE

At 18Z, as the cold front was moving east of WMC, a band of convection was developing from south-central Idaho south along the Nevada/Utah border. Satellite pictures showed an elongated PVA comma lifting northeast out of Nevada and far northwest Arizona and into the area of concern (Figs. 13 and 14). At this point it appeared that the 12 hr LFM forecast would be almost six hours too slow, and too weak.

At 21Z surface dewpoints continued at 45°F or higher through southern Idaho and eastern Utah (Fig. 15). A surface thermal ridge was advancing northeastward into northeast Nevada and western Utah toward a pool of very moist surface air. A developing warm front extended from the remnants of the morning sea level low in west-central Idaho south-southeast to Wendover (ENV), then southeast through central Utah. A 20-30 knot surface jet extended from central Nevada through southeast Idaho. The temperature at ENV was 100°F.

Sea-level pressures through the threat area were from 1005 to 1010 mb with surface pressure falls of 1 to 3 mb from 18Z to 21Z (Fig. 16). A bubble high was beginning to appear as the convection moved east to the developing surface discontinuity and strong thermal gradient along the Nevada/Utah border near ENV. This suggested the development of a surface pressure fall/rise couplet, frequently associated with the formation or passage of severe thunderstorms. The isallobaric falls pattern in Fig. 16 attests to the strength of the net divergence occurring from Utah and Colorado northward.

The 21Z surface analysis shows a well-defined dewpoint ridge from western Montana south through central Idaho, then southeastward. The high dewpoints resulted from moisture deposited by the previous day's convection. The pool of moisture was, by this time of day, well-mixed through the PBL. The corresponding mean mixing ratios at cloud base were estimated to vary from 6 to 8 gm kg^{-1}. While studying a High Plains hailstorm which did not produce large amounts of hail Foote and Fankhauser (1973) observed mixing ratios of 6 to 7 gm kg^{-1}. They noted that most High Plains hailstorms have mixing ratios of 9 to 10 gm kg^{-1} at cloud base. Any squall line, or its individual elements, would benefit little from the scouring of the moisture from the subcloud layer and the advection of it into its dynamics. The moisture was small enough for the "Inverted-V" type airmass

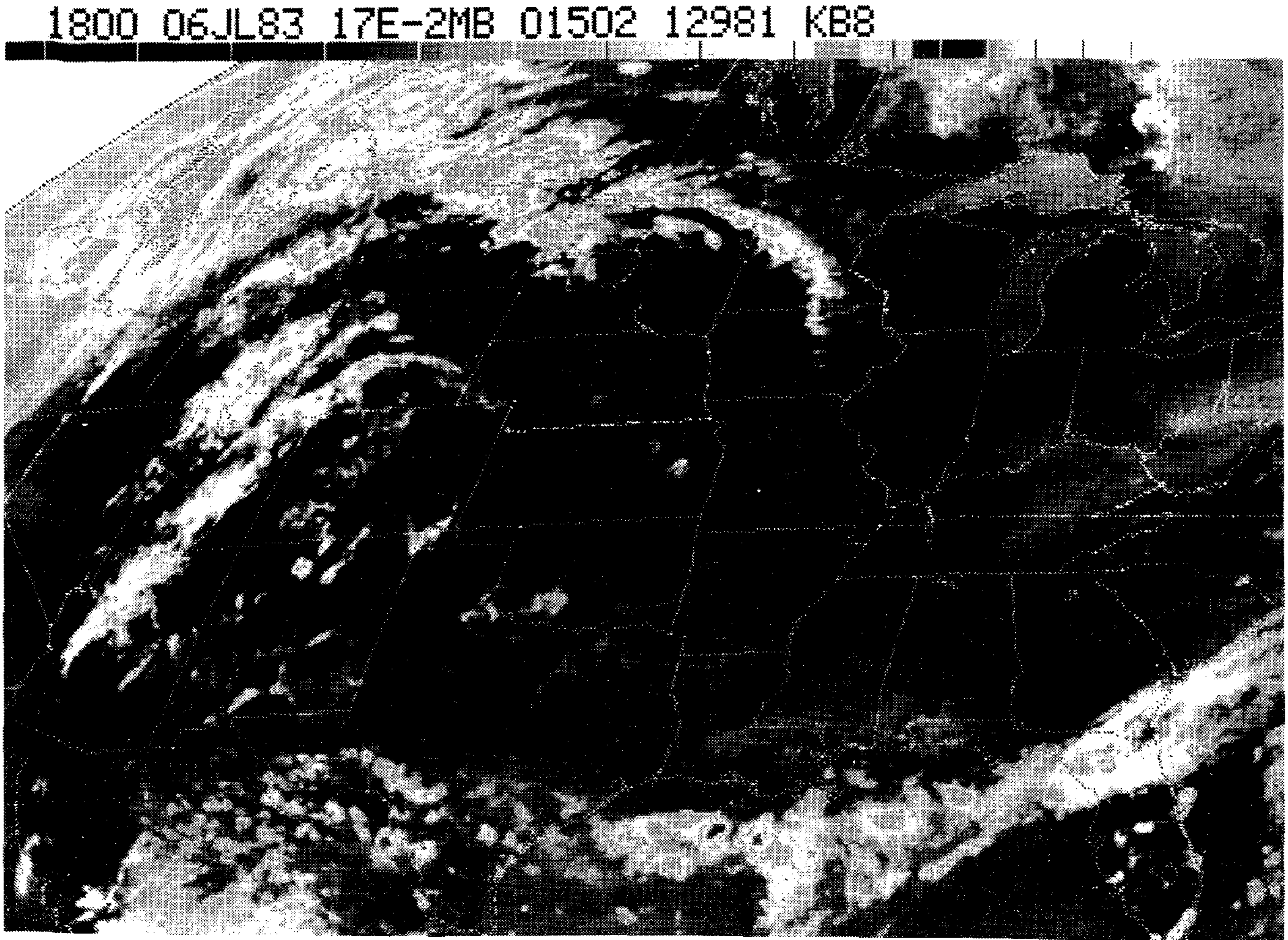

Fig. 13. Enhanced infrared satellite image for 18Z July 6, 1983.

