WESTERN REGION TECHNICAL ATTACHMENT
NO. 98-17
APRIL 21, 1998

# SYNOPTIC PATTERNS ASSOCIATED WITH SNOW ACCUMULATION IN LAS VEGAS, NEVADA

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## Introduction

Significant snowfall events at lower elevations in southern Nevada are rare. In the city of Las Vegas, which is roughly 2200 feet above mean sea level (MSL), snow flurries are observed once or twice during most winters, but snowfall of an inch or more occurs only once every four to five years. This study will concentrate on an even more unusual event in the Las Vegas valley: snowfall of two inches or more in a given storm.

References in the literature which focus on southern Nevada winter forecasting are few. However, several studies have been published to identify synoptic patterns and other meteorological variables associated with significant snow events in lower elevations of the Desert Southwest (e.g., McCollum and Meyer, 1997; Reynolds, 1996; Novlan, 1981).

Prior to 1997, the criterion for a winter storm warning for elevations up to 2500 feet MSL in Southern Nevada was accumulation of two inches or more for a given storm. Historically, only eight storms have exceeded this criterion since 1949, thus, it is an exceptionally rare event (Table 1). Nonetheless, given the impact of such an event on the local populace and economy, it is extremely important these situations are forecast accurately when they do occur. This Technical Attachment (TA) will document three basic synoptic conditions favorable for snow accumulation in the Las Vegas valley: the first being a slow-moving, deep cut-off low situated over the Great Basin, and the second a long wave trough along the west coast extending from the Pacific Northwest south to northern Baja California. A third "hybrid" case begins as a Great Basin storm before becoming positively tilted and digging offshore. This TA compares the characteristics of historic events which exceeded the two-inch threshold and introduces a composite checklist intended to be used as a practical forecast aid in evaluating potential snow cases. In addition, we will attempt to explain the physical parameters and synoptic patterns associated with such events.

## Data

The data used to investigate historical snow cases and develop a composite checklist were obtained from two CD-ROMs. The first was "Global Historical Fields", v1.0, August, 1994, which was jointly produced by the Fleet Numerical Meteorology and Oceanography Detachment and the National Climatic Data Center. From this data set, we examined and classified synoptic patterns associated with the eight significant snowstorm since 1949. For each storm, geopotential heights and temperatures at selected standard pressure levels were analyzed, and thickness values were calculated for various layers. Mean values for each of these fields were then calculated in order to build a composite for each synoptic type.

From the second data set ("Radiosonde Data of North America, 1946-1995), v1.0, August 1996), radiosonde data was extracted in order to derive precipitable water and mixing ratio values for each storm from the sample. The soundings used for this study were taken from three sites: Desert Rock, located about 60 miles northwest of Las Vegas; Yucca Flat, about 90 miles northwest of Las Vegas; and McCarran International Airport in Las Vegas. No correction was attempted for any possible differences between the sounding sites and the Las Vegas valley.

Recognizing that the sample of cases is limited, a composite of some of the critical physical parameters was developed with the presupposition that these cases would be representative of typical antecedent conditions for Las Vegas snowstorms. The same caveat holds true for the objective forecast checklist.

## Discussion

*Pattern 1: The Deep Positive Tilt Trough*

The most significant snow events have been associated with a pattern in which a series of mid-tropospheric low pressure systems dig southward along the California coast, carving out a large positively tilted long wave trough, which then rotates eastward across the Great Basin. The initial system allows cold air to become entrenched deep into the southwestern United States. Subsequently, a secondary cyclone translates across the Region providing strong synoptic scale lift and jet dynamics as a vigorous cyclonically curved jetstreak sets up just south of the area, resulting in locally heavy snowfall across the Mojave Desert.

On January 4-5, 1974, a storm representative of this evolution produced 9.0 inches of snow in Las Vegas (see Fig. 1), the most ever in a 24-hour period since official records have been kept. A similar scenario during the period from January 30 through February 2, 1979 (not shown), resulted in a storm total of 7.8 inches. Surprisingly, pre-storm soundings associated with the heavier snow events did not exhibit a substantially richer source of available moisture than those which produced more moderate snows. This fact is evident in the total column precipitable water and mixing ratio values at 850-700mb shown in Table 2. It appears that sustained large-scale upward vertical motion (UVV) is a more significant factor than available moisture for winter storm events. Intuitively, this makes sense given the relatively long duration of cool-season storms as compared to those of the convective season.

The January 4-5, 1974 storm was the one anomaly where low available moisture (PW=0.23") and relatively short duration (16 hours) combined to produce nine inches of snow. It seems illogical, however, that such a dramatic snowfall could occur in Las Vegas without tapping into a plume of subtropical moisture, regardless of a system's precipitation efficiency. Personal experience has shown that an eastern Pacific moist tongue can be entrained into a system rather quickly, sometimes depicted only by tools such as SSM/I or GOES Sounder PW, with little evidence in the sparse upper air network. An assumption is made on our part, therefore, that this intense snowstorm was in fact characterized by a subtropical moisture fetch from the eastern Pacific. Figure 2 depicts storm total snowfall against precipitable water from the nearest relevant sounding, and stratifies each event by synoptic type.

*Pattern 2: The Great Basin or Nevada Low*

The second category, which produces a more modest snowfall in the area, is associated with a deep, slowly progressive closed low which settles in over central Nevada. This type of pattern is best illustrated by the storms of January 28, 1979 (Fig. 3) and January 19-20, 1949, each of which resulted in just over two inches accumulation at Las Vegas' McCarran International Airport. We surmise this pattern is less effective at generating heavy snowfall because it is less conducive to developing a subtropical moist fetch across the eastern Pacific. Jet energy is also a weaker factor in these storms. However, close proximity of the upper-level cold pool tends to steepen mid-level lapse rates, promoting embedded convection. Thus, isolated heavy snows might be observed, especially near the foothills, despite relatively light amounts on the valley floor.

One might expect that if a closed low were to dig far enough south, such that a slow-moving deformation zone were to stretch out across southern Nevada (around the northern quadrant of the circulation center), a heavy snowfall would be realized. Interestingly, there were no cases in the historical data base which produced heavy snow across the area in association with such a storm. There are, however, dozens of cases of low latitude closed lows moving across southern California/western Arizona. Typically this scenario occurs within the southern split branch of a highly zonal jetstream flow. As a result, such a storm tends to be an efficient rain producer, but does not tap sufficiently cold air to lower snow levels to the desert floor.

*Pattern 3: The Hybrid Storm*

The third "hybrid" category begins as a Great Basin storm, but the trough evolves into a positive tilt and digs offshore as a fresh surge of potential vorticity is injected into the back side of the upper low. This storm type is best illustrated by the January 10-12, 1949 event (Figs .4 and 5), which produced nearly ten inches (9.7) of snow over a three-day period.

This storm still stands as the biggest official snowstorm in Las Vegas' recorded history. Other undocumented storms from earlier in the 20th century have topped this, however. In 1909, a local newspaper called "The Las Vegas Age", headlined a story recounting 10-15 inches of snow across the valley on December 20-21 of that year. Another winter storm was highlighted by the "Las Vegas Evening Review" on January 10, 1930. Five inches of snow blanketed what was then little more than a frontier town (Fig. 6).

Knowledge obtained from a climatological data base has been shown to have value in setting the skill level for a given process above that of random guesswork (Doswell, 1984). While climatology does not provide an explicit forecast of winter storm conditions, it can be useful in indicating when heavy snows are most likely from a historical perspective. For example, significant snowfall in Las Vegas is most likely during the month of January. In addition, all of the significant snow events in Las Vegas have occurred one or two seasons after the warm phase of the El Niño-Southern Oscillation cycle (Trenberth, 1997). Figure 7 depicts the seasonal snowfall in the Las Vegas valley since 1949 and its relationship to El Niño and La Niña years.

El Niño years are characterized by above normal heights in the lower and middle troposphere over the Mojave Desert. Thus, the corresponding thickness field (which represents a given layer's mean virtual temperature) is typically higher than normal. Therefore, while El Niño winters are frequently wetter than normal, they do not tend to favor substantial snow production at unusually low elevations in southern Nevada. Interestingly, this is consistent with snow climatology elsewhere in the western United States as well (Ferber, 1992). In contrast, after the ENSO warm phase has subsided, positive correlation shifts to a tendency toward higher than normal heights over the eastern Pacific and below normal heights over the Intermountain West, consistent with the traditional "PNA" climatological pattern (Namias, 1975; Wallace and Gutzler, 1981). This results in a long-wave pattern favoring enhanced northwest flow aloft over the west coast which feeds cold air deep into the western US and fosters the development of mid-tropospheric cyclones over the Great Basin. These observations suggest that warm (cold) equatorial SST anomalies are associated with lesser (greater) chances of a significant snow event occurring in Las Vegas during any given winter season.

