An Analysis of the December 17-18, 2008 Snow Event In The Las Vegas Valley

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Introduction

On December 17-18, 2008 a rare winter weather event occurred in the Desert Southwest resulting in measureable snowfall across portions of the Las Vegas Valley. Officially, 3.6 inches of snow was recorded in Las Vegas at the National Weather Service (NWS) Forecast Office, making it the highest total ever during the month of December. Snow accumulations in the Las Vegas Valley have historically corresponded to elevation (with the higher totals in the higher elevations). This event was characterized primarily by cold air damming and evaporational cooling which, when combined with the synoptic scale storm track, resulted in a snow accumulation pattern rarely, if ever, observed in this area.

Synoptic Overview

A deep, upper-level trough had become established over the western United States during the weekend of December 13-14, 2008. Reanalysis data obtained online from Penn State University shows 700 mb temperatures across the area dropped to -10°C to -12°C across southern Nevada by 06Z on December 14th and remained there through 12Z on December 17th. An upper-level low moved southward along the West Coast of the United States, reaching the coast of southern California by 06Z on December 17th. The low moved southeastward through the base of the upper-level trough axis and by the morning of December 17th was located along the coast of southern California. By 12Z on December 17th, the low was accompanied by a 120+ knot jet stream that was located across the Mojave Desert (Figure 1). As the low approached southern California, the Mojave Desert was located under the left front quadrant of the jet, an area of typically favorable for lift. An area of diffluence, associated with this jet, was noted over southern California and western Arizona ahead of the upper low around 00Z on December 18th, which also helped to further enhance lift across the area.

As a southwesterly flow aloft pushed moist air over the Mojave Desert, surface analysis indicated a north to northeast pressure gradient was also present in this area due to high pressure centered over eastern Utah. The 12Z sounding from Desert Rock (KDRA) indicated low-level northeasterly flow was present up through 850 mb with primarily southwesterly flow above that level (Figure 2). Between 12Z on December 17th and 00Z on December 18th, a plume of subtropical moisture accompanied by precipitable water values of 0.30 to 0.50 of an inch was streaming northeastward toward the Mojave Desert. By 18Z on December 17th, the jet stream had strengthened to 140 knots over Arizona, which placed southern Nevada near the left rear quadrant of the jet. Typically, the left rear quadrant of the jet corresponds to an area of subsidence, but in this case the curvature effects of the jet resulted in additional vertical motion in this quadrant. The upper low by then had moved towards the coast of southern California, with a distinct area of maximum Positive Vorticity Advection (PVA) at 500 mb having moved inland across the Mojave Desert (Figure 3).

Snow and a mix of snow and rain began to fall in the Las Vegas Valley shortly before 20Z on December 17th. Radiosonde data from Desert Rock depicted warm advection took place between 12Z on December 17th and 00Z on December 18th with temperatures at 700 mb rising from -12°C to -8°C during that period. By around 02Z on December 18th, precipitation generally became more intermittent as the area of maximum PVA had moved away from the area. Rain or a mixture of rain and snow tapered off between 05Z and 08Z on December 18th as warmer air finally infiltrated the lower levels and the upper low moved northeast over the Mojave Desert.

Snowfall Accumulations In The Las Vegas Valley

Snow levels and amounts varied tremendously across the Las Vegas Valley with the greatest amounts located in the southeastern portion of the valley (Figures 4 and 5). Officially 3.6 inches of snow fell at the National Weather Service Office, which is located 2 miles southwest of McCarran International Airport. Generally 3 to 6 inches fell across the southern half of the valley. A maximum of 10 inches of snow was measured at the residence of a National Weather Service employee in southeast Henderson, near Railroad Pass, at an elevation of just under 2400 feet. The Henderson Executive Airport, located at an elevation of 2464 feet, in the southwestern part of Henderson received 8 inches. Snow amounts were highly variable along the famous Las Vegas Strip with the heaviest amounts on the southern end. At the “Welcome to

Fabulous Las Vegas" sign on the far south end 1.7 inches of snow was measured while central and northern parts of The Strip saw snow barely coat some grassy surfaces and a few rooftops and metal objects at best. This corresponded well to a sharp-cut off noted overall across the center of the valley, where snow amounts decreased markedly. Across the northern half of the valley, snow levels were about 500 feet higher thus resulting in little to no snow accumulating here.

Observations and Analysis

In the Las Vegas Valley, precipitation began just before 20Z on December 17th across the southern end of the valley, but did not commence until nearly one to two hours later across the northern half of the valley. Although surface temperatures were generally around 3.9°C at all four NWS automated weather stations in the Las Vegas Valley (KLAS, KHND, KVGT and KLSV) at the onset of precipitation, precipitation initially started out as all snow on the south end of the valley at McCarran International Airport (KLAS) and the Henderson Executive Airport (KHND). Further north, both the North Las Vegas Airport (KVGT) and Nellis Air Force Base (KLSV) initially reported all rain (location shown in Figure 6).

The wide variation in initial precipitation type across the Las Vegas Valley with nearly uniform surface temperatures suggests that several processes had to be occurring in the atmosphere to allow for different precipitation types. At the onset of precipitation, a -10°C to -13°C dew point depression was observed at the four reporting stations stated above. Once precipitation had occurred, evaporative cooling took place enabling the lower atmosphere to support precipitation falling in the form of snow.

As was noted in the Desert Rock 12Z sounding from December 17th, a low-level northeast flow was present. This is the closest sounding to Las Vegas; however in order to better gauge the vertical profile of the atmosphere over the Las Vegas Valley, it was decided to examine the VAD Wind Profile from the McCarran Terminal Doppler Radar (TDWR). From 18Z on December 17th through 00Z on December 18th, the TDWR showed a northeast wind up to around 10,000 feet above the surface with south to southwest flow above 10,000 feet. Figure 7 shows a representative image of this from 21:02Z to 22:01Z on December 17th. With a low-level northerly flow present across the Las Vegas Valley this allowed the low-level cold air that was in place in the valley to become pushed into the south end of the valley or "dammed" up against the Bird Spring and McCullough mountain ranges. A cross section cut across the Las Vegas Valley from north to south of potential temperature and wind shows this quite well. As can be seen in Figure 8, where potential temperature values were plotted from the NAM 12, a dome of colder air can be noted from the central portion of the Las Vegas Valley towards the south end, with the top of the dome ascending to near the peaks of the mountain ranges just to the south of the valley indicative of cold air damming.

Bell and Bosart (1988) noted that evaporational cooling can contribute up to 30% of cooling within the cold dome of air formed from a cold air damming situation and help to maintain the strength of a cold dome. Model soundings from the NAM12 show the vertical profile in the south end of the Las Vegas Valley was entirely below 0°C at 21Z on December 17th and remained there through 03Z on December 18th, thus indicating a thermal profile cold enough to support snow that was achieved primarily through cold air damming and likely aided to an extent by evaporational cooling. In areas further north in the valley, the lowest levels of the atmosphere were about 2°C to 3°C warmer and thus favored precipitation falling as rain or a rain/snow mix at times (Figure 9).