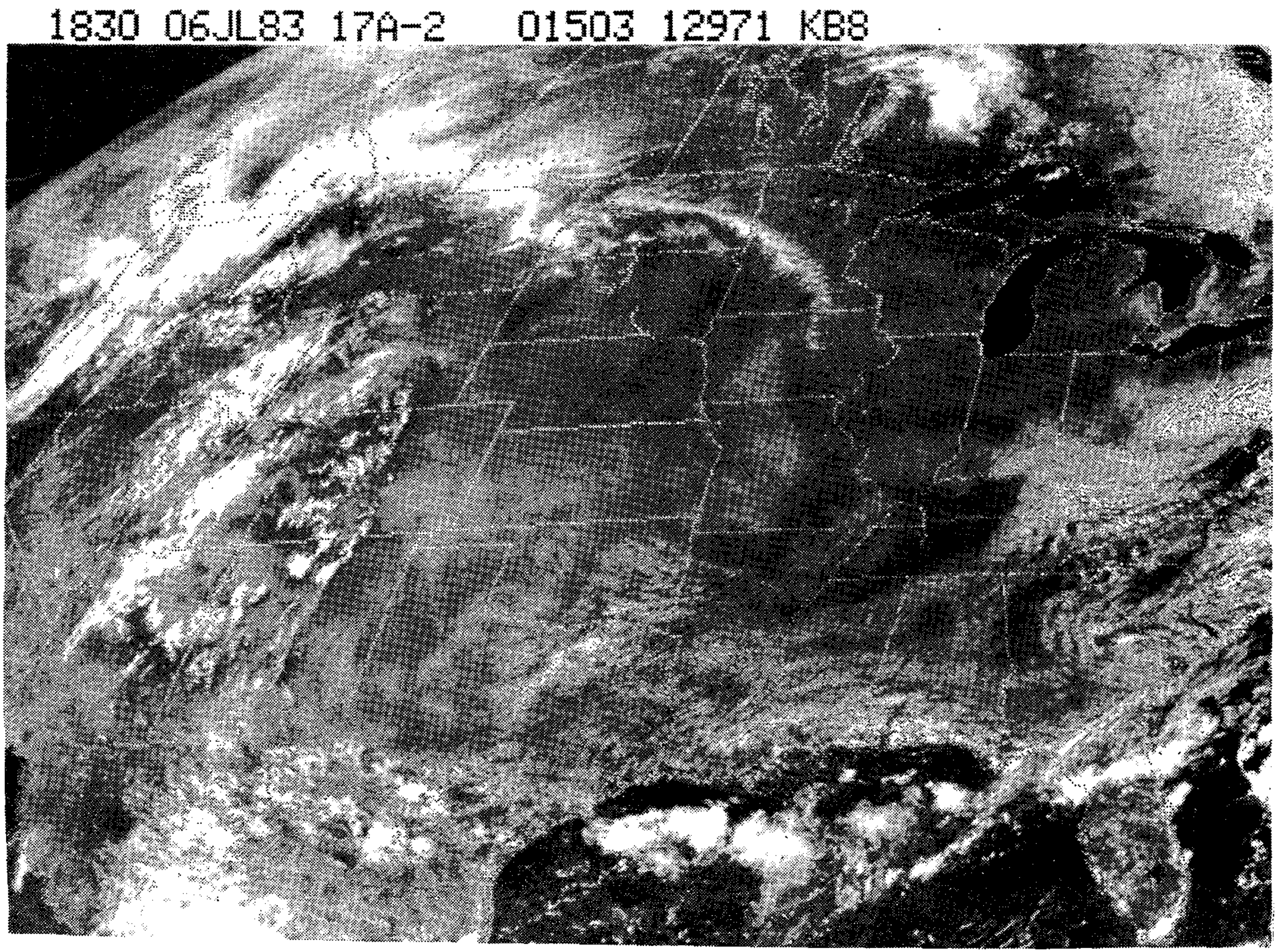

Fig. 14. Visual satellite image for 1830Z July 6, 1983.

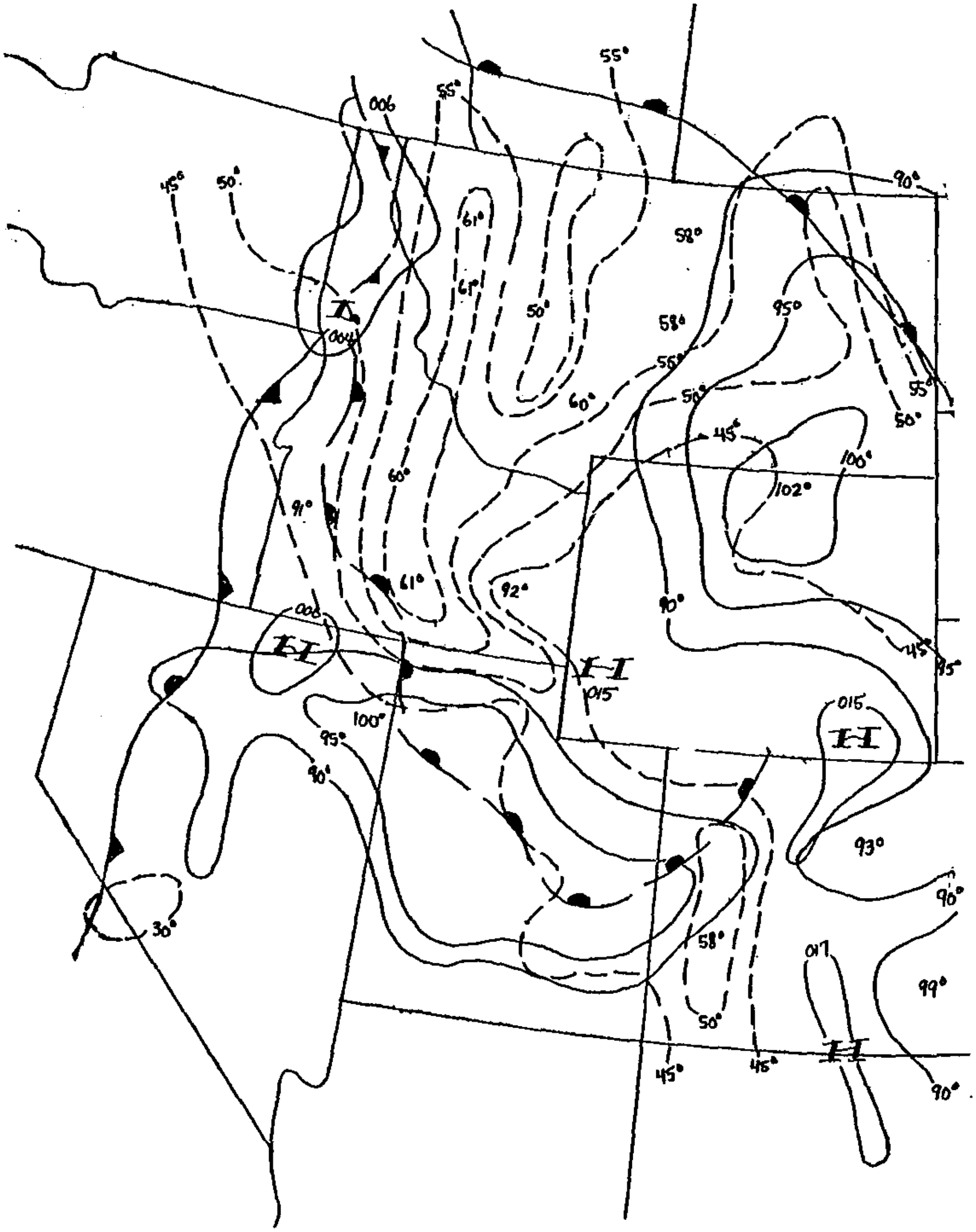

Fig. 15. Surface Analysis for 21Z July 6, 1983. Solid lines isobars or isotherms. Dashed lines isodrosotherms.

classification to remain valid and preserve the potential for severe downrush winds in the subcloud layer.