Temperatures at selected constant pressure levels have long been used as a guideline for rain/snow elevations (NWSTC, 1994). Another approach that has proven successful involves the use of thickness (Naistat, 1988). Each of these methods suffers from a similar shortcoming, namely that limited data is being applied to assume representation of a large mass of air. The former case uses temperature for a single level while the latter uses a mean between two levels (recall that thickness is simply the difference in geopotential height between two levels). A shallow layer of cold surface-based air will indicate a higher snow level that which actually exists, particularly if it is superimposed by relatively warm air near the top of the thickness layer being analyzed. Conversely, a layer of cold air aloft which does not extend to the surface may indicate an unrealistically low snow level. Notwithstanding these limitations, various studies and practical experience have shown good statistical correlation between specific thickness values and forecast snow levels in the short term.

Since southern Nevada is well above mean sea level, the layer between 850-500mb has proven more useful that the standard 1000-500mb thickness layer frequently used in the Great Plains states. This layer more closely approximates the near-surface temperatures, but is still deep enough to represent an airmass with sufficient cold air to support frozen precipitation in the lower valleys. Forecasts of the 850-500mb thickness coupled with 700mb temperatures have provided the most reliable estimates of snow levels at the Las Vegas Forecast Office. Table 2 summarizes favorable parameters for significant snowfall in Las Vegas. Snow levels associated with specific values of 850-500mb thickness and 700mb temperatures are listed in Table 3.

## Summary

Although heavy snow is extraordinarily rare in the city of Las Vegas, it is very important to recognize and predict such an event with a reasonable amount of lead time and reliability given the economic impact it has on the local area. We believe there is sufficient similarity between cases to justify the use of these research results in determining the potential for significant snow in the future. Indeed, utilization of the forecast checklist presented here was an important factor in the issuance of a snow advisory during the February 26, 1996 storm. This system produced the first measurable snow in six years at McCarran Airport. It is our hope that this study will form the basis for further research in this area. On the large scale, the key ingredients are clearly similar for all three major synoptic patterns: strong potential vorticity and attendant jetstreak dynamics in concert with a moderate source of moisture overspreading a relatively deep dome of cold air. The presence of sustained UVV and the stability profile appear to be more important factors than availability of moisture, probably because of the long time scales involved with the evolution of cool-season storms. Furthermore, major snowfall events in Las Vegas are climatologically favored during winter seasons which are one or two years subsequent to an El Niño winter. By building on these results, operational forecasters can cultivate a broader understanding of both synoptic and mesoscale features which are important to the development of significant snow events over the deserts of southern Nevada, northwest Arizona and southeast California.

## Acknowledgments

The authors would like to thank Mr. Kim Runk, Science and Operations Officer at NWSO Las Vegas for his review and technical advise on this study. In addition, we would like to thank Mr. Charles Schlott, HMT at NWSO Las Vegas, for calculating the various thickness parameters for the respective case studies.

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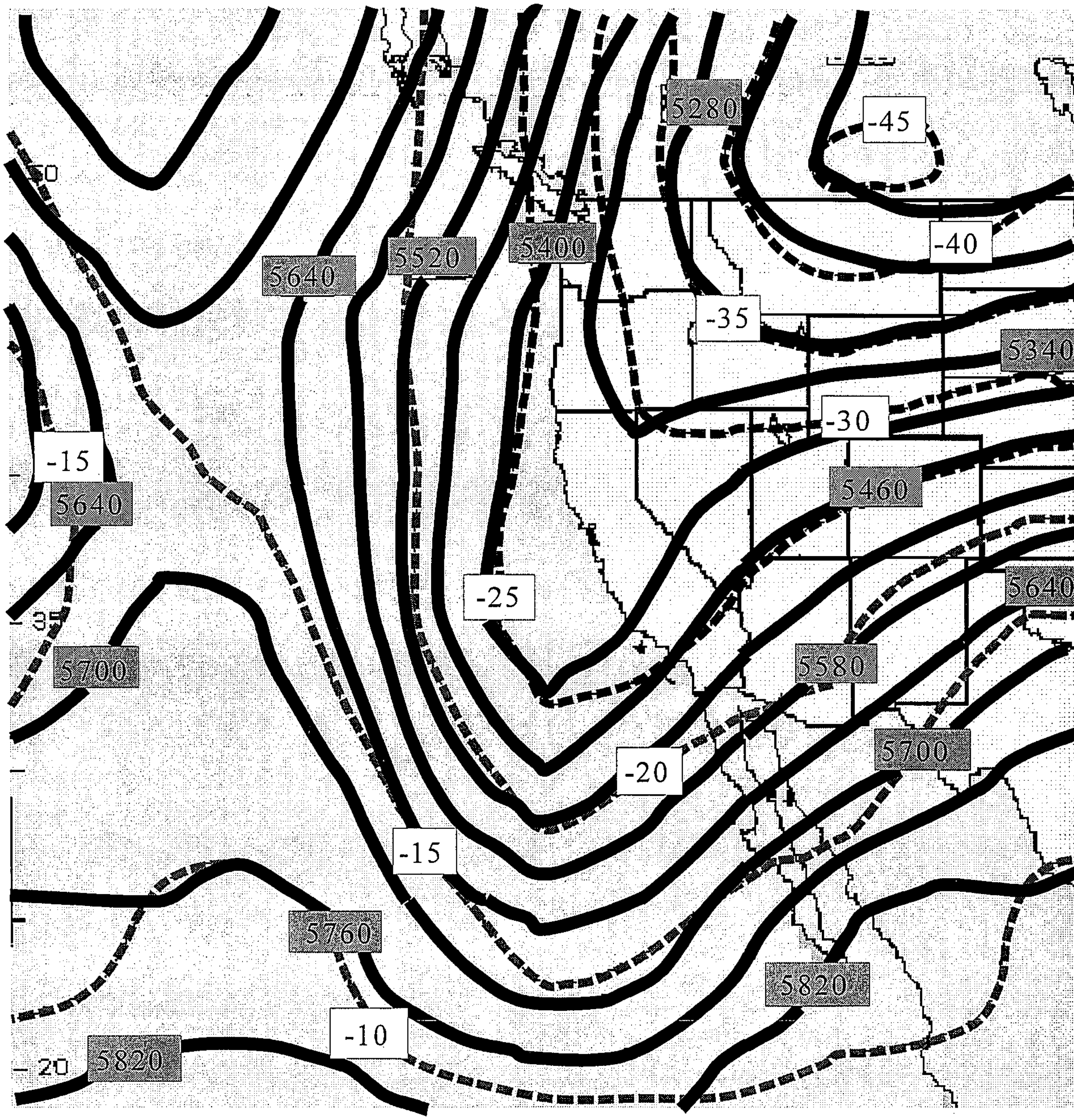



**Figure 1a.** 500 mb analysis valid 0000 UTC 5 January 1974.
(Solid lines = geopotential heights in meters, dashed lines = isotherms °C)