The main axis of precipitation occurred along and just north of where surface observations and mean sea level pressure analysis indicated a warm front was present from the surface low off the southern California Coast eastward along the California-Mexican border into central Arizona (Figure 10) and resulted in the highest liquid precipitation storm totals across the southern end of the Las Vegas Valley. The highest liquid precipitation total was 1.03 inches at the Henderson Executive Airport (Figure 11). Liquid precipitation storm totals by comparison in the northwest part of the Las Vegas Valley were around a half of an inch. Surface observations at McCarran showed several observations of moderate to heavy precipitation, all of which fell as snow. These observations occurred between 1 PM (21Z on December 17th) and 7 PM (03Z on December 18th), the same time that a favorable area of PVA and jet dynamics were over the Las Vegas Valley and lifting of air parcels was greatest to produce clouds and precipitation. A time height series plotted for Las Vegas (Figure 12) shows that the times when reports of moderate to heavy snow occurred coincided with the time of greatest upward vertical motion and moisture and was associated with snow crystal growth in the dendritic growth zone. A plot of 700 mb omega from the NAM indicates there was a very sharp gradient that ran across the middle of the Las Vegas Valley with the greatest upward vertical motion noted across the southeast corner of the valley (Figure 13). This correlates to the area that also saw the greatest amount of snow accumulate. The sharp delineation noted with the 700 mb omega was likely related to the track of the 700 mb and 850 mb lows being northwest of the surface low (Figure 14 shows the track of the 850 mb low). Studies east of the Rockies have shown a correlation to heavy snow falling about 100 miles northwest of the

850 mb low (Browne and Younkin 1970). Based on this, the heavier snow totals in the southeast part of the Las Vegas Valley were in an area that was part of heavy snow track that existed across the Mojave Desert (Figure 15). Snow totals were also likely enhanced on the south end of the valley from upslope flow in the low-levels.

Warmer ground temperatures, mainly in areas near Downtown Las Vegas and northern and central parts of The Strip which are more heavily urbanized, also likely kept snow from sticking in these areas. Whatever snow did accumulate in these areas was limited to grassy surfaces and colder metal objects. Across the northern part of the Las Vegas Valley liquid precipitation totals were lower due to precipitation falling for a shorter duration and weaker upward vertical motion which resulted in precipitation falling at a less intense rate than areas further south.

Forecasters often use traditional rules of thumb such as 700 mb temperatures to predict snow levels, especially in longer range forecasts. The observed 700 mb temperature on the 12Z December 17th Desert Rock sounding was -12°C and at 00Z on December 18th was -8°C. Rules of thumb for 700 mb temperatures have shown a reading of -12°C typically correlates to a snow level of 2500 feet and -8°C to 4500 feet. A study done by Cordero et al. (1998) showed the average 700 mb temperature for the greatest snow events in Las Vegas to be -11.1°C. Using the 700 mb temperature from the 00Z sounding on December 18th at Desert Rock, which is about 60 miles northwest of Las Vegas, would have yielded a misleading snow level for this event that was too high.

Czyzyk (2004) noted that in the snow event of December 30, 2003 in Las Vegas that the use of the 850-700 mb thickness layer and wet bulb zero heights could result in a more accurate snow level forecast. From the 12Z Desert Rock sounding on December 17, 2008, the 850-700 mb thickness computed was 1515 meters, which is 25 meters below the critical value for snow at this level when significant upward vertical motion is present (Cantin and Bachand 1990). The 12Z December 17th Desert Rock sounding also had a wet bulb zero height was 3303 feet or at the surface for this station. Since the Las Vegas Valley is located at an elevation roughly 500 to 1000 feet lower than Desert Rock, another resource was deemed necessary to compute a more reasonable wet bulb zero height over the Las Vegas Valley. Soundings from the 18Z run of the NAM 12 on December 17th indicated a wet bulb zero height of around 2500 feet over the southeast end of the valley to 3200 feet on the north side. Model soundings showed a near freezing thermal profile throughout just about the entire event especially on the south side of the valley which would support a forecast of snow. Thus using either the observed 850-700 mb thickness or the wet bulb zero height from a sounding based on a high resolution model that initialized well would have given a better estimate of snow levels during this event than using strictly 700 mb temperatures.

Storm Snow Statistics and Snow Climatology In Las Vegas

Cordero et al. (1998) noted that accumulating snow of an inch ore more typically occurs in Las Vegas every 4 to 5 years. This was the first official measurable snow event in Las Vegas since 1.3 inches fell on December 30, 2003.

Based on information gathered from *The Climate of Las Vegas* (Gorelow 2005, most recent update available online) the following records were set during this event:

- 3.6 inches of snow fell on December 17th, setting a daily snowfall record. The old daily record was a trace in 1992.
- The 3.6 inches of snow set an all-time record snowfall for a single storm for the month of December as well as a new December monthly snowfall total since the start of official records in 1937. The previous record for a single storm was 2.0 inches recorded on December 15, 1967 and the previous monthly record for December was 2.0" set in 1967.
- This was only the 5th time measurable snow has fallen at Las Vegas during December.
- This was the most snow to fall at Las Vegas from a single storm since 7.8 inches of snow fell from January 30th through February 2nd, 1979.
- This was the 8th greatest snowstorm ever in Las Vegas.
- December 2008 was the 6th snowiest month ever in Las Vegas.

It should be noted that while this storm officially stands as the greatest snowfall ever in the month of December in Las Vegas, a review of newspaper accounts and weather records kept by volunteers from the early days of Las Vegas show that a snow storm dropped 13.0 inches of snow in Las Vegas from December 20-21, 1909. This is the largest unofficial snow event ever documented in Las Vegas.

The deep upper-level positively tilted trough that was present across the western United States at the time of the December 17th through 18th, 2008 fits the pattern identified in a study conducted by Cordero et al. (1998) on synoptic patterns associated with snow accumulation in Las Vegas as the most favorable for significant snowfall accumulation in Las Vegas. Three other significant snow events have had such a set up – the event of December 15-16, 1967; the event of January 4-5, 1974 and the event of January 30 - February 1, 1979.

Impacts

The winter storm of December 17th-18th, 2008 had widespread impacts on travel across the region. A ground stop was put into place at McCarran International Airport for outgoing flights and inbound flights were cancelled resulting in a few hundred people being stranded at the airport. Henderson Executive Airport was closed from the afternoon of December 17th through midday on December 18th. Highways over mountain passes that connect Las Vegas to other areas were closed from the later hours of December 17th into the 18th. A number of minor vehicle crashes occurred in the Las Vegas metro area, with Henderson police putting the number in that city at 16. Evening rush hour traffic was significantly impacted as snow was falling across much of the valley with some commuters taking as much as two hours to go 15 miles. Secondary roads, especially in Henderson, became coated by snow and thus treacherous to travel. In some instances in the Anthem section of Henderson, people parked their cars at lower elevations and walked several miles uphill to get home. Clark County closed all schools for December 18th, making it the first snow day for the district since 1979. Several areas in Las Vegas experienced power outages due to the snow. Trees or large branches also fell down due to the weight of the snow. According to Nevada Power, there were 5,000 customers who lost power for up to 5 hours in the Las Vegas Valley. One carport collapsed from the weight of the snow in the Las Vegas Valley and damaged several vehicles parked underneath. Local stores that did sell snow shovels reported an increase in sales on such, especially in the Henderson area. Total damages in the Las Vegas Valley from this event were estimated at $500,000.

The Response of NWS Las Vegas to a High Impact Event

This was an unusual event that was reasonably forecasted from several days out. As early as December 11th, the potential for snow was mentioned in the afternoon Area Forecast Discussion, which was six days before this event occurred. A Special Weather Statement issued on the afternoon of Friday, December 12th, mentioned that additional chances for snow existed towards the middle to later part of the upcoming week. A Winter Storm Watch was posted initially at 11:16 AM PST on December 16th for the Las Vegas Valley, and was upgraded to an Advisory at 3:25 PM PST on December 16th. The Winter Weather Advisory was upgraded to a Winter Storm Warning at 1:31 PM PST on December 17th. A Special Weather Statement issued at 2:05 PM PST on December 17th highlighted the event as “extremely rare” and specifically stated that this would have the potential to be the greatest snowfall in Las Vegas in 30 years. Plans for additional staff to work the event at the office were made several days ahead of the event. Numerous conference calls and briefings were given to emergency management officials, the Clark County School District and Air Traffic Control at McCarran International Airport before and during the storm. Specialized graphics and event summaries were created during the later part of the event reporting how much snow had fallen. Previous studies conducted by the staff at NWS Las Vegas on winter weather events were extremely valuable in the forecast process.