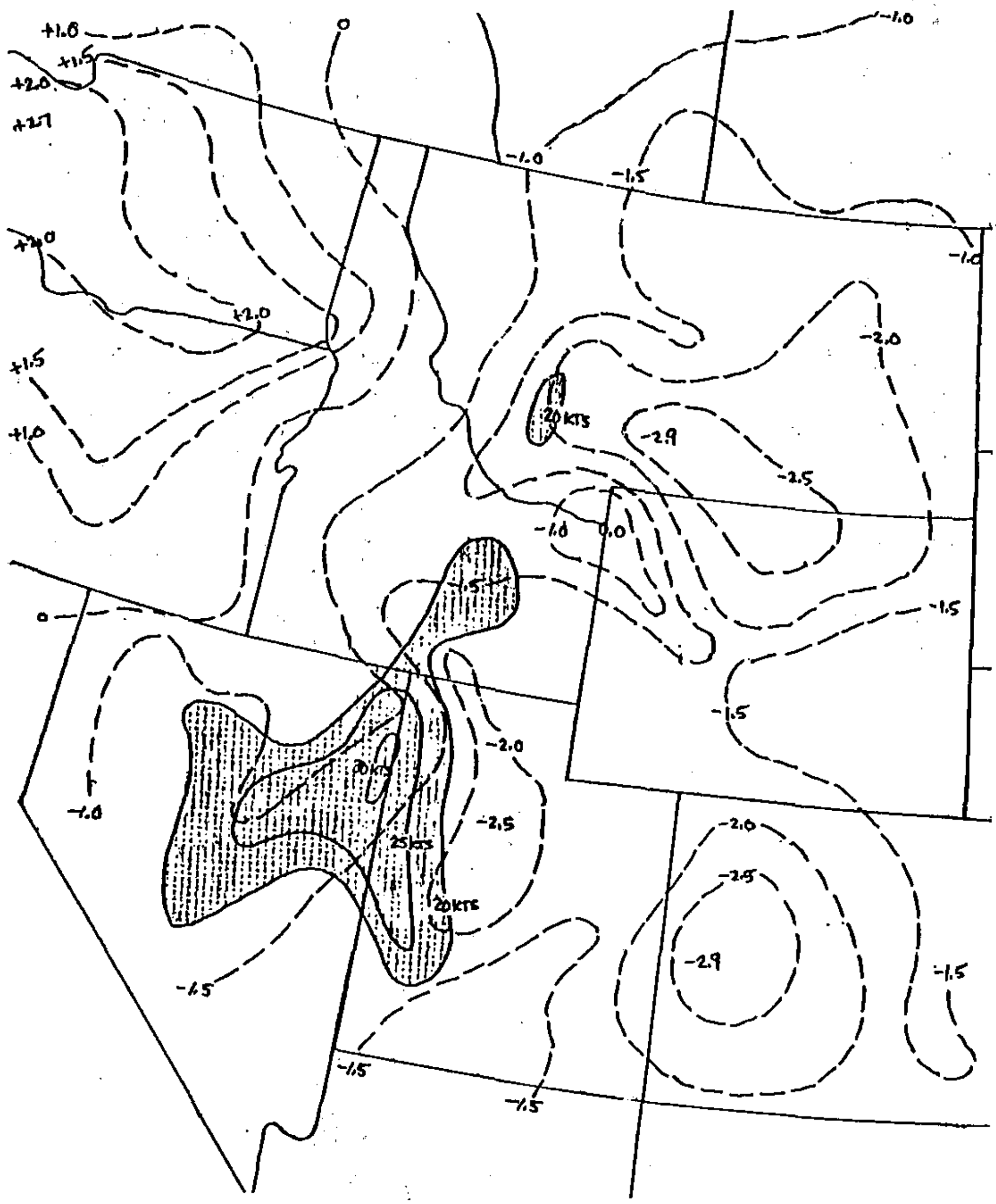

Fig. 16. Surface isallobaric (dashed lines) and isotachs (shaded areas) analysis for 21Z July 6, 1983.

The 2135Z radar summary (Fig. 17) showed scattered thunderstorms had developed from northwest Utah through southeast Idaho in the area of strong low-level warm air advection. Strong thunderstorms were also noted in the northern Idaho Panhandle and far west Montana in

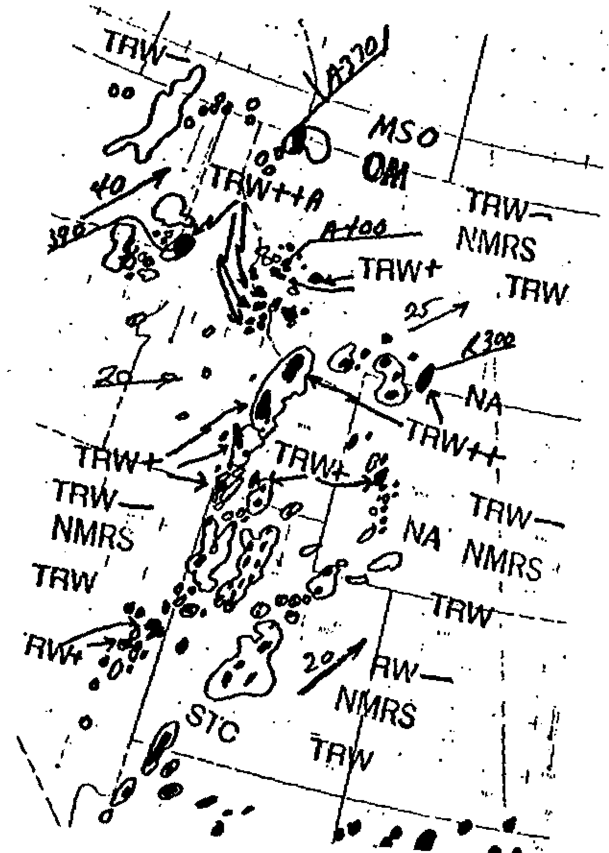

Fig. 17. Radar Summary for 2135Z July 6, 1983.

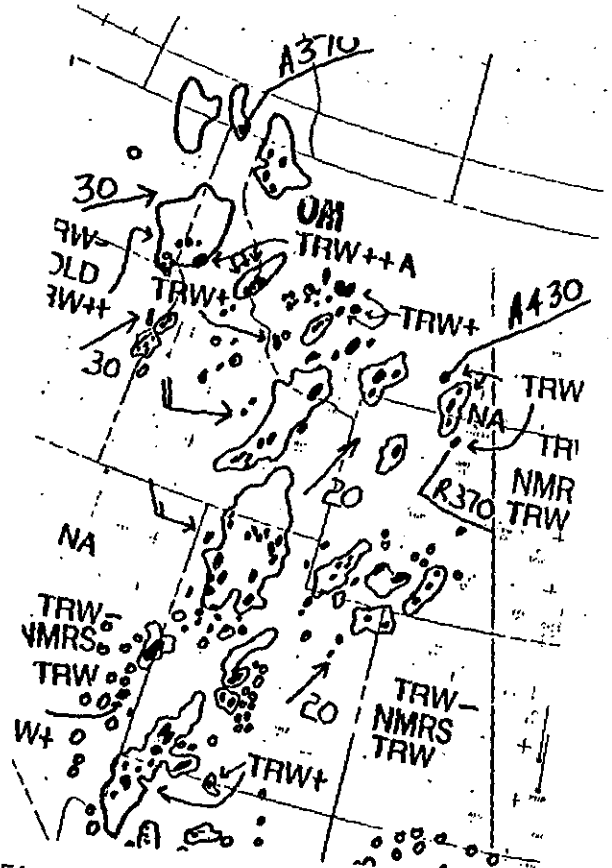

Fig. 18. Radar Summary for 2235Z July 6, 1983.