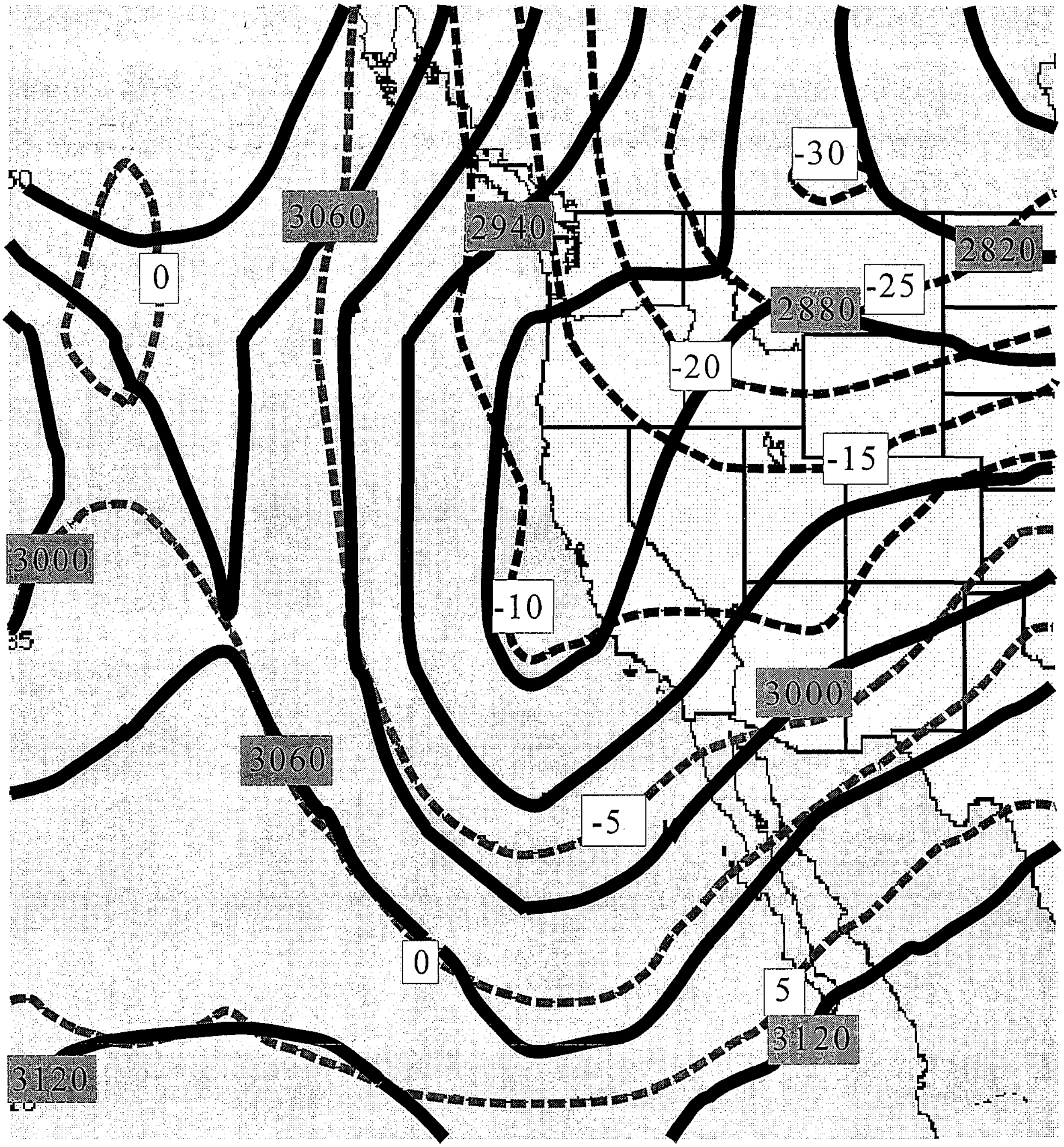



**Figure 1b.** 700 mb analysis valid 0000 UTC 5 January 1974.
(Solid lines = geopotential heights in meters, dashed lines = isotherms °C)

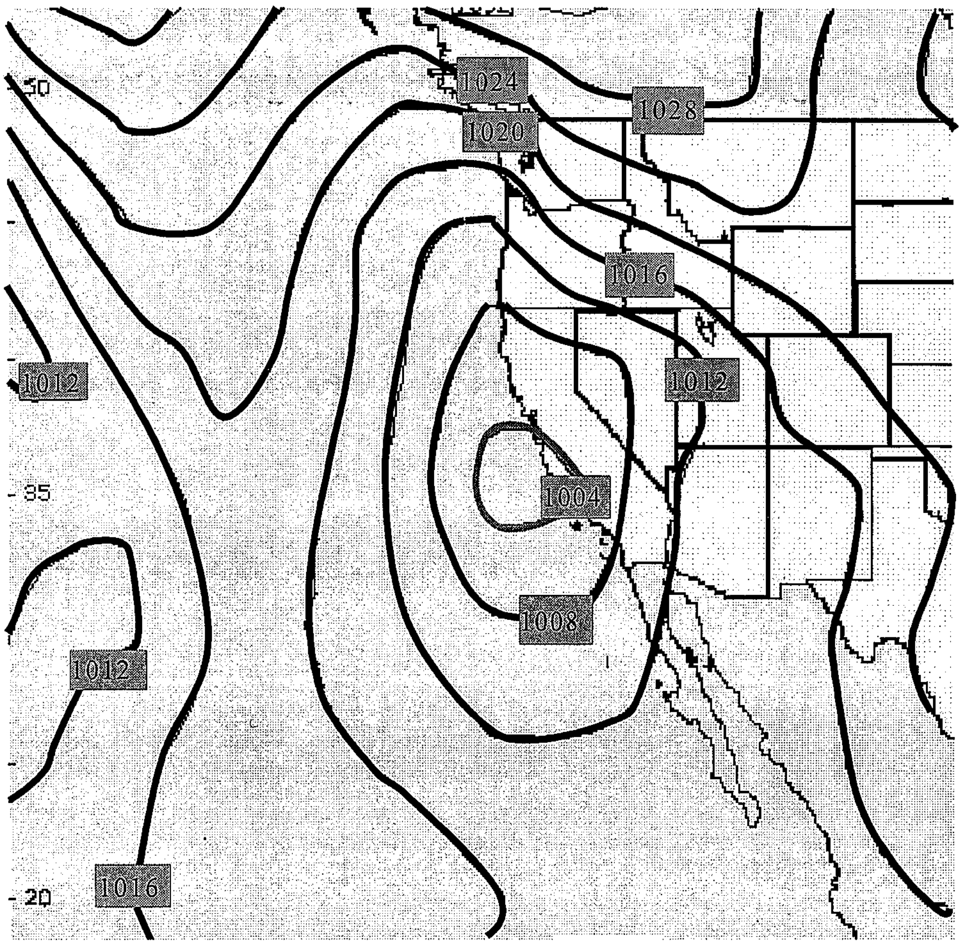
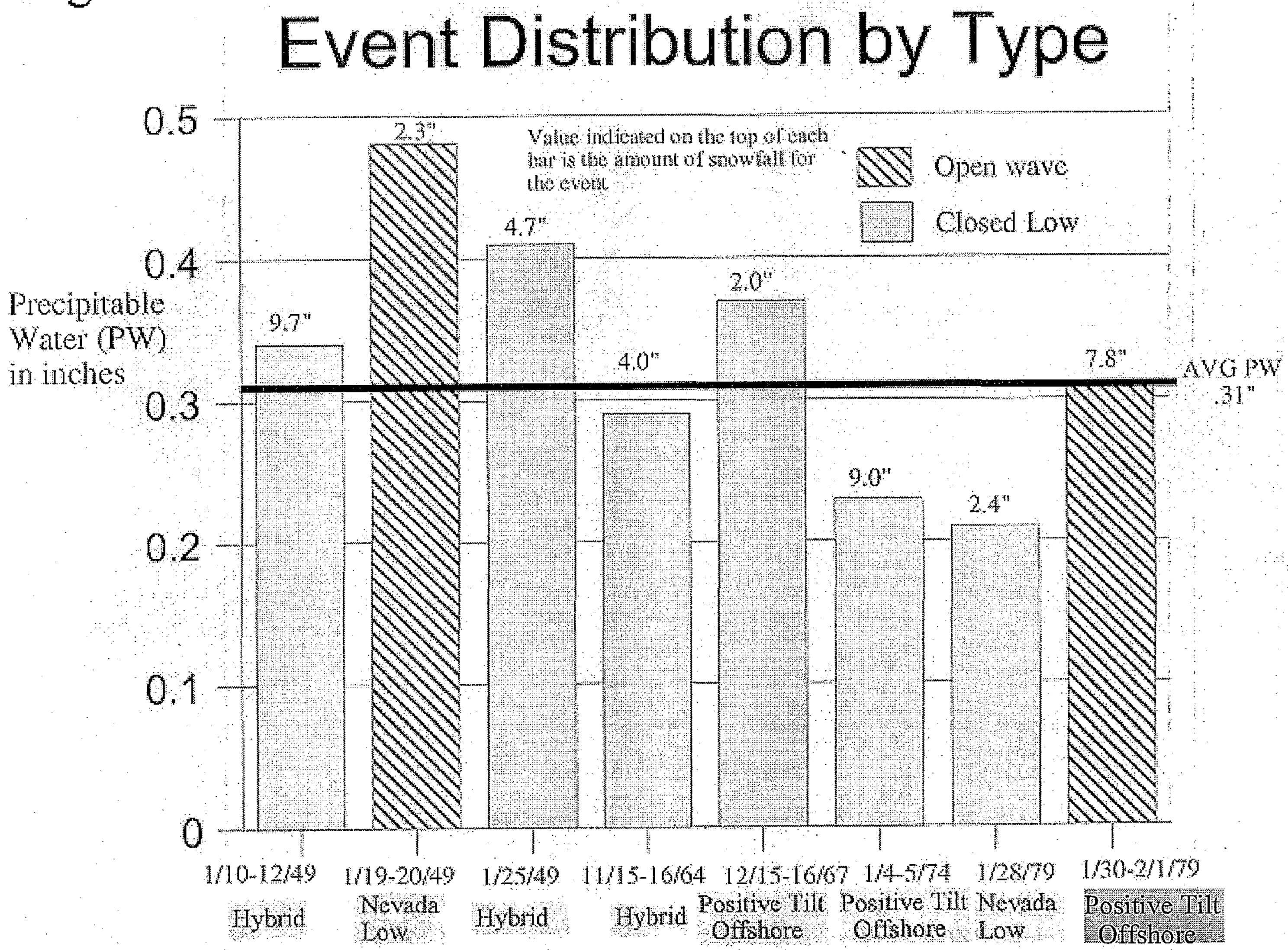



**Figure 1c.** Surface isobaric (solid, mb) analysis valid 0000 UTC 5 January 1974.

Figure 2


Event Distribution by Type
0.5
0.4
0.3
0.2
0.1
0
Precipitable Water (PW) in inches
Value indicated on the top of each bar is the amount of snowfall for the event
Open wave
Closed Low
9.7"
2.3"
4.7"
4.0"
2.0"
9.0"
2.4"
7.8"
AVG PW .31"
1/10-12/49
Hybrid
1/19-20/49
Nevada Low
1/25/49
Hybrid
11/15-16/64
Hybrid
12/15-16/67
Positive Tilt Offshore
1/4-5/74
Positive Tilt Offshore
1/28/79
Nevada Low
1/30-2/1/79
Positive Tilt Offshore