Conclusion

A rare winter weather event occurred in the Las Vegas Valley on December 17-18, 2008 resulting in snow falling and accumulating across much of the valley. A combination of factors resulted in precipitation falling as all snow or a snow/rain mix. This was primarily due to cold air damming and evaporational cooling. These factors combined with an area of maximum liquid precipitation due to the track of the 700 mb and 850 mb lows, enhanced upward vertical motion via jet dynamics being pronounced in the southern part of the valley along with local terrain effects, and the extent of urbanization in the valley resulted in an unusual snow accumulation pattern that has rarely been documented in snow events in the Las Vegas Valley. Forecasters should be aware that snow accumulation events can occur in the Las Vegas Valley that do not fit the climatological pattern of increased snow accumulations with elevation.

Acknowledgements

I would like to thank all the staff members who provided resources for this report. A special thanks is extended to Stan Czyzyk, for his comments and advice on this report and for his encouragement in pursuing it. Additional special thanks are extended to Mike Staudenmaier for also reviewing this paper, Clay Morgan and John Adair for their insights with this storm and assistance with creating some of the images used in this paper and to John Salmen for the use of his AWIPS procedures which allowed for some of the images used

here to be generated. Lastly, additional thanks is extended to the observers and spotters who submitted many of the reports that helped compile this report, especially National Weather Service Las Vegas employees Don Maker and Joe Nemeth who provided many detailed weather observations and reports during and after this event.

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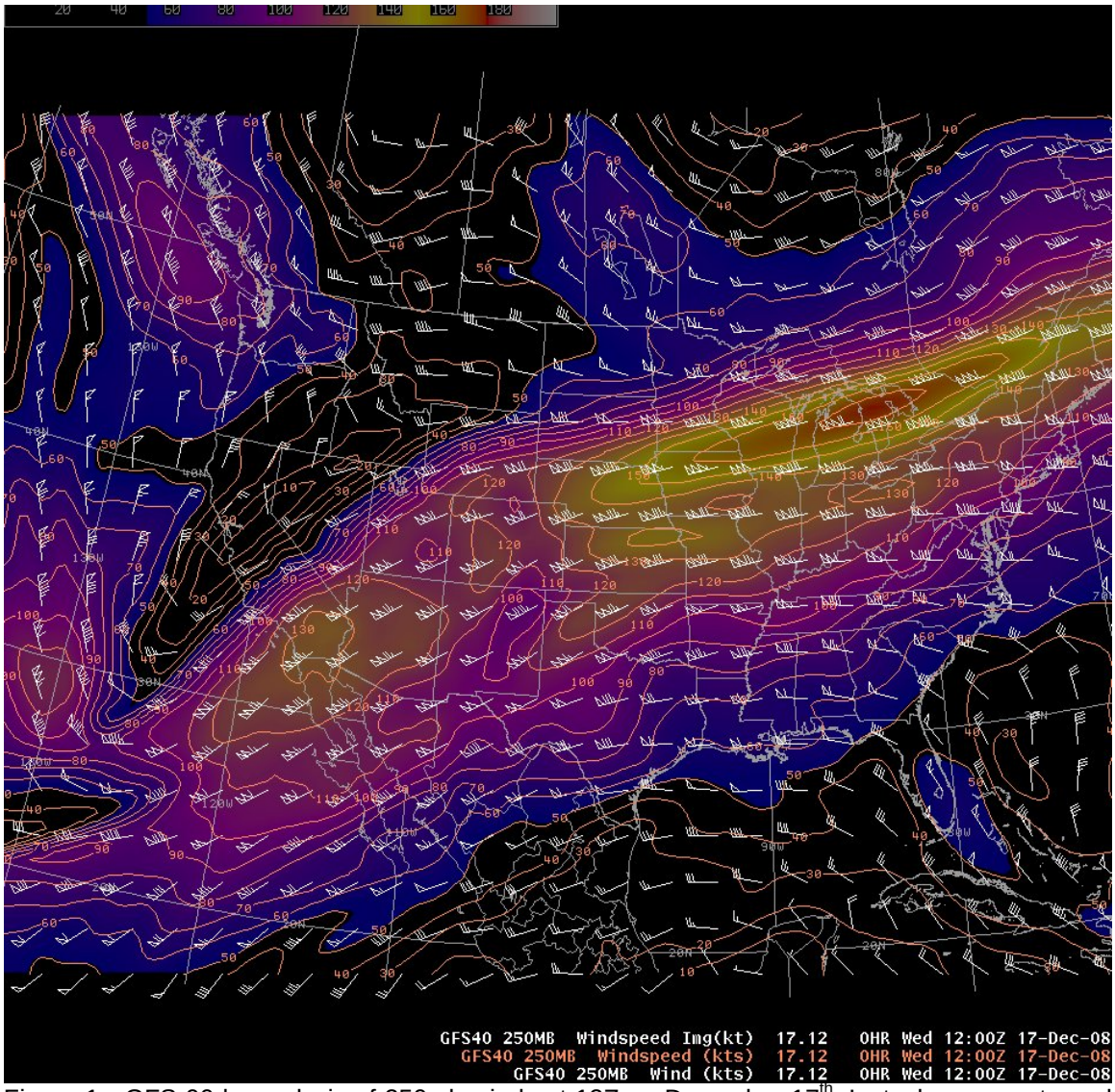

Figure 1 - GFS 00-hr analysis of 250mb winds at 12Z on December 17th. Isotachs are contoured every 10 knots. Note the core of strong winds of 120 knots or greater, indicative of a jetstreak, located across southern parts of California and Nevada extending into Arizona.

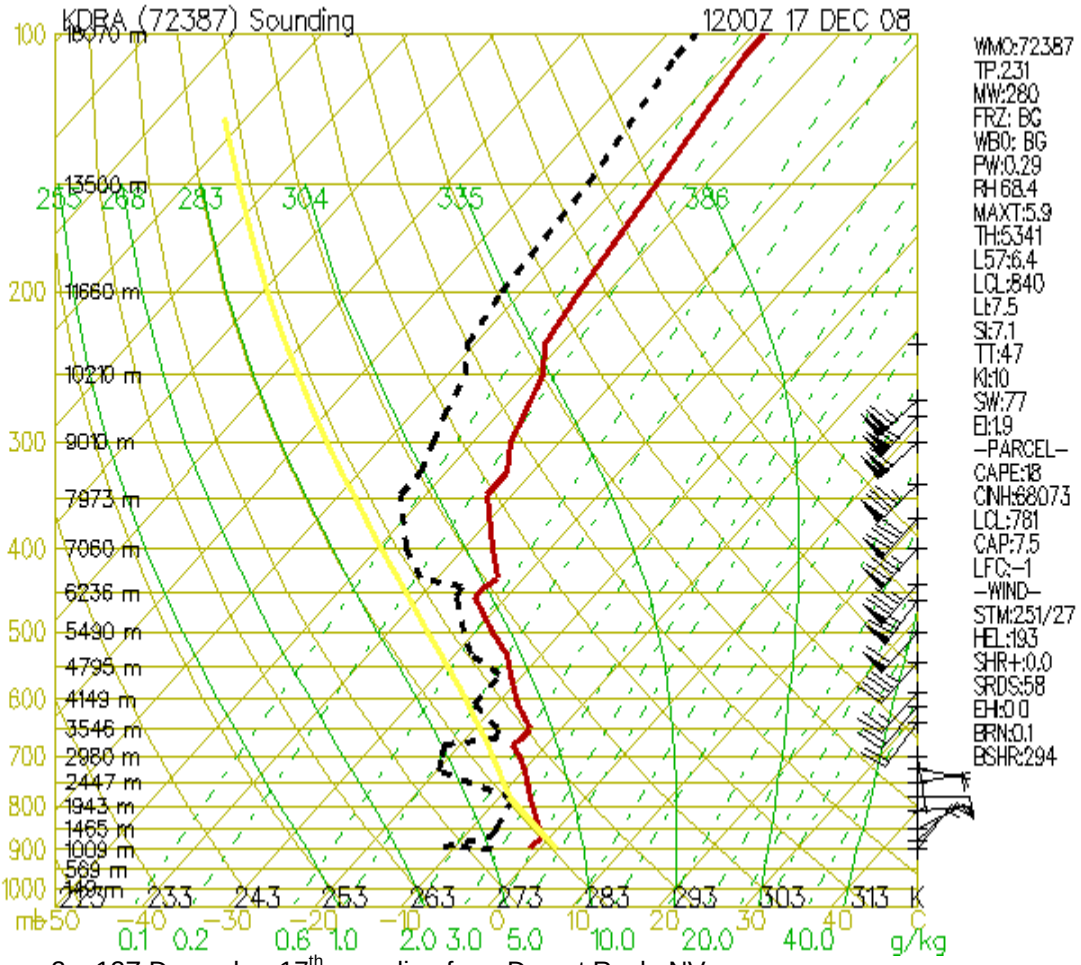

Figure 2 – 12Z December 17th sounding from Desert Rock, NV
(Image courtesy Plymouth State University).