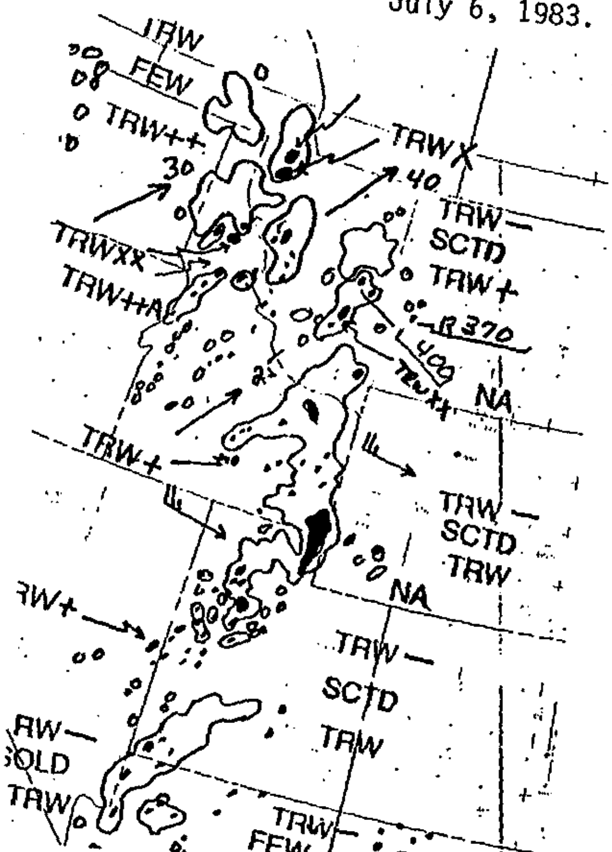

Fig. 19. Radar Summary for 2335Z July 6, 1983.

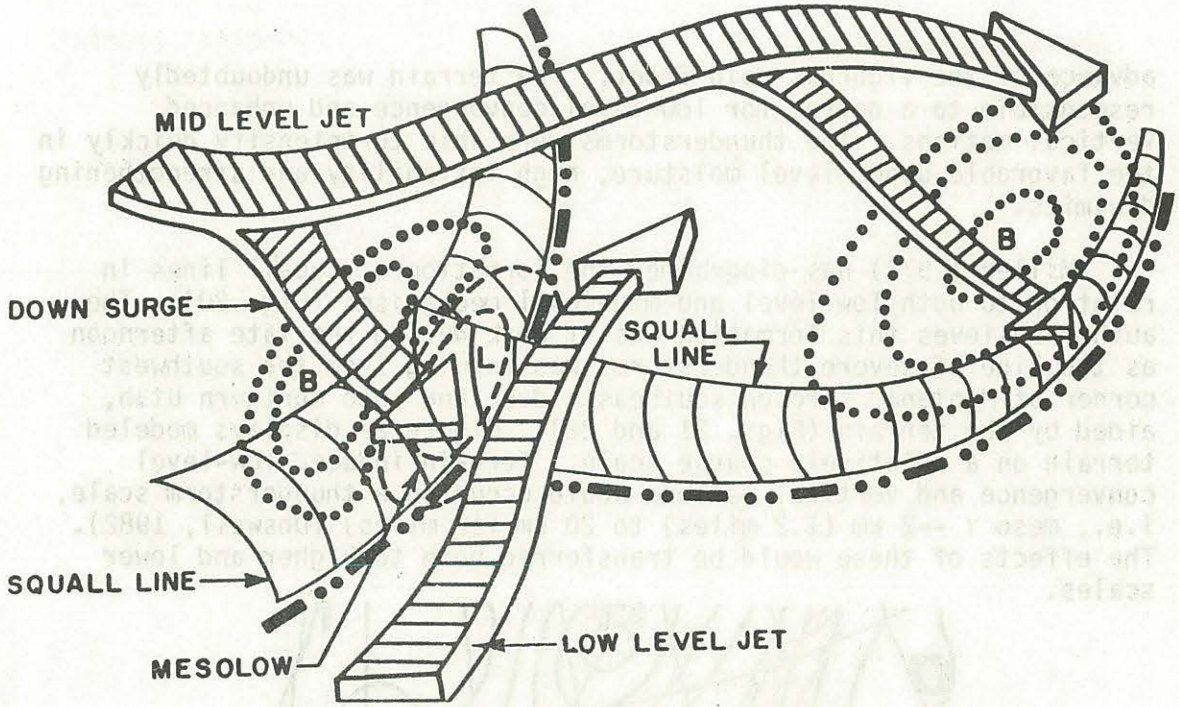

Fig. 20. Formation of mesolows and the location of the most intense severe weather activity (from Miller, 1972).

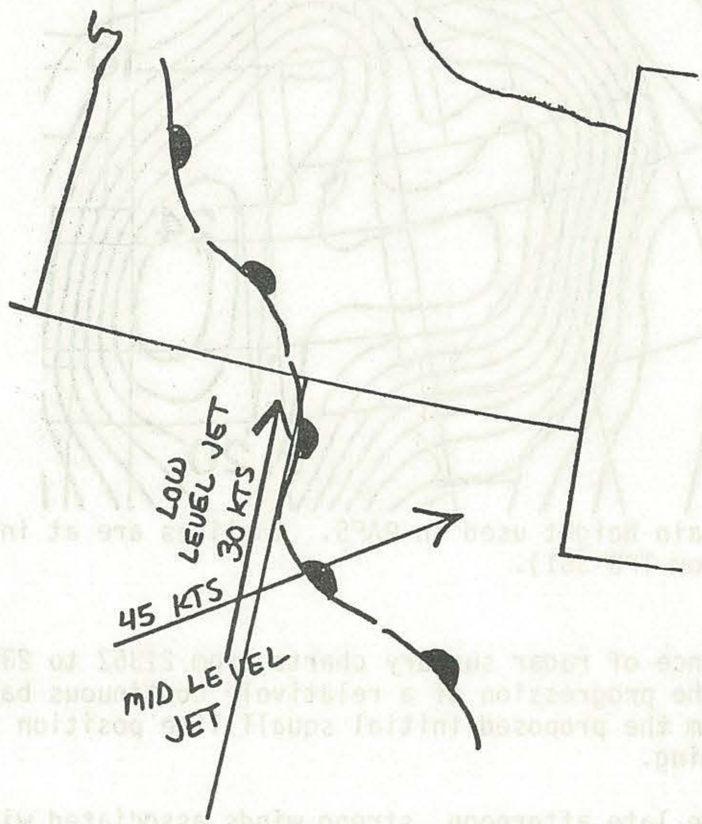

Fig. 21. Surface discontinuity, and low- and mid-level jets for 21Z July 6, 1983.

advance of the vigorous cold front. The terrain was undoubtedly responsible to a degree for low-level convergence and enhanced vertical motions. The thunderstorms were able to intensify quickly in the favorable upper-level moisture, high instability and strengthening dynamics.