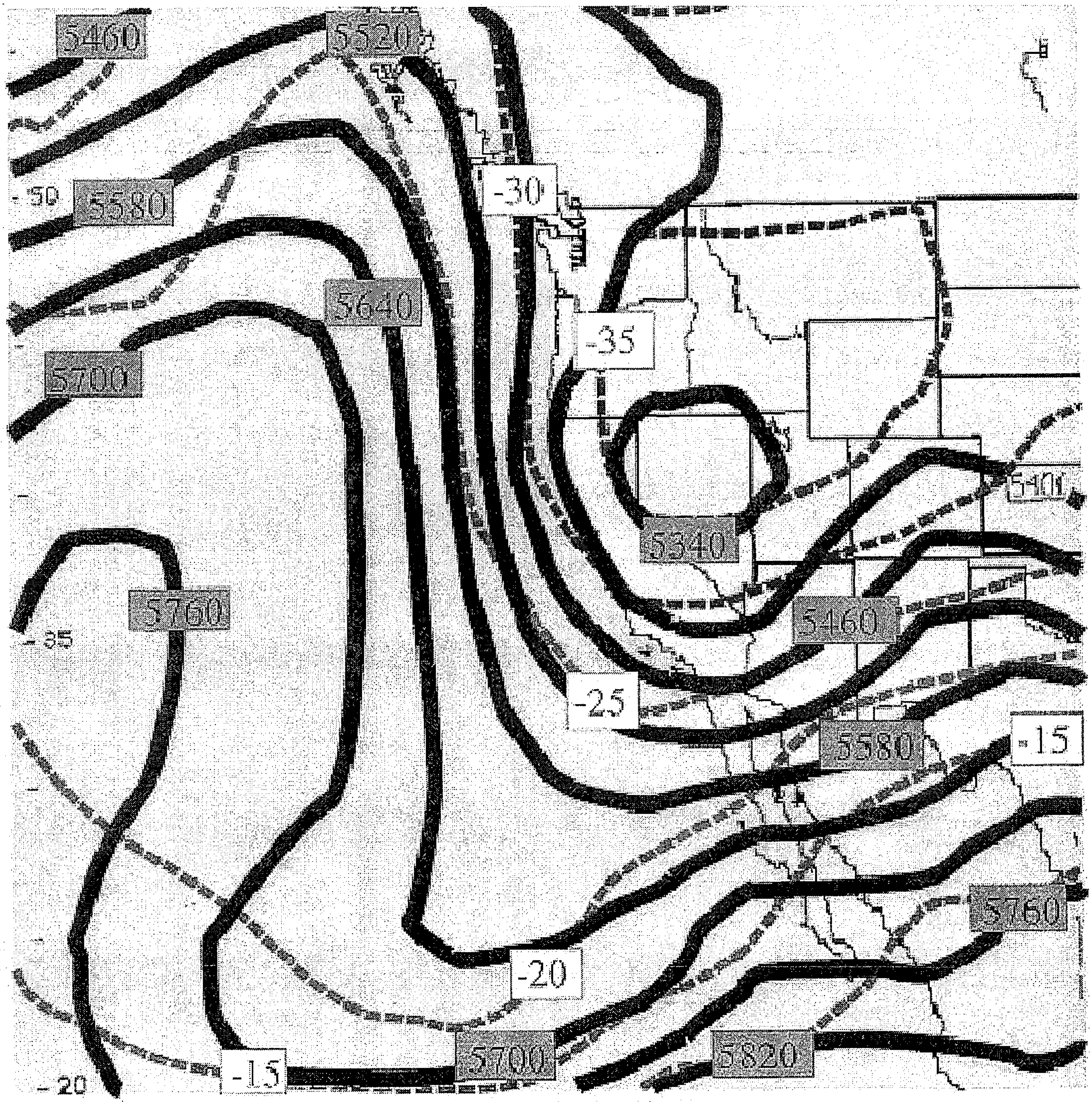



**Figure 3a.** 500 mb analysis, valid 1200 UTC 28 January 1979.
(Solid lines = geopotential heights in meters, dashed lines = isotherms °C)

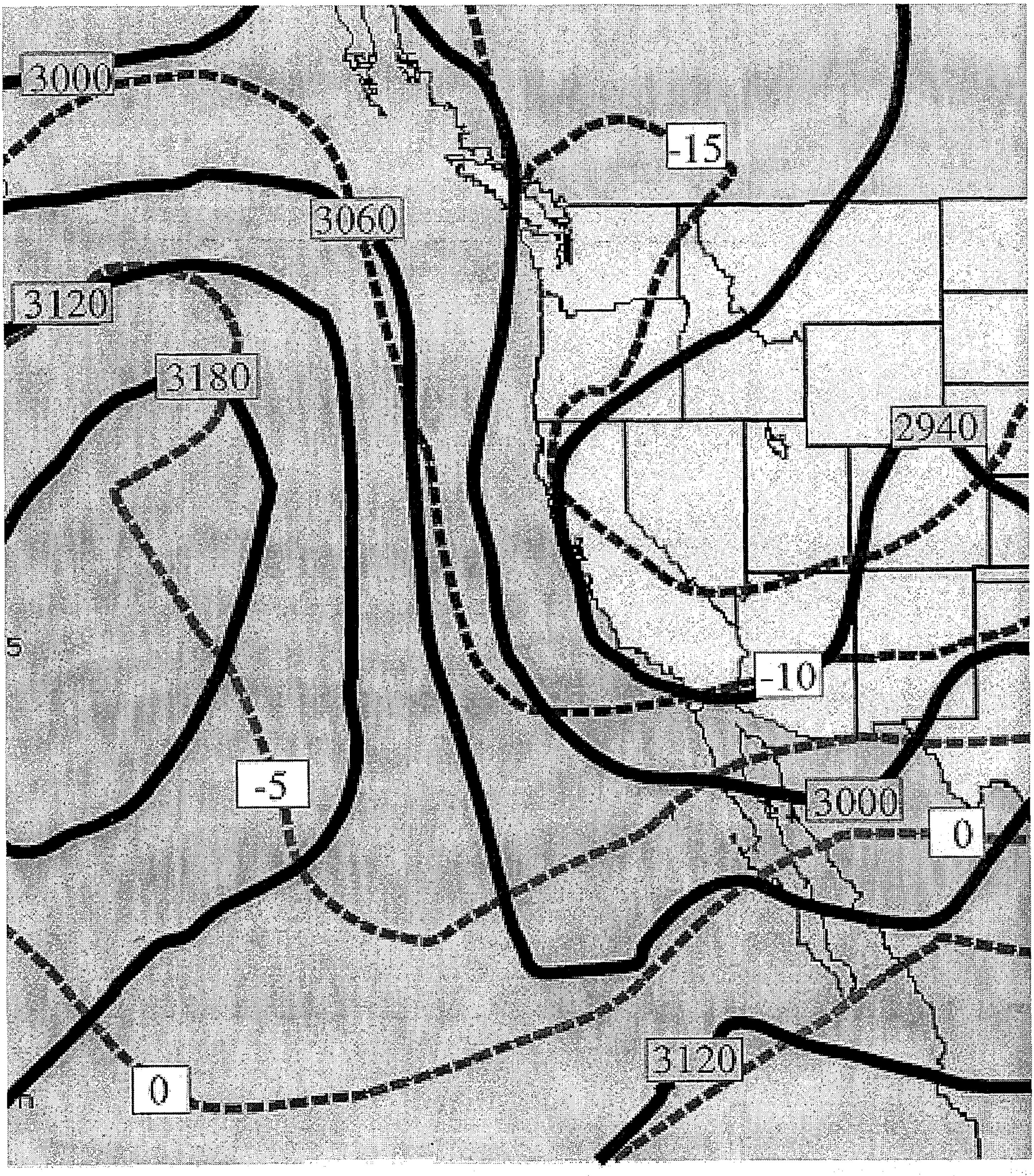



**Figure 3b.** 700 mb analysis, valid 1200 UTC 28 January 1979.
(Solid lines = geopotential heights in meters, dashed lines = isotherms °C)