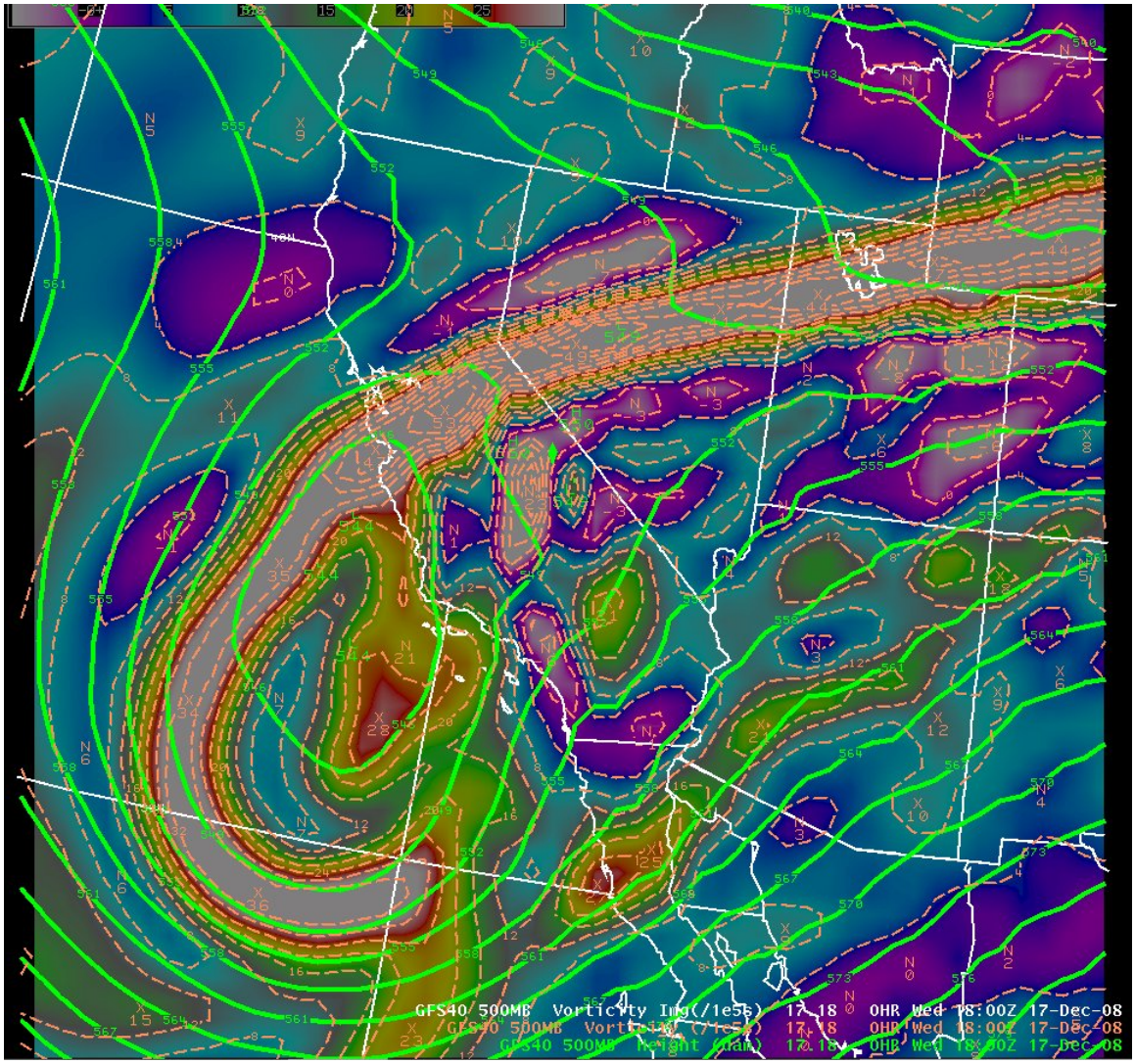

Figure 3 - GFS initialized heights in decameters (lime green lines) and vorticity (shaded colors outlined with orange dashed lines) at 500 mb on December 17th at 18Z. Note the area of positive vorticity (bright colors) over interior southeast California in San Bernardino County.

Snowfall Totals in the Las Vegas Valley

Henderson (Southeast)	10.0”	The Strip (Fabulous LV Sign)	1.7”
Henderson Executive Airport	8.0”	Summerlin	1.3”
Henderson (near Black Mt.)	7.0”	The Strip (at Tropicana)	1.0”
Mountains Edge (south)	5.0”	Centennial Hills	0.5”
Las Vegas (south)	4.5”	Aliante (west side)	0.4”
Las Vegas NWS Office	3.6”	Near Lone Mountain Rd, NLV	0.2”
Henderson (Green Valley)	3.5”	Near North Las Vegas Airport	0.1”
Las Vegas (Boulder Highway)	2.5”	Downtown Las Vegas	Trace
Las Vegas (southwest)	2.0”	Cheyenne Avenue (far west)	Trace

Figure 4 – Table of snowfall accumulations in the Las Vegas Valley.