Miller (1972) has diagrammed the formation of squall lines in relation to both low-level and mid-level mechanisms (Fig. 20). The author believes this formation was at work during the late afternoon as the line of severe thunderstorms was forming from the southwest corner of Montana, through southeast Idaho and into northern Utah, aided by the terrain (Figs. 21 and 22). Figure 22 displays modeled terrain on a relatively course scale. Terrain induced low-level convergence and vertical motions would occur on a thunderstorm scale, i.e., meso γ --2 km (1.2 miles) to 20 km (12 miles) (Doswell, 1982). The effects of these would be transferred both to higher and lower scales.

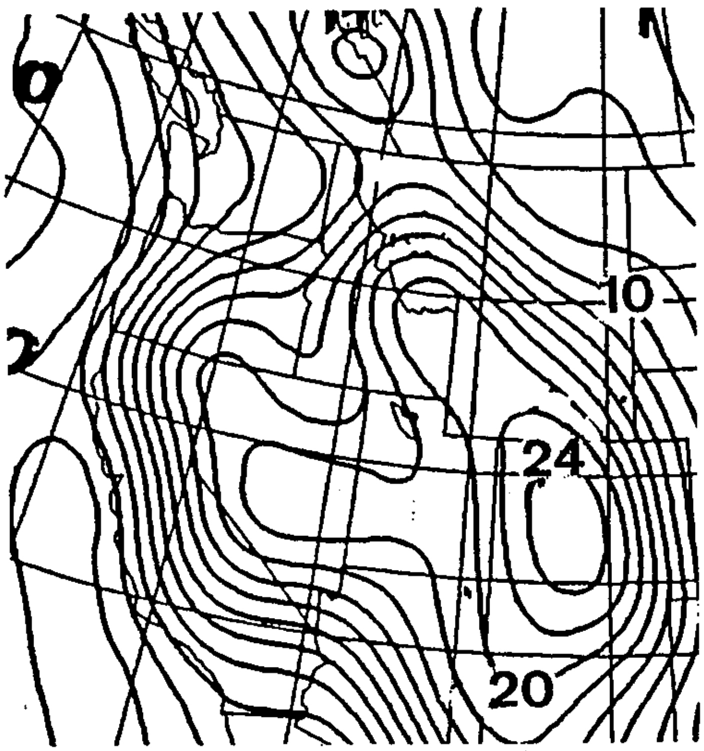

Fig. 22. Terrain height used in RAFS. Isolines are at intervals of 200 meters (from TPB 351).

The sequence of radar summary charts from 2135Z to 2335Z (Figs. 17-19) shows the progression of a relatively continuous band of convection from the proposed initial squall line position to the west border of Wyoming.

During the late afternoon, strong winds associated with the line of thunderstorms blew down trees and power lines in southeast Idaho.

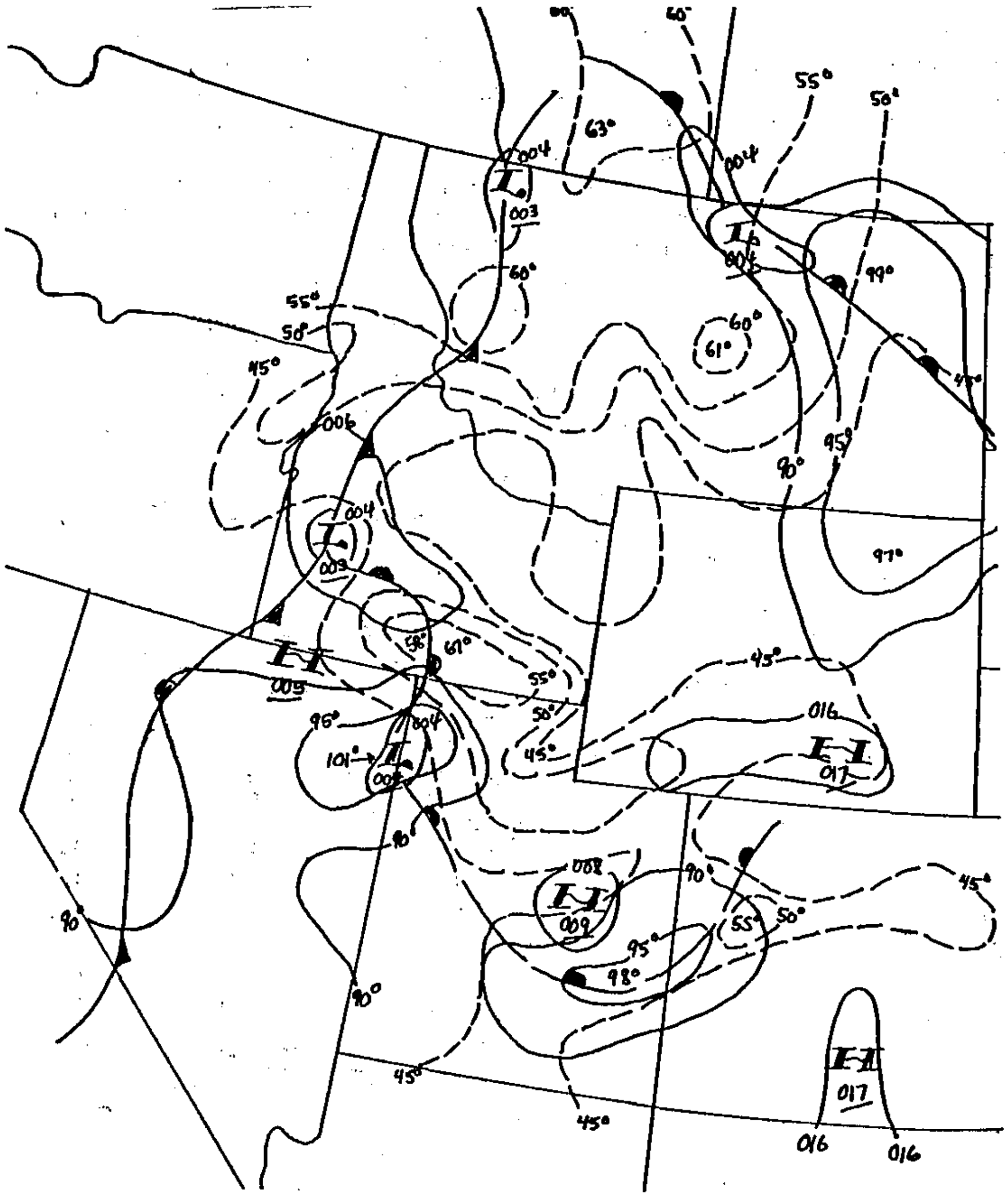

Fig. 23. Surface/sea level analysis for 00Z July 7, 1983. Solid lines isobars or isotherms. Dashed lines isodrosotherms.

Several cars and a trailer home were heavily damaged by downed trees. At Palisades Reservoir in Bonneville County, one man was killed and two were injured as strong winds toppled 30 trees in a campground. At 2204Z a wind gust of 82 mph was recorded at the Pocatello Airport. Through mid-evening, winds estimated to 100 mph caused extensive damage to buildings, power lines and trees in Park County, Montana, mostly at Livingston. A line of thunderstorms roared through far west Wyoming producing wind gusts of up to 90 mph. Most of the damage occurred in the Pinedale and Big Piney areas where large uprooted trees fell on houses, vehicles and power lines. There was no mention of hail damage with these severe thunderstorms. Large hail is rare in comparison to the occurrence of destructive wind gusts in the Intermountain Region. In addition to the climatological dryness, large variations in terrain prevents the persistent wind shear (Marwitz, 1972) and uninterrupted low-level moisture flow (Foote and Fankhauser, 1973) necessary for severe hailstorms.