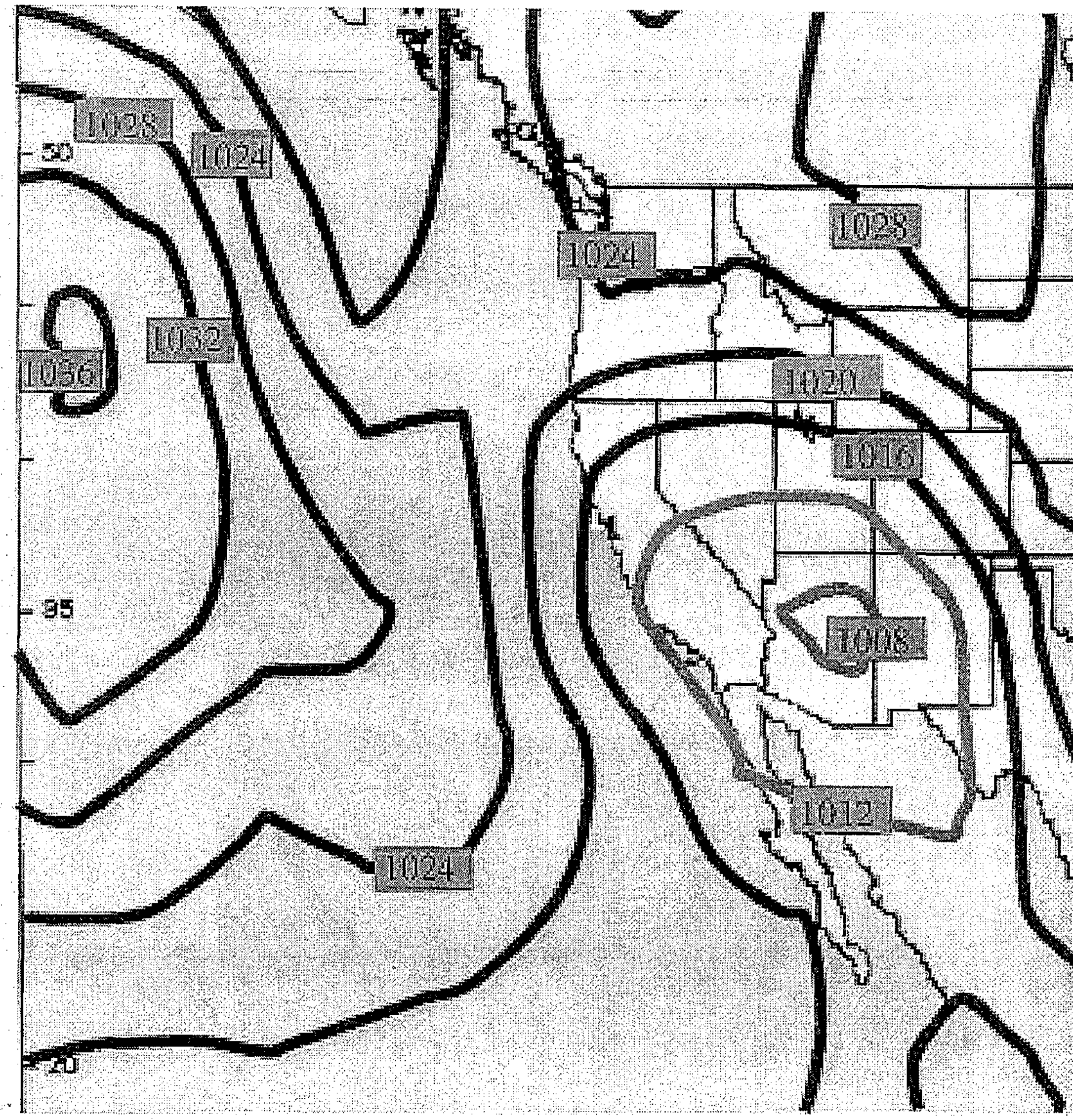



**Figure 3c.** Surface isobaric (solid, mb) analysis valid 1200 UTC 28 January 28 1979.

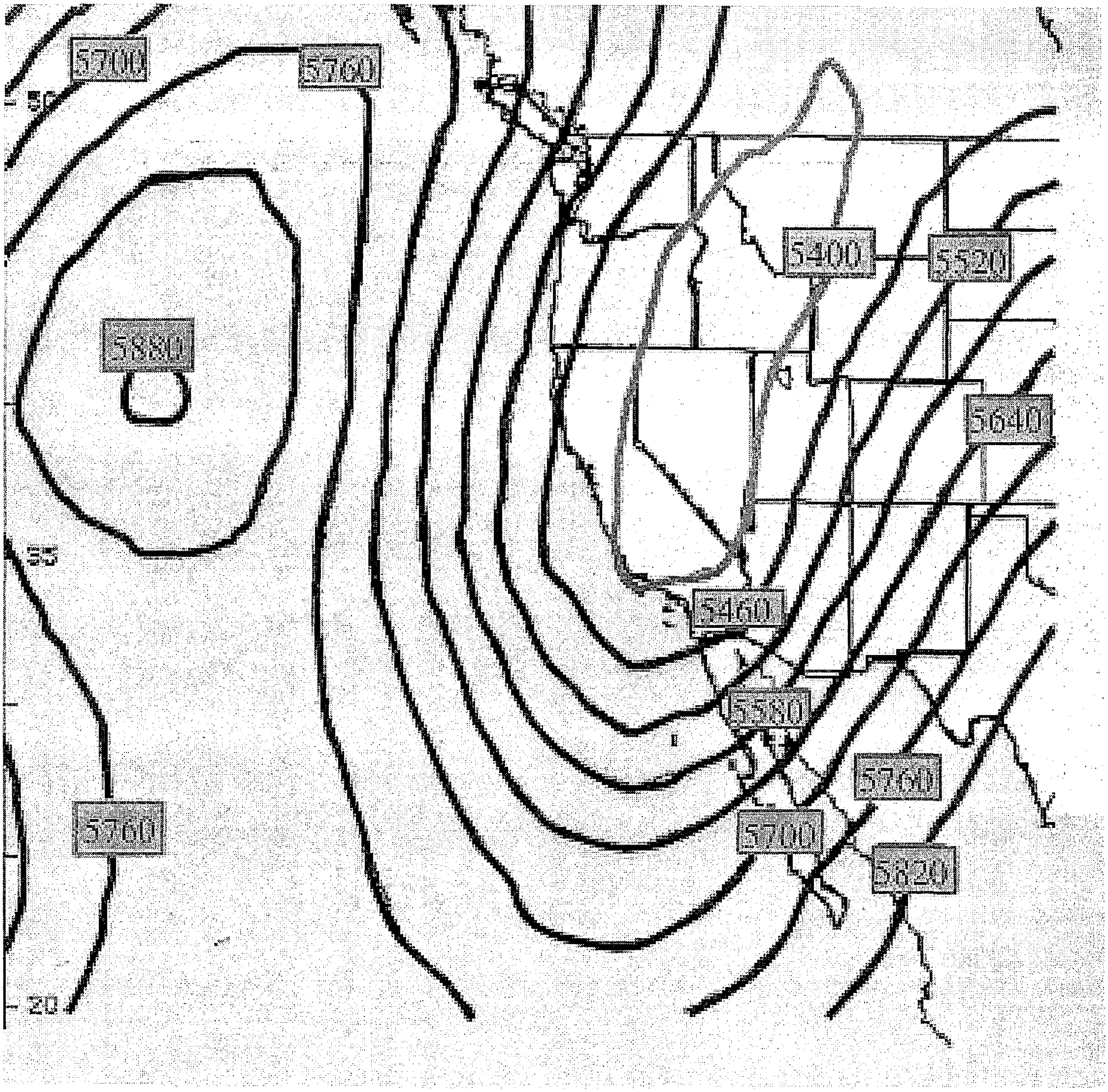



**Figure 4a.** 500 mb analysis valid 1200 UTC 10 January 1949.
(Solid Lines = geopotential heights in meters)

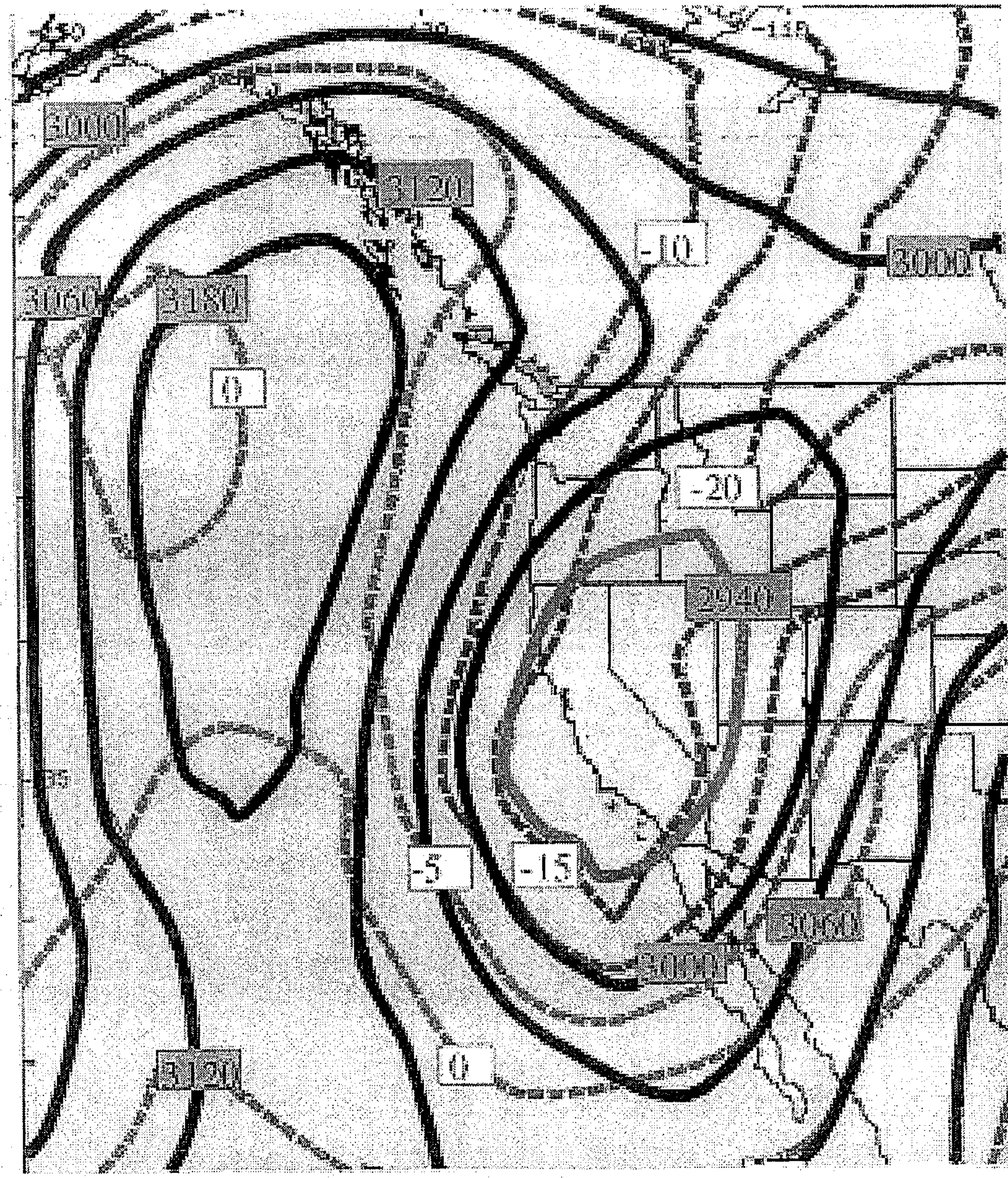



**Figure 4b.** 700 mb analysis valid 1200 UTC 10 January 1949.
(Solid lines = geopotential heights in meters, dashed lines = isotherms °C)