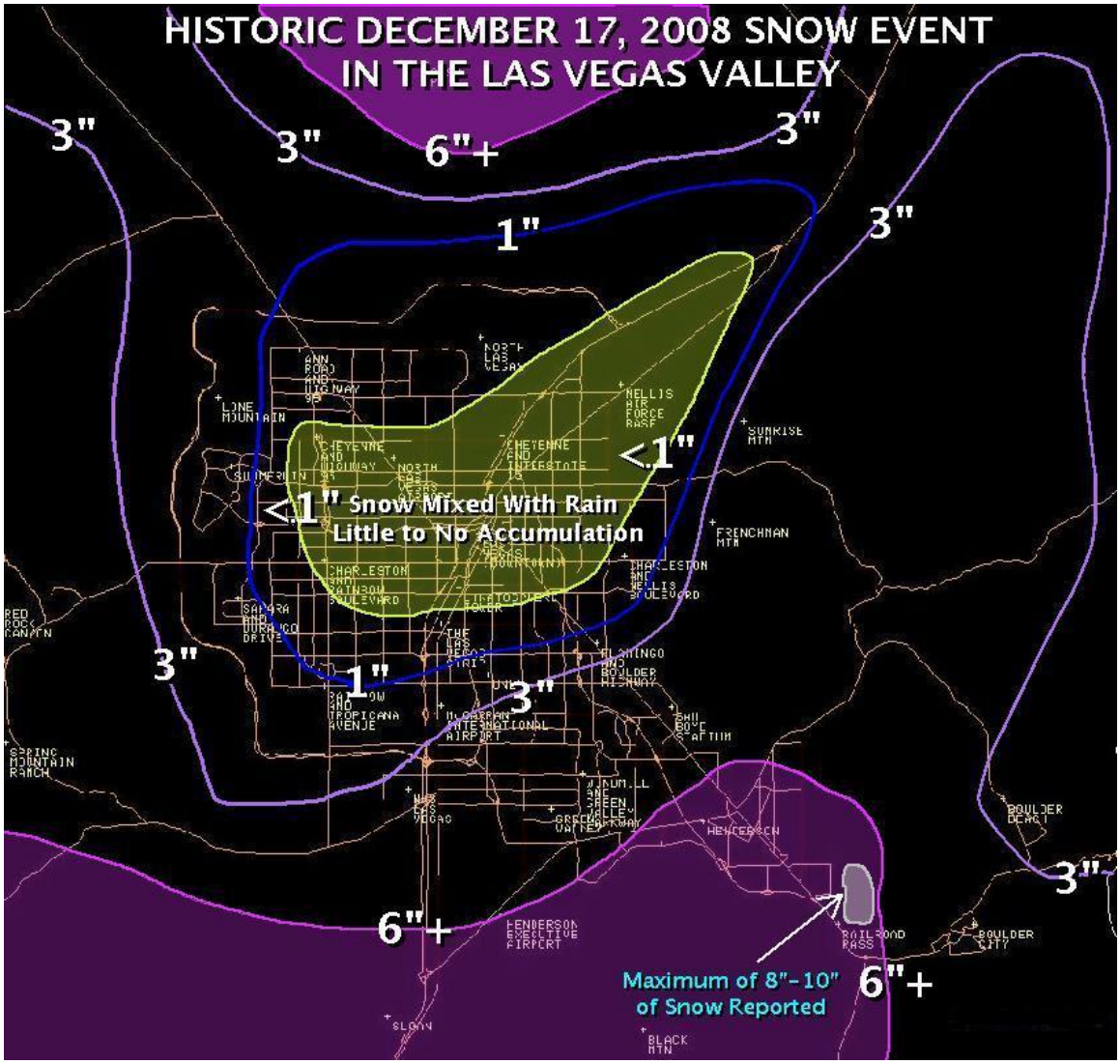

Figure 5 – Map of snowfall accumulations in the Las Vegas Valley.

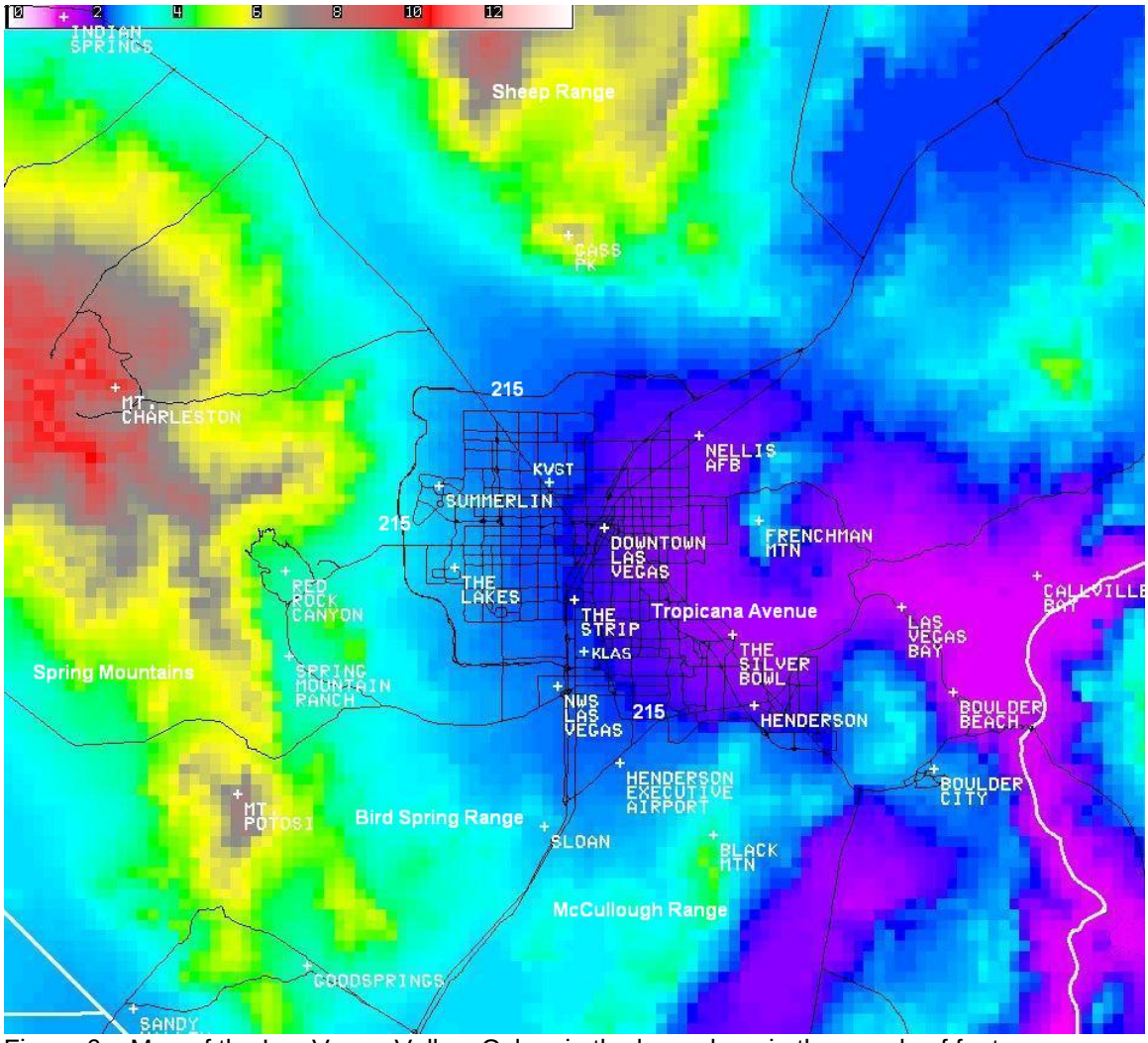

Figure 6 – Map of the Las Vegas Valley. Colors in the legend are in thousands of feet.