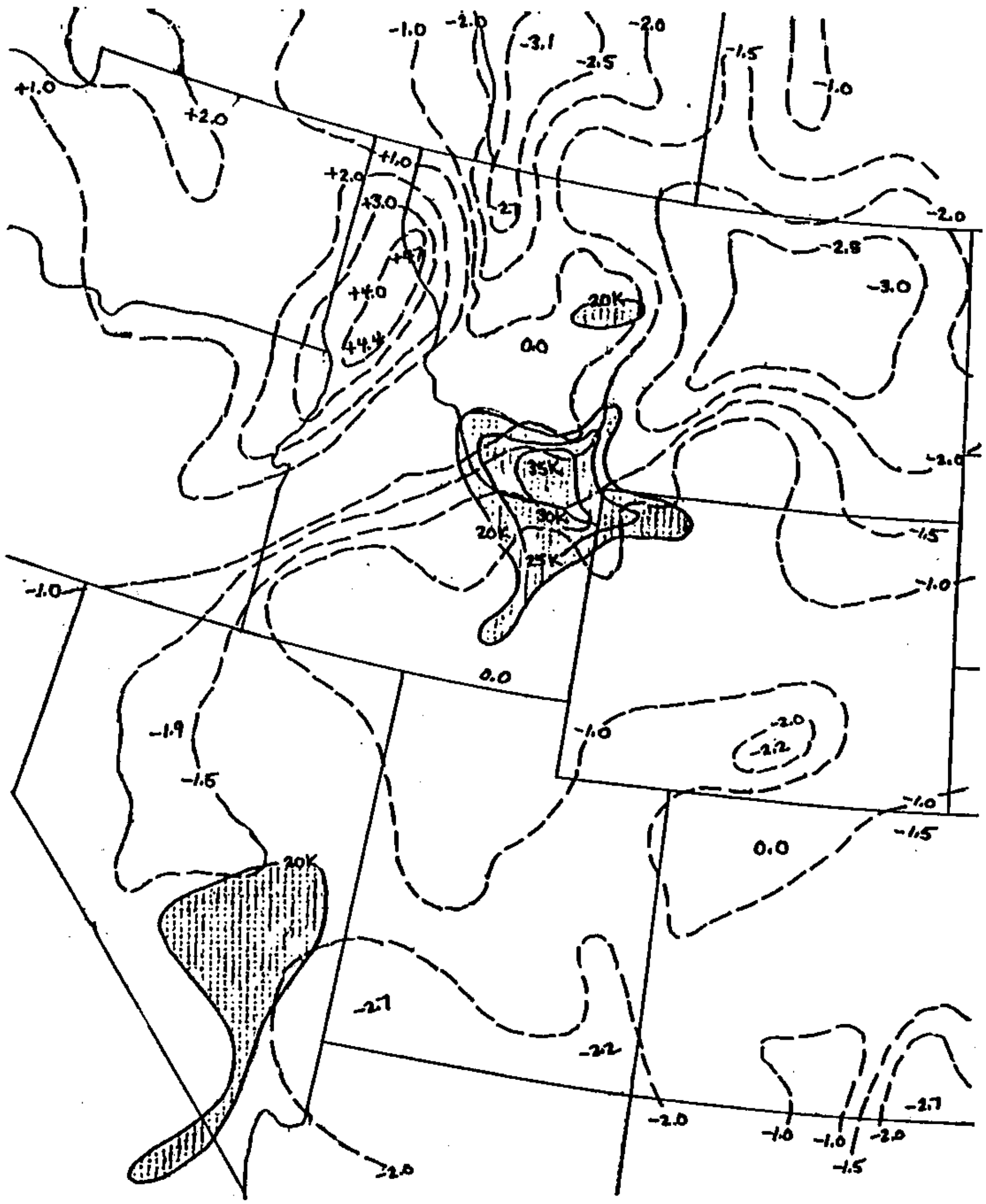

Fig. 24. Isallobaric (dashed lines) and isotachs (shaded areas) analysis for 00Z July 7, 1983.

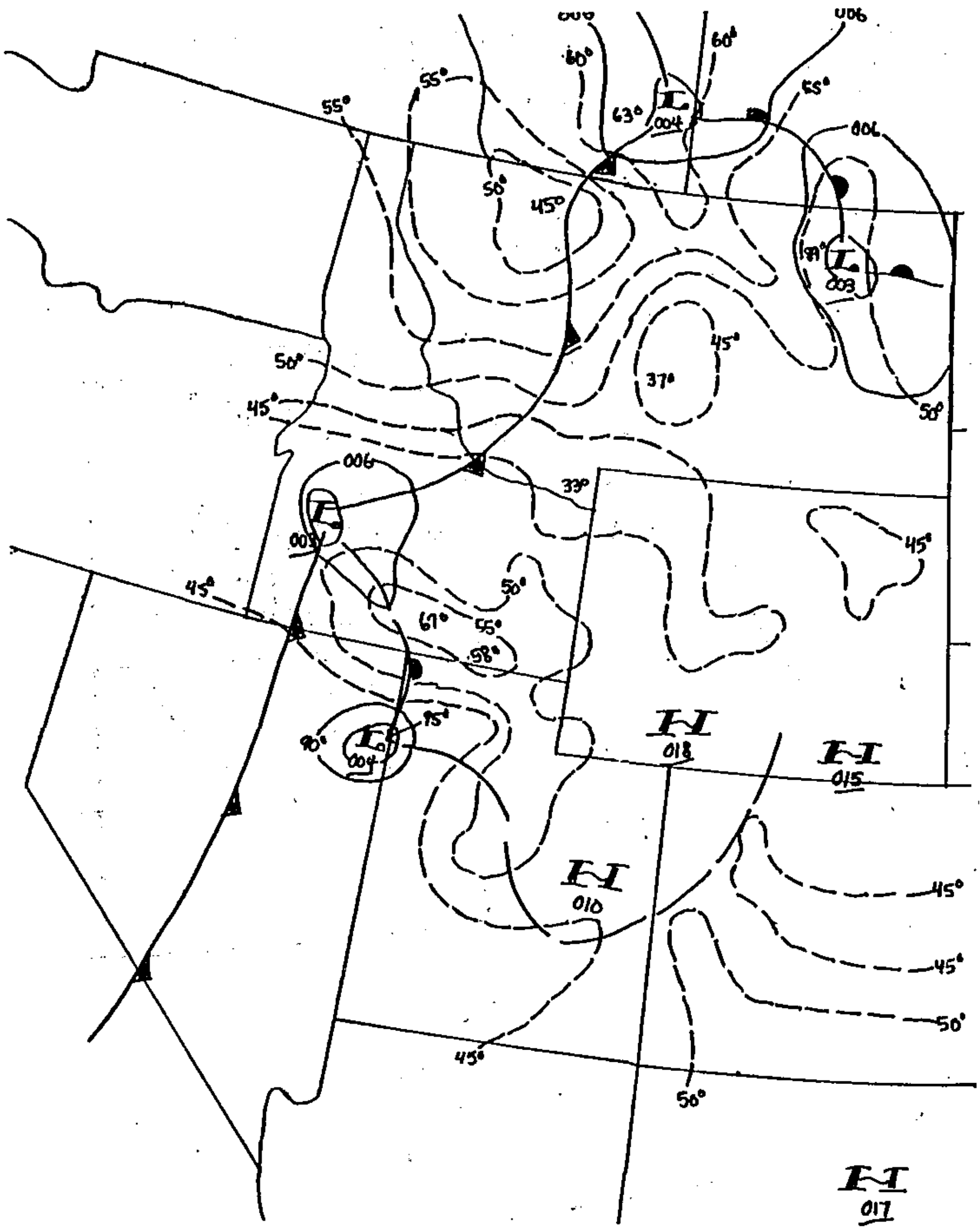

Fig. 25. Surface/sea level pressure analysis for 03Z July 7, 1983. Solid lines isobars or isotherms. Dashed lines isodrosotherms.