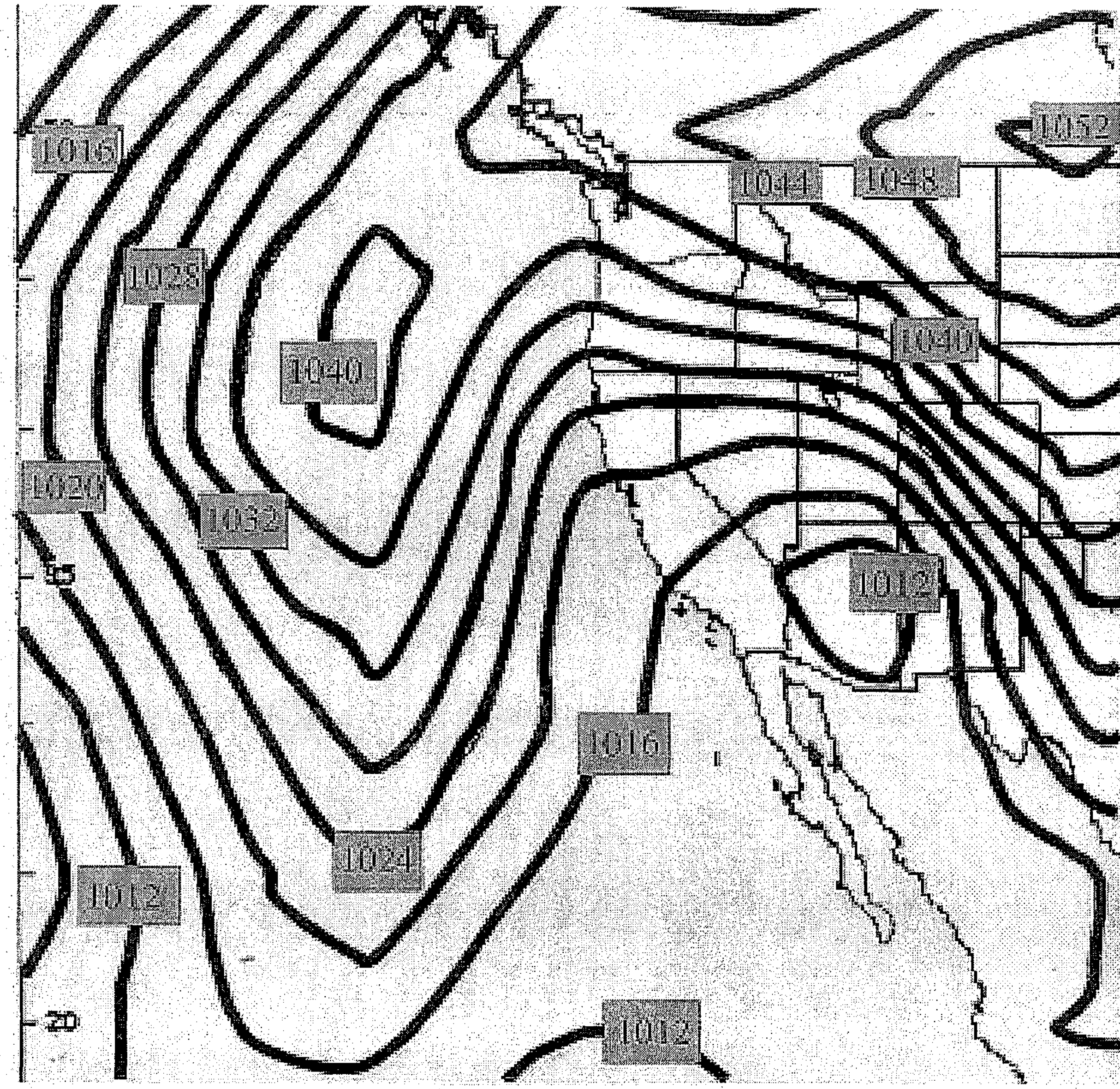



**Fig 4c.** Surface isobaric (solid, mb) analysis valid 1200 UTC 10 January 1949

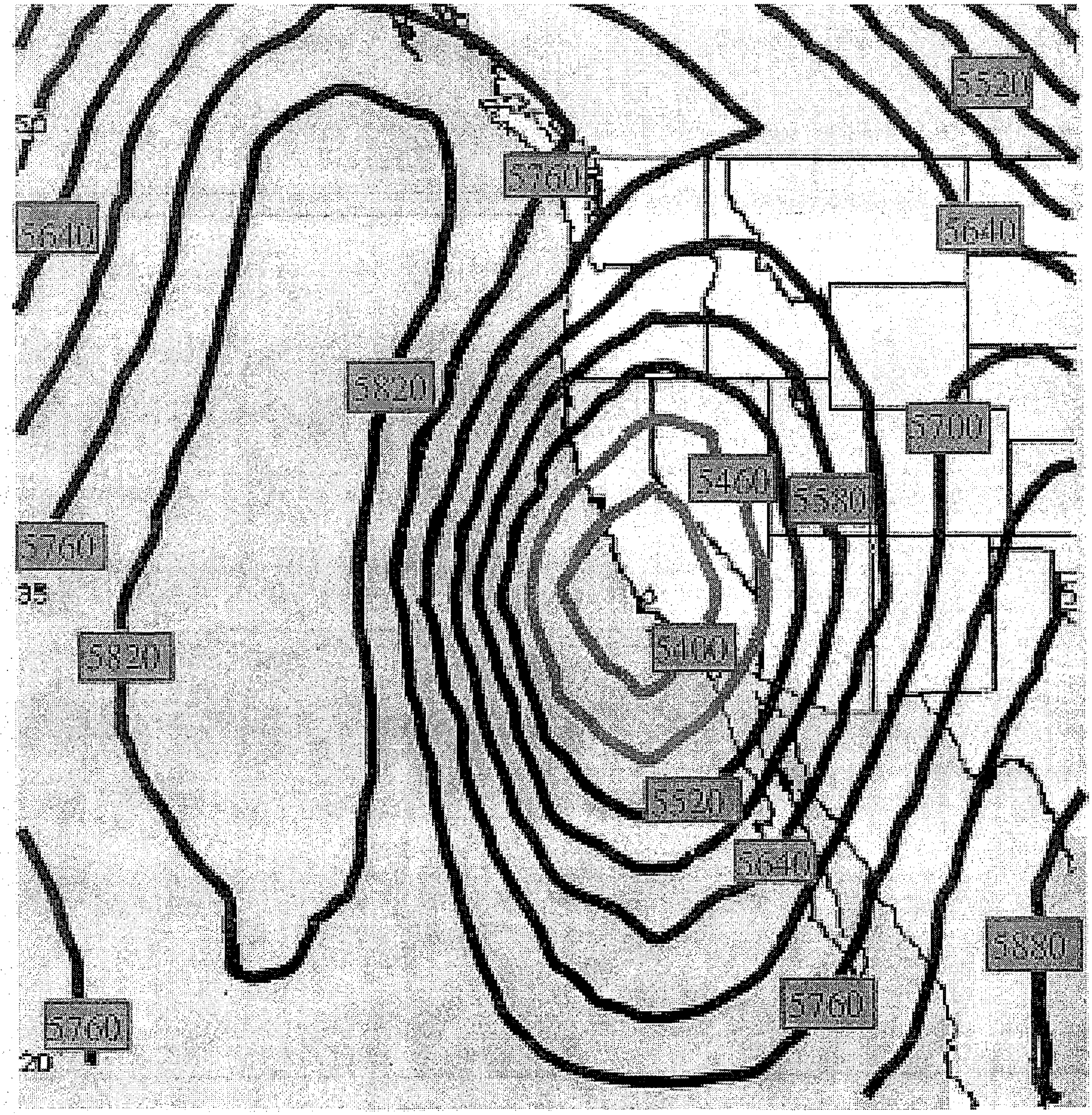



**Figure 5a.** 500 mb analysis valid 1200 UTC 12 January 1949.
(Solid lines = geopotential heights in meters)

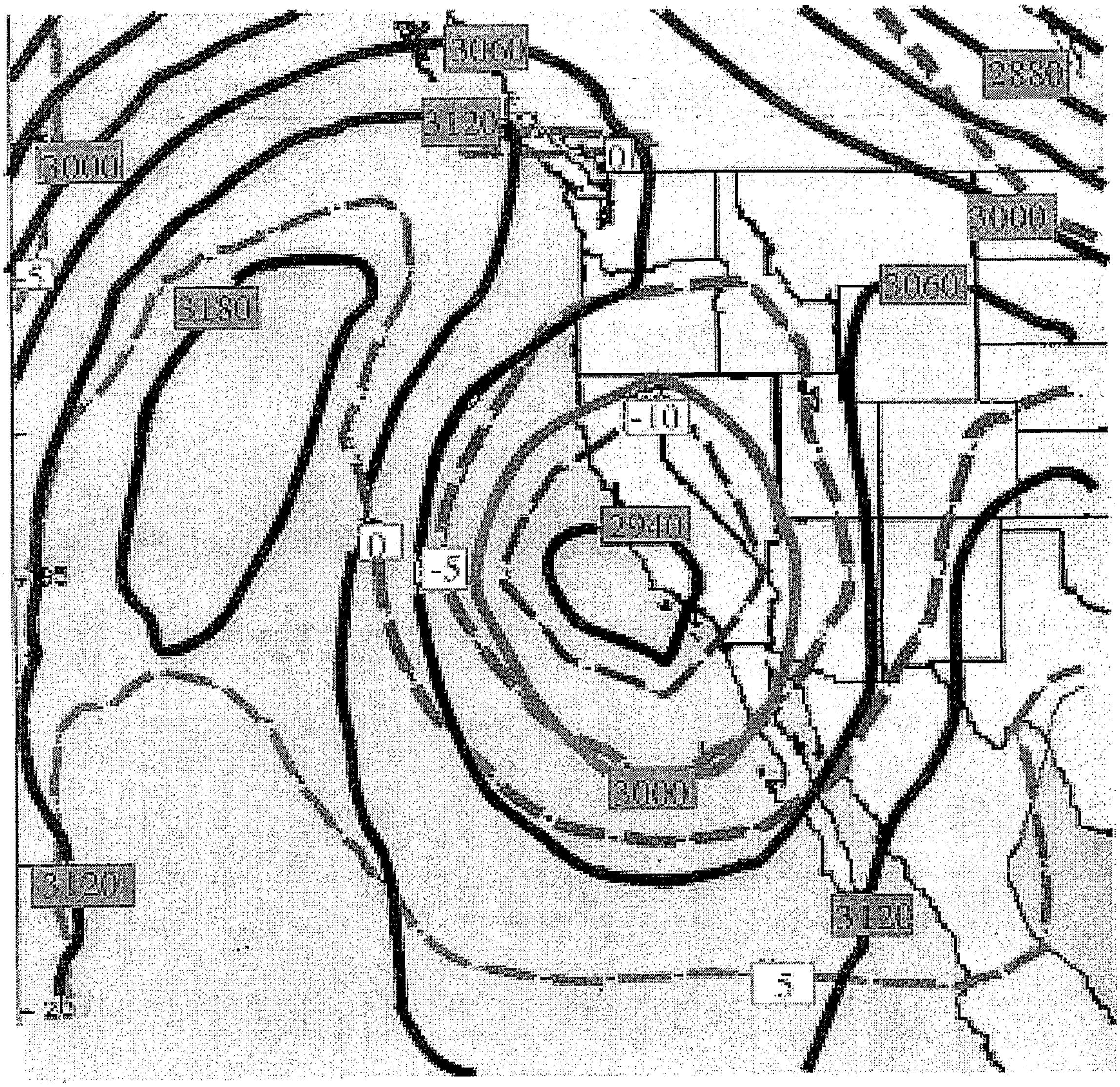



**Figure 5b. 700 mb analysis valid 1200 UTC 12 January 1949. (Solid lines = geopotential heights in meters, Dashed lines = isotherms °C)**