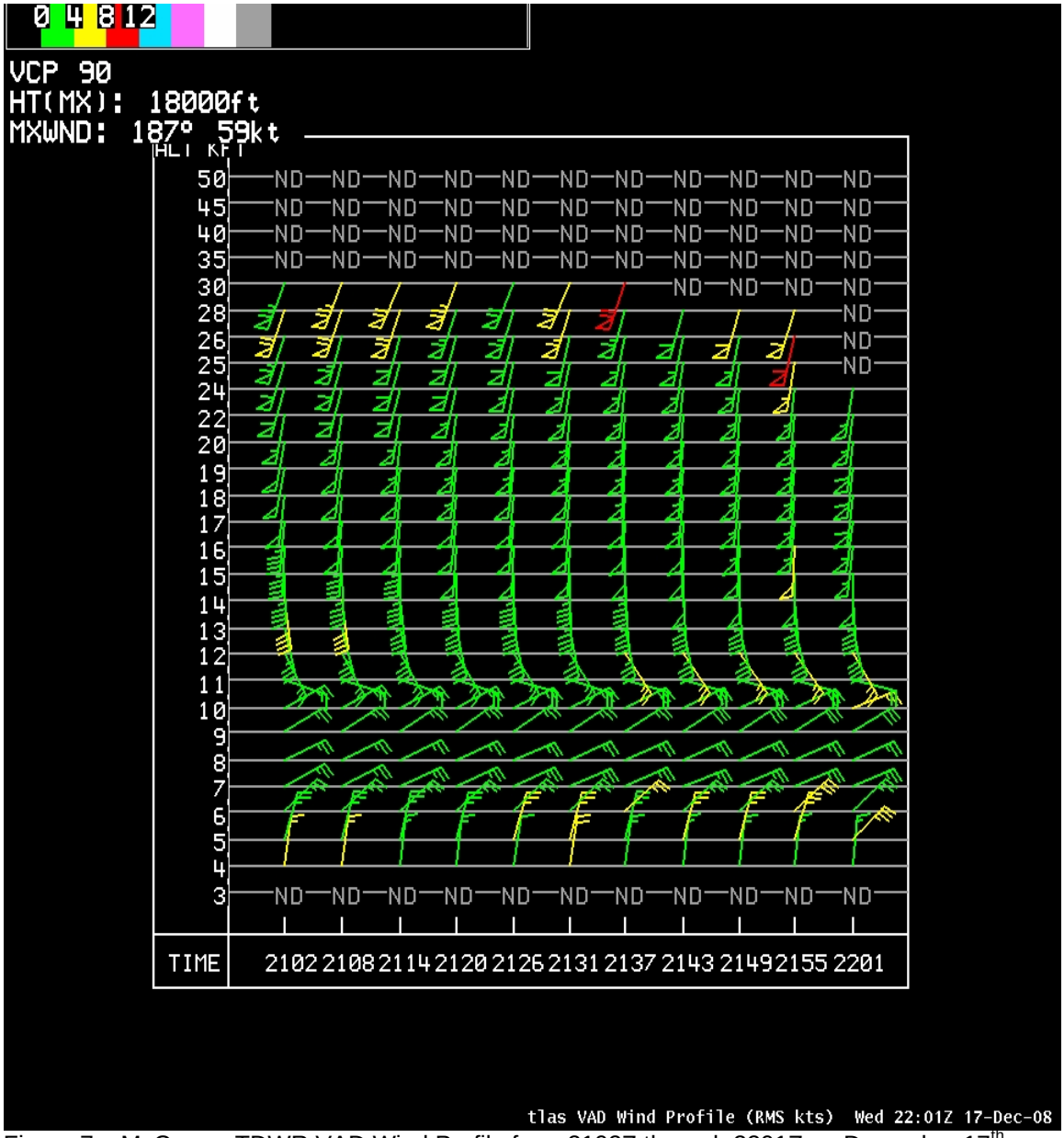

Figure 7 – McCarran TDWR VAD Wind Profile from 2102Z through 2201Z on December 17th. Note the low-level northeast flow that was in place across the Las Vegas Valley.

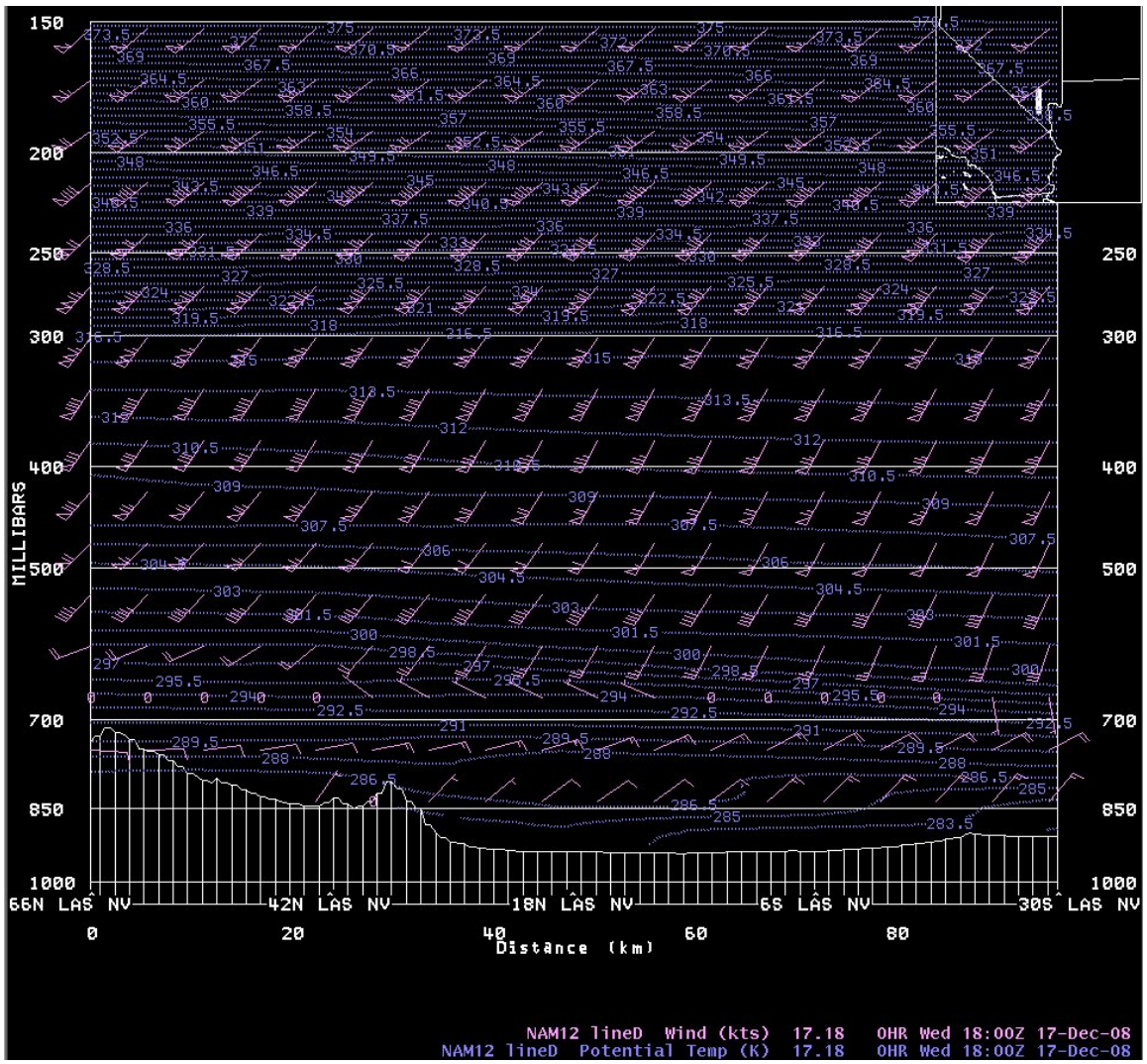

Figure 8 – North-south cross section across the Las Vegas Valley of potential temperature (purple lines) and wind (pink barbs) plotted from the NAM 12 at 18Z on December 17th. The north end of the valley is on the left and the south end is on the right. A dome of colder air can be noted from the central portion of the Las Vegas Valley towards the south end, with the top of the dome ascending to near the peaks of the mountain ranges just to the south of the valley indicative of cold air damming.