The 00Z and 03Z surface charts (Figs. 24 and 26) show the progression of the 30 knot surface jet northeast from the Great Basin. The sequence could be taken as a reflection of the progression of the triggering mechanism, or down surge. The isallobaric patterns in Figs. 24 and 26 show a transition from net divergence toward net convergence as pressure rises now prevailed in the area of the remnants of the squall line. The thunderstorms were losing their triggering mechanisms throughout the depth of the atmosphere.

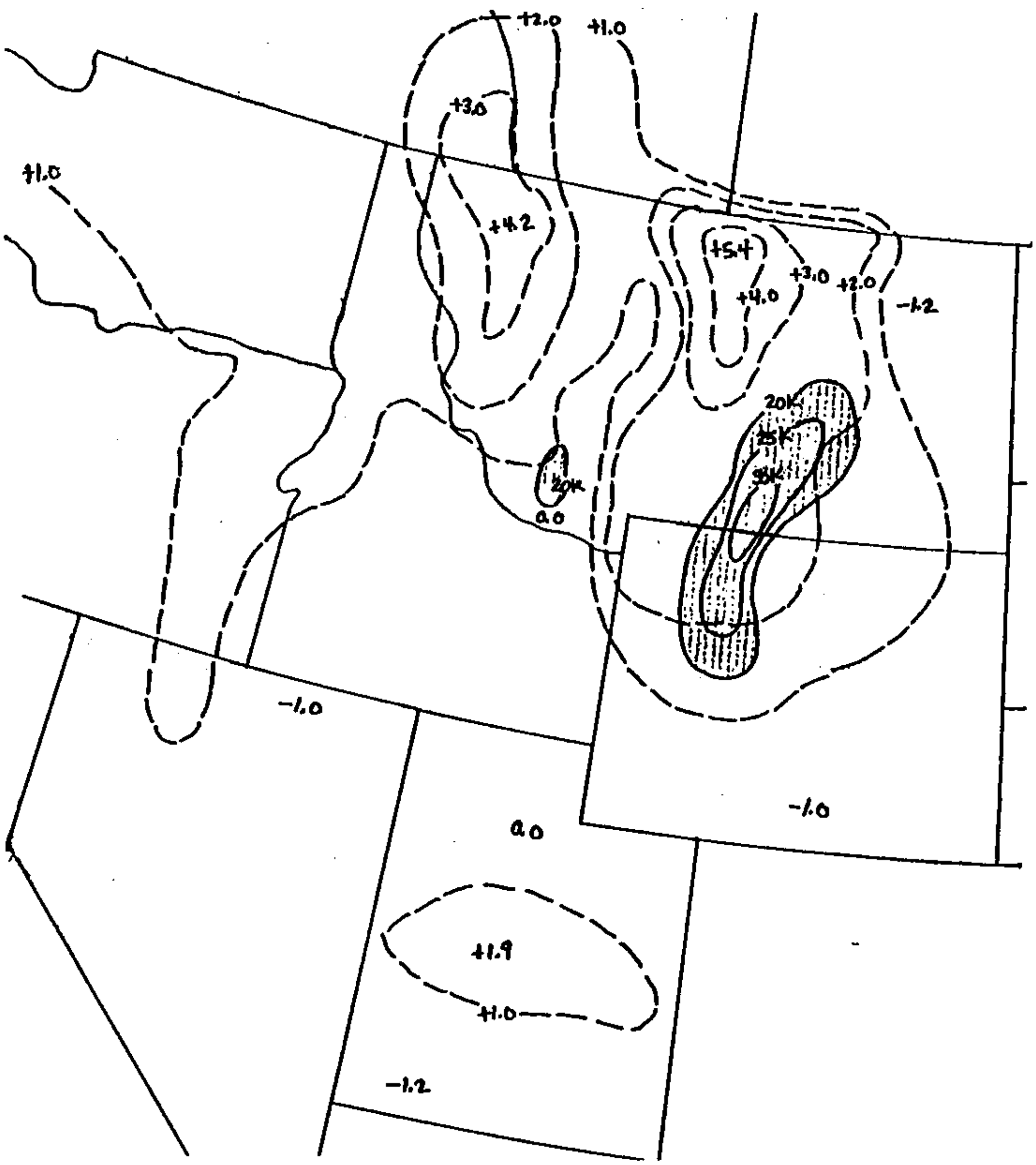

Fig. 26. Surface isallobaric (dashed lines) and isotach (shaded areas) analysis for 03Z July 7, 1983.

As the thunderstorms moved east of the Continental Divide by mid-evening, the effects of terrain became a dissipating influence (Fig. 22) and the few lingering clusters of thunderstorms were increasingly disorganized and dissipative (Figs. 27-30). Also cooling, although gradual, in the lower layers with the onset of evening was diminishing the maximum potential of the downrush thunderstorm winds.

4. SUMMARY AND RECOMMENDATIONS

During the convective season in the Intermountain Region, the forecaster who encounters an "Inverted-V" morning sounding in or upstream of his or her area of responsibility should carefully assess the instability and triggering mechanism(s), and more importantly, how these elements basic to convection will evolve during the heating cycle. This should be done without an over-reliance on numerical prognostic charts. The "Inverted-V" sounding is not particularly unusual near the semi-arid northern Rockies. With a classic "Inverted-V" sounding, e.g., depicted in Western Region Technical Attachment 76-14 or in Wakimoto (1985), and weak instability and triggering mechanism(s), near severe wind gusts are not uncommon with thunderstorms. If the forecaster determines that a potential for severe weather exists, he must redouble his care in monitoring satellite, radar and surface reports during the course of the day. The author realizes this is easier said than done in light of the demands of routine forecast products.

Close monitoring of both the large and fine-scale features of a complete surface analysis will give the forecaster a physical basis to forecast how any triggered convection will be further aided, and how it will interact with nearby terrain.

This close monitoring will also allow the forecaster to begin issuing cautioning statements to the public once he becomes confident that a severe weather episode will begin within the next hour or two.

Once the first severe report is received, the forecaster is frequently too busy responding with warnings and severe weather statements to carefully monitor the meteorology.