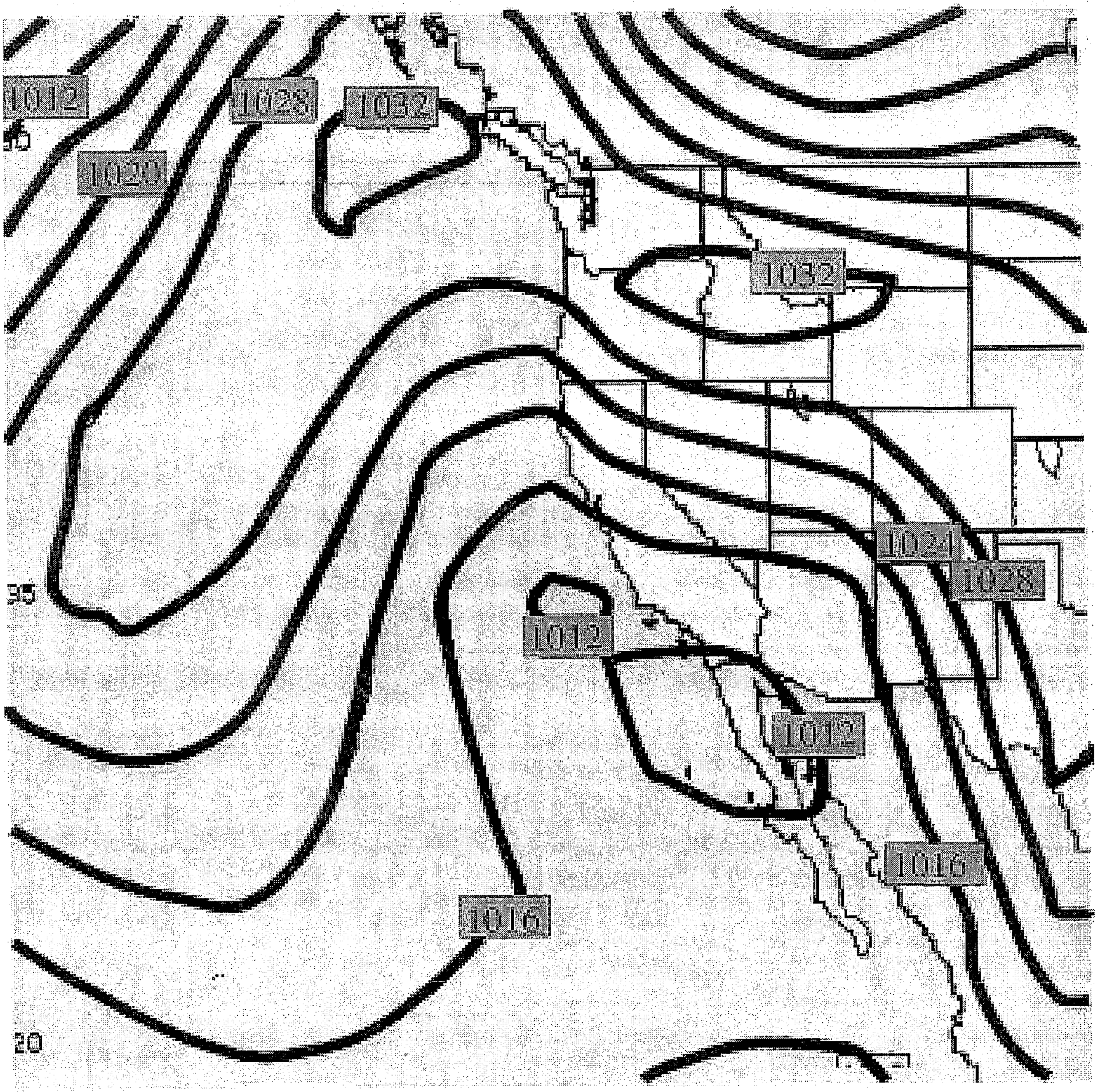



**Figure 5c.** Surface isobaric (solid, mb) analysis valid 1200 UTC 12 January 1949.

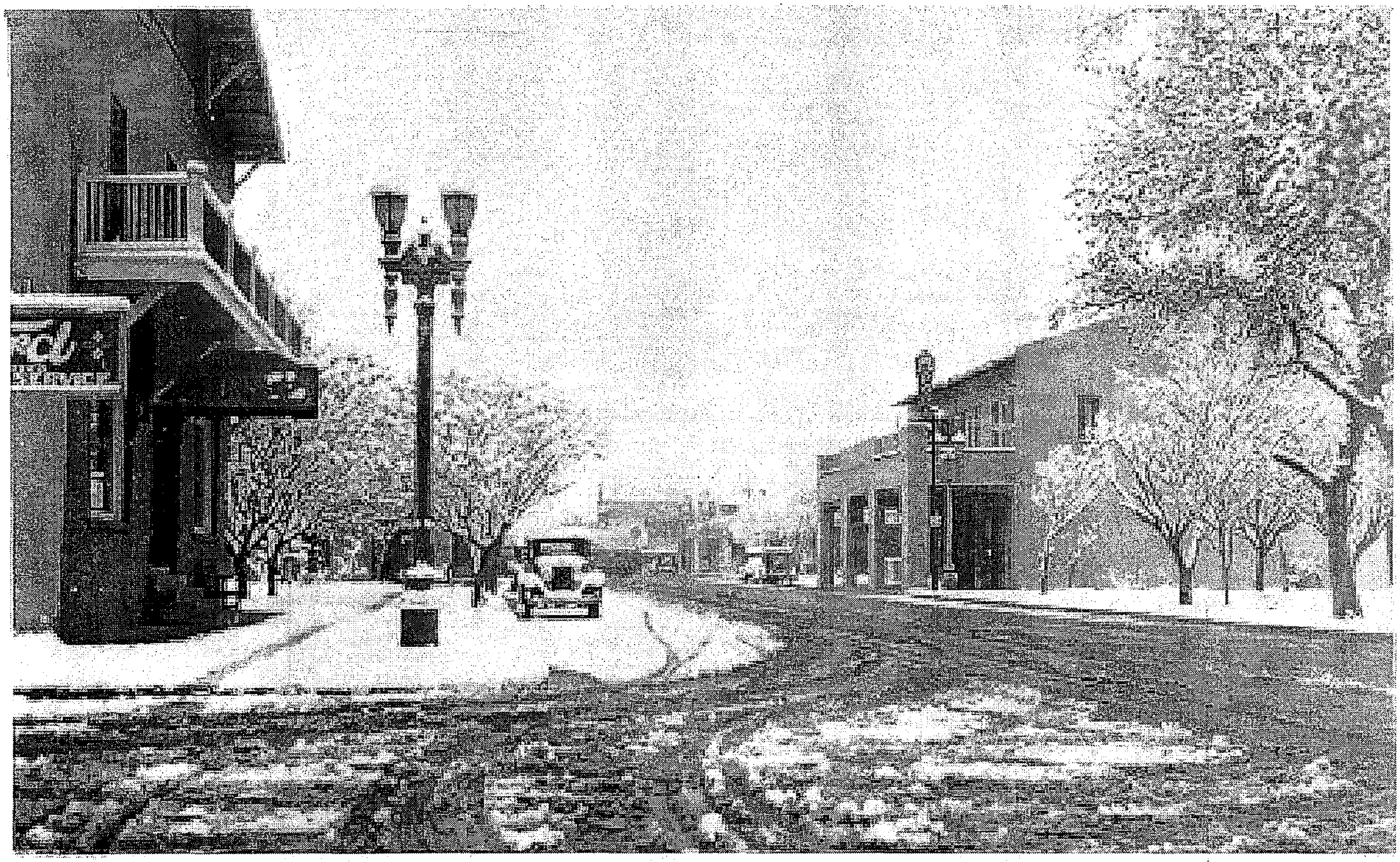
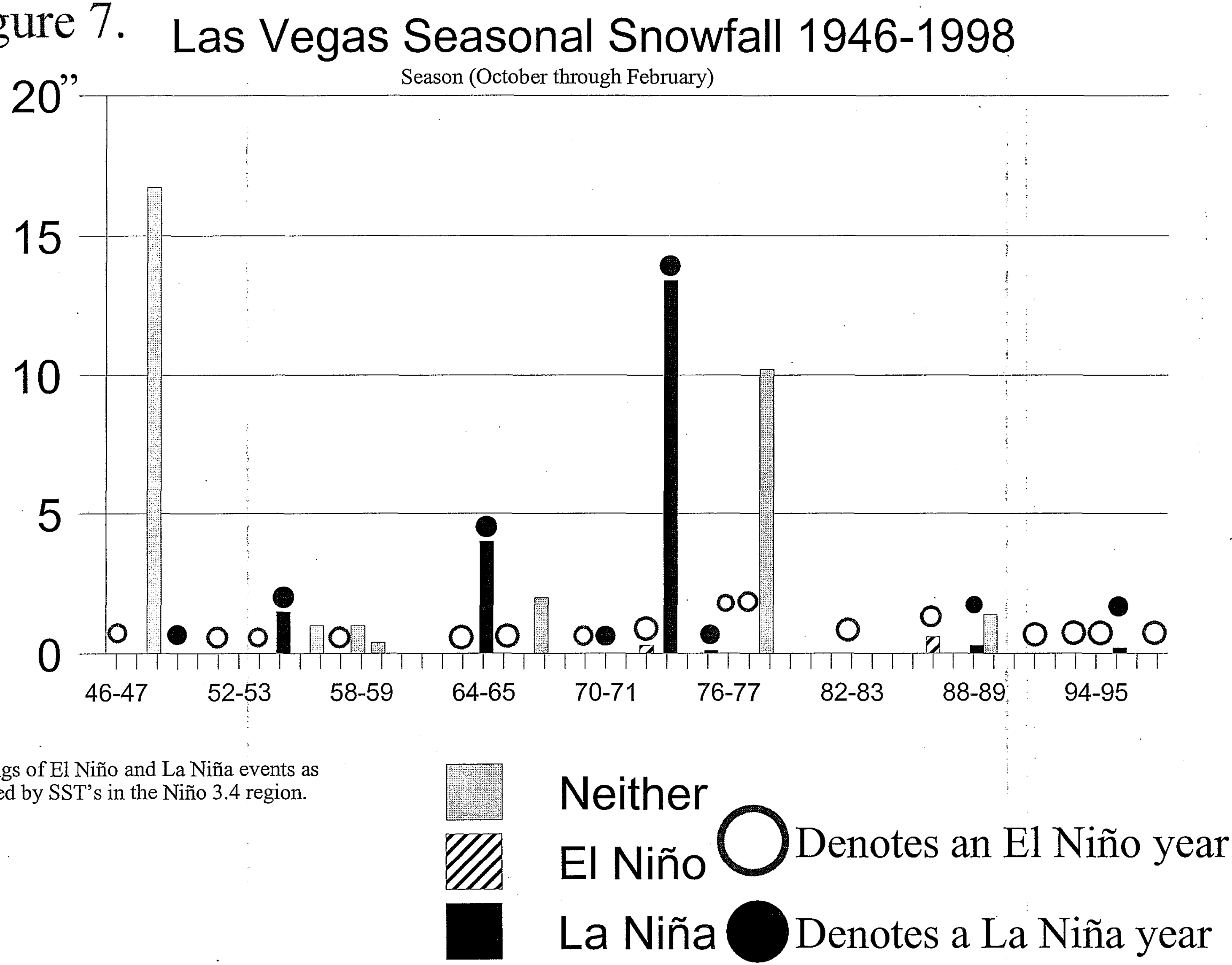


Figure 6

**Downtown Las Vegas - Fremont St. looking West - January 10, 1930**

Picture provided by the University of Nevada - Las Vegas (Lake Eglington Collection)

Figure 7.




Listings of El Niño and La Niña events as defined by SST’s in the Niño 3.4 region.

| Table 1. Significant Snowstorms over the Las Vegas Valley since 1949 | |
|---|---|
| Dec 15, 1967 | 2.0 inches |
| Jan 19-20, 1949 | 2.3 inches |
| Jan 28, 1979 | 2.4 inches |
| Nov 15, 1964 | 4.0 inches |
| Jan 25, 1949 | 4.7 inches |
| Jan 30-Feb 2,1979 | 7.8 inches |
| Jan 4-5, 1974 | 9.0 inches |
| Jan 10-12, 1949 | 9.7 inches |

Derived from Climate of Las Vegas.
Skrbac and Cordero, 1995

| Table 2 | | | |
|---|---|---|---|