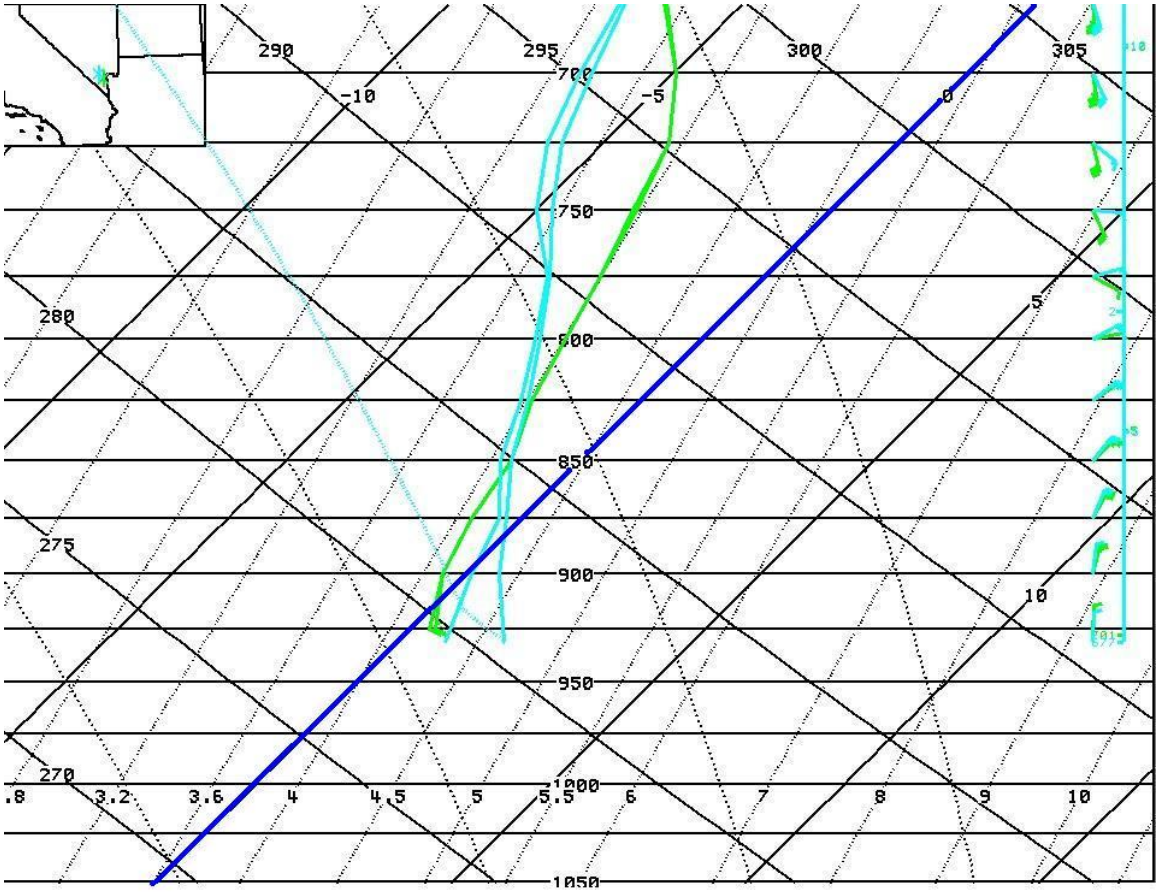

Figure 9 – NAM 12 soundings at 03Z on December 18th for two locations in the Las Vegas Valley. Point A (lime green colored sounding) is located on the far southeast end, very near where the maximum area of snow was measured in Henderson, while Point B (aqua blue colored sounding) is located on the northwest side of the valley near KVGT. Note the colder (and more saturated) sounding in Henderson where the heavier snow fell versus the warmer (and not as moist) profile near KVGT where rain was often reported and snow amounts were lower. The 0°C isotherm is highlighted in blue and shows Point B was around 2°C warmer than Point A from 900 mb to very near the surface.

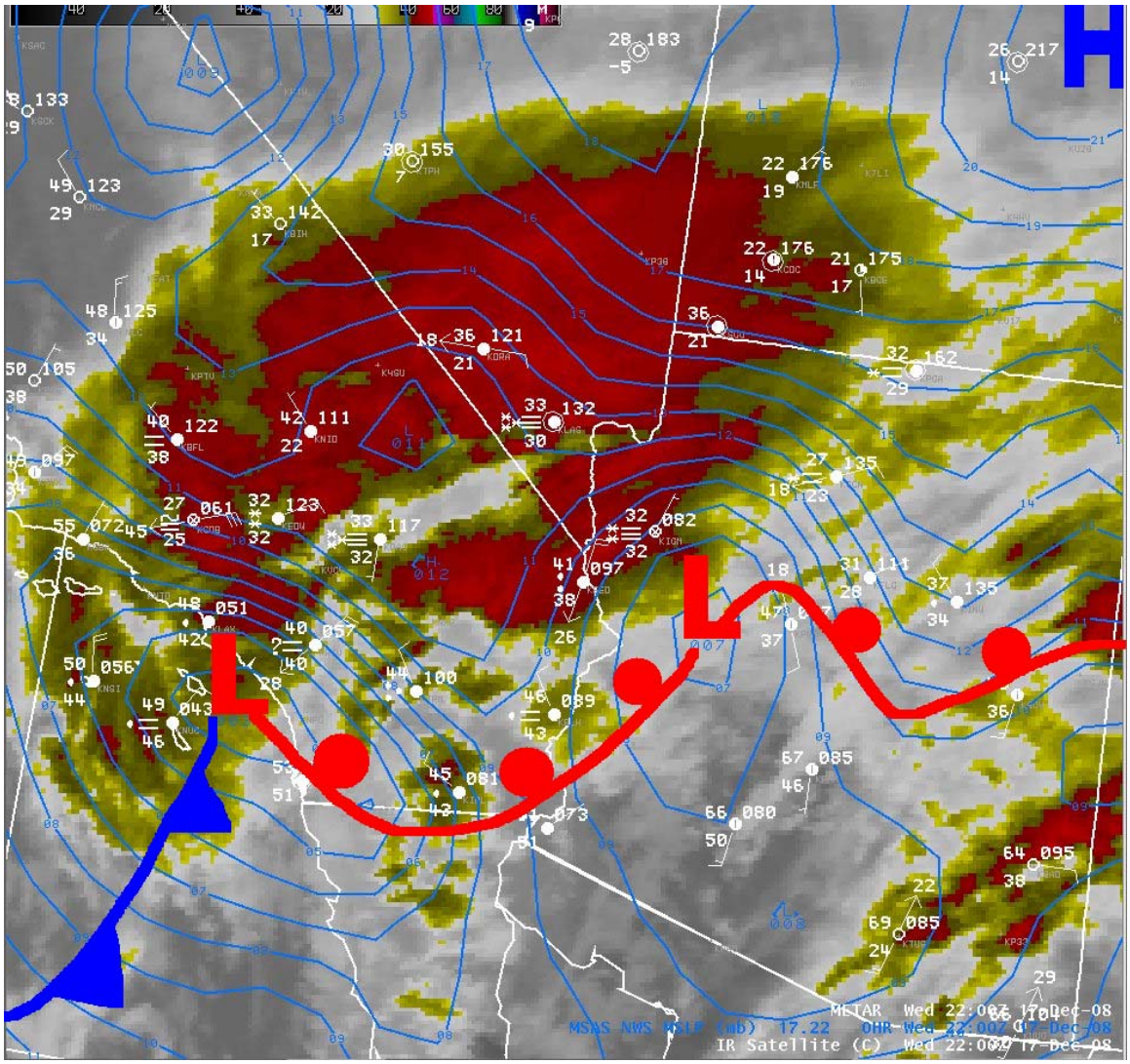

Figure 10 – Infrared satellite image with MSLP analysis (blue lines denote mean sea level pressure every 10 millibars) and plotted METAR observations at 22Z on December 17th with surface front analysis.

Liquid Precipitation Totals in the Las Vegas Valley

Henderson Executive Airport	1.03”
Henderson (southeast)	0.98”
NWS Office	0.76”
McCarran International Airport	0.73”
North Las Vegas Airport	0.61”
Cheyenne & N. Grand Canyon	0.46”
Aliante (west side)	0.40”
Nellis Air Force Base	0.30”

Figure 11 – Table of liquid precipitation totals in the Las Vegas Valley.