5. ACKNOWLEDGEMENTS

The author wishes to thank Steve Carmel, WSFO Denver (formerly of WSO Lander), for giving him one piece to a puzzle, which spurred the author on to find the others and assemble them, a much lengthier process than anticipated. Thanks are also in order to Dean Jackman, DMIC WSFO Salt Lake City, for providing copies of the SLC sounding and radar summary charts, and to the staff at NSSFC for raw surface and upper air data, thermodynamic values, and even blank plotting maps. Special thanks to Dr. W. E. Sangster, CR SSD, for the use of output from one of his computer programs and the patience to guide the author to completion of this memorandum.

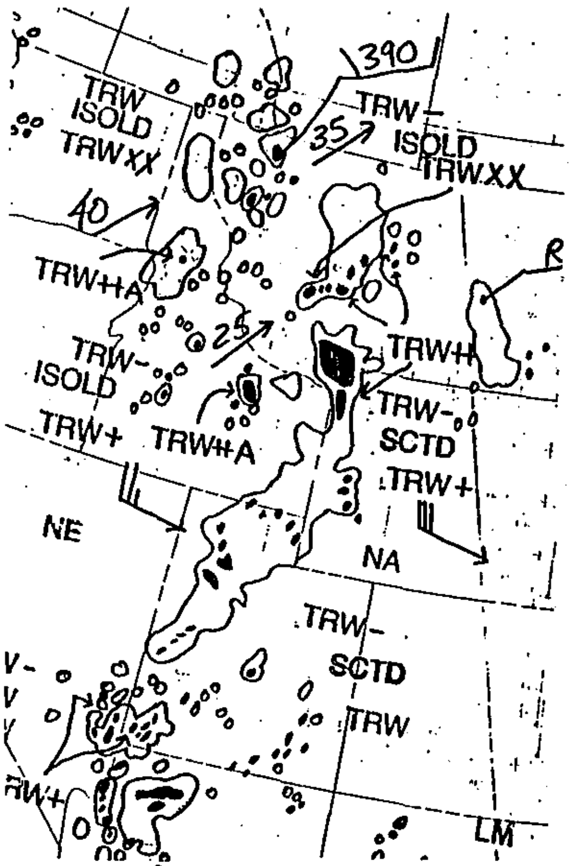

Fig. 27. Radar Summary for 0035Z July 7, 1983.

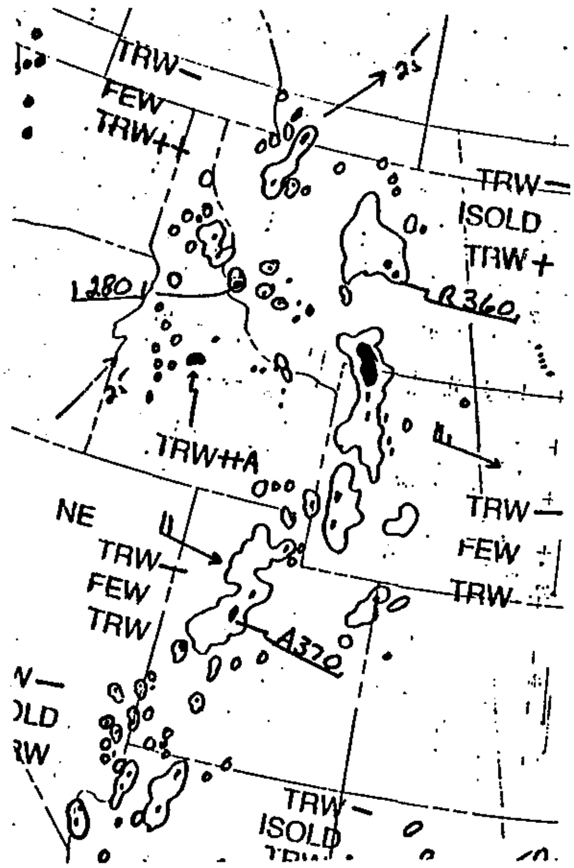

Fig. 28. Radar Summary for 0135Z July 7, 1983.

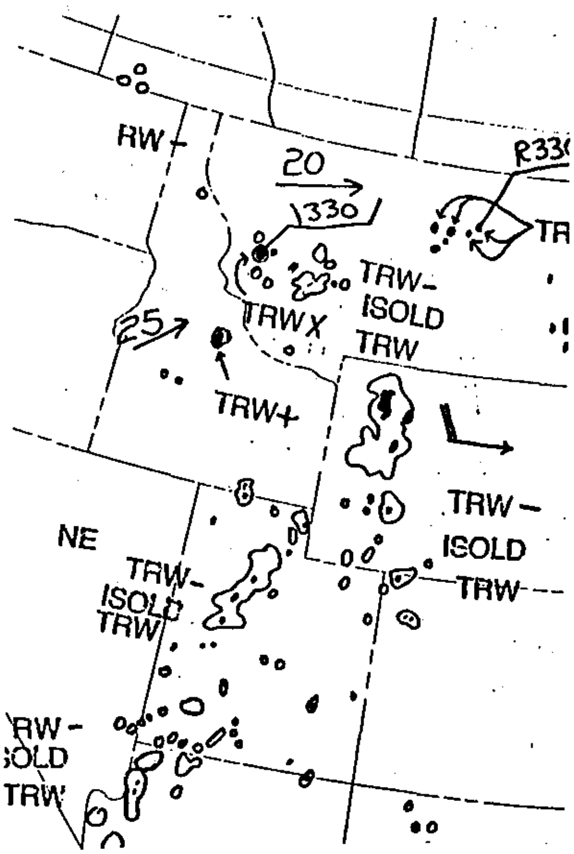

Fig. 29. Radar Summary for 0235Z July 7, 1983.

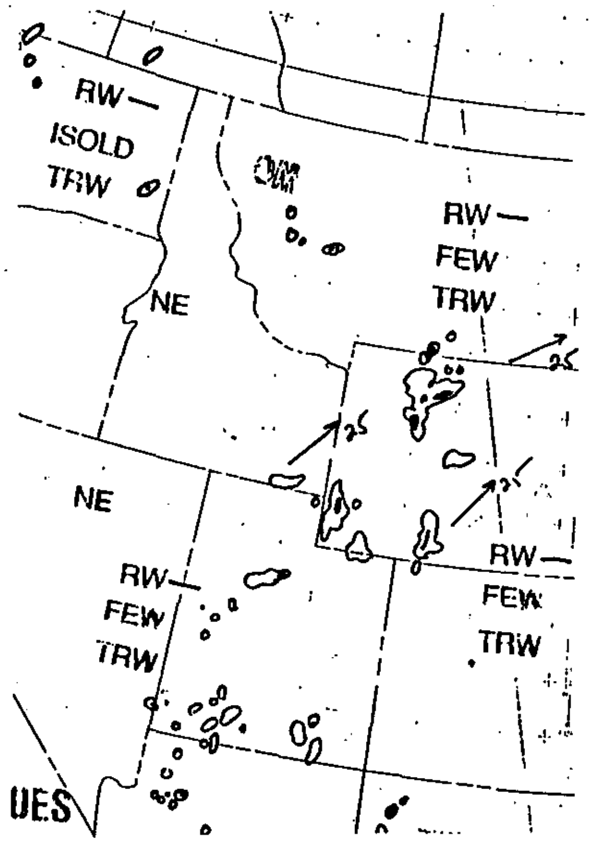

Fig. 30. Radar Summary for 0335Z July 7, 1983.

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