| Parameter averages for the Great Snowstorms in Las Vegas, Nevada History | | | |
| 200 mb temperature | -47.9° C | Surface temperature | -0.1° C |
| 300 mb temperature | -45.2° C | 1000-500 mb thickness | 5300 m |
| 500 mb temperature | -27.3° C | 850-500 mb thickness | 4018 m |
| 700 mb temperature | -11.1° C | 300 mb heights | 8951 m |
| 850 mb temperature | -3.4 ° C | 500 mb heights | 5421 m |
| Precipitable Water | 0.31" | 700 mb heights | 2953 m |
| 700 mb mixing ratio | 2.0 g/kg | 850 mb mixing ratio | 2.8 g/kg |

Table 3.

| Snow Levels Associated with Specific Values of 850-500 mb Thickness and 700 mb Temperatures | | |
|---|---|---|
| Snow Levels | 700 mb Temperatures | 850-500 mb ΔZ |
| 0 | -17 °C | 400 dm |
| 1000 feet | -15 °C | 402 dm |
| 2000 feet | -13 °C | 404 dm |
| 3000 feet | -11 °C | 406 dm |
| 4000 feet | -9 °C | 408 dm |
| 5000 feet | -7 °C | 410 dm |
| 6000 feet | -5 °C | 412 dm |
| 7000 feet | -3 °C | 414 dm |
| 8000 feet | -1 °C | 416 dm |