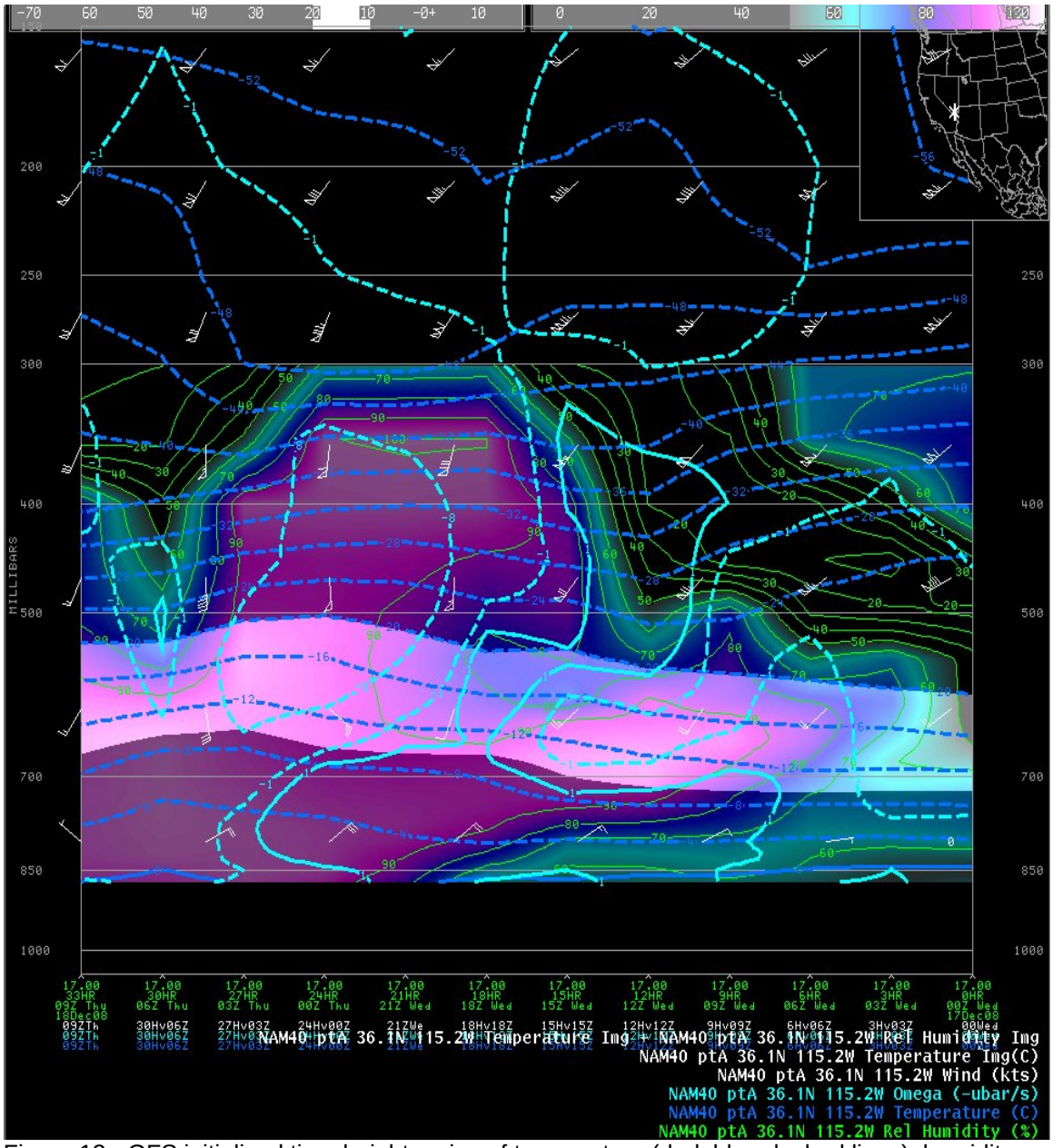

Figure 12 - GFS initialized time height series of temperature (dark blue dashed lines), humidity (green solid lines) and omega (light blue solid and dashed lines) for Las Vegas for the December 17-18, 2008 storm. The dendritic growth zone is highlighted in the bright shaded band. Relative humidity values greater than 50 percent are shaded in greens, blues and purples. Note the maximum amount of moisture available during this storm coincided with the maximum amount of upward vertical motion available allowing for ice crystal growth in the dendritic growth zone between 21Z on December 17th and 03Z on December 18th.

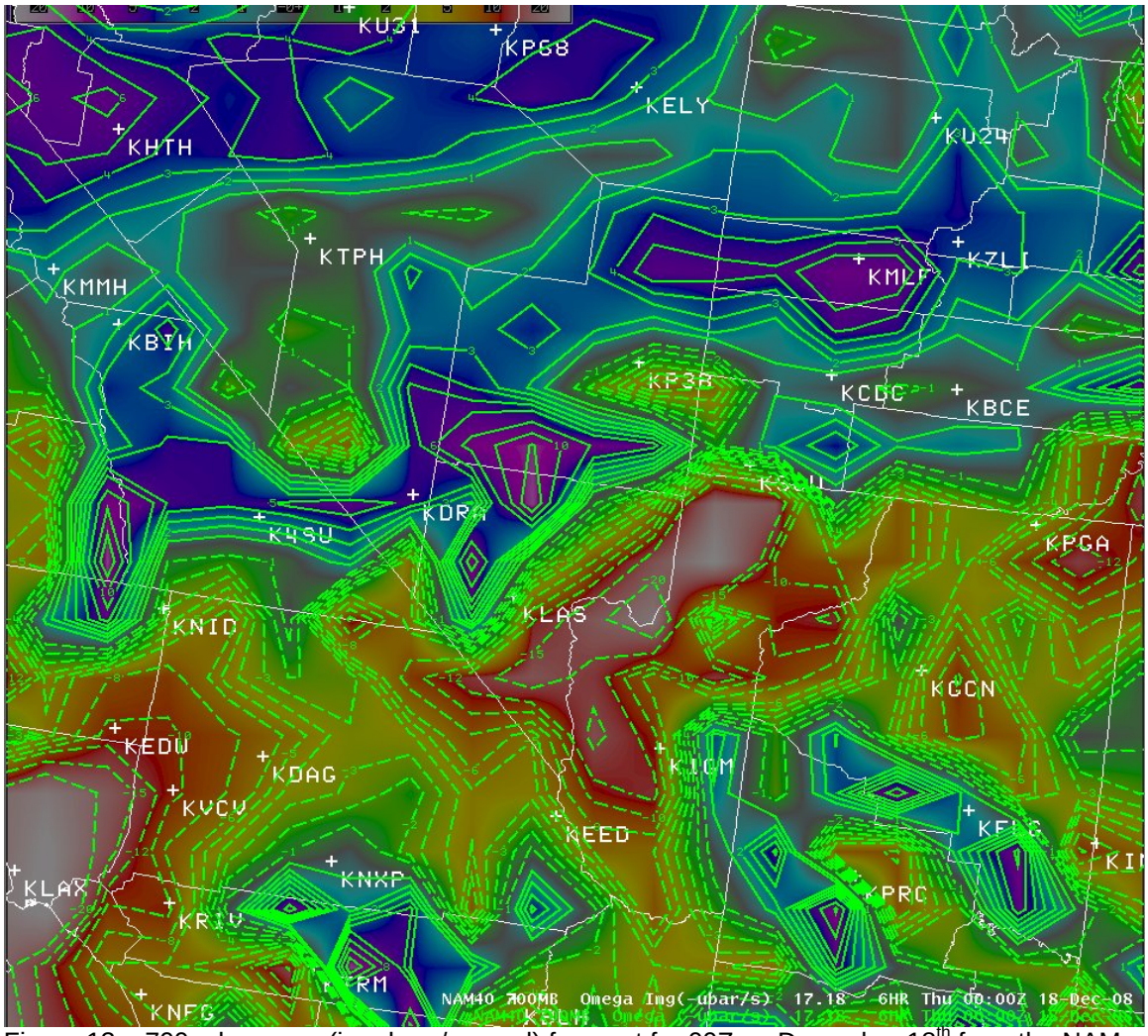

Figure 13 – 700 mb omega (in -ubars/second) forecast for 00Z on December 18th from the NAM 40. Upward vertical motion is noted in warm colors such as red and orange. Downward vertical motion is noted in darker colors such as blue and purple. Note the sharp gradient across the Las Vegas Valley with the greatest upward vertical motion across the southeast side of the Las Vegas Valley, the same area that also saw the greatest snowfall accumulation in metro Las Vegas.

Figure 14 – Positions and track of the 850 mb low based on upper air plots. An axis of heavy snow fell about 50 to 100 miles to the north of the track of the 850 mb low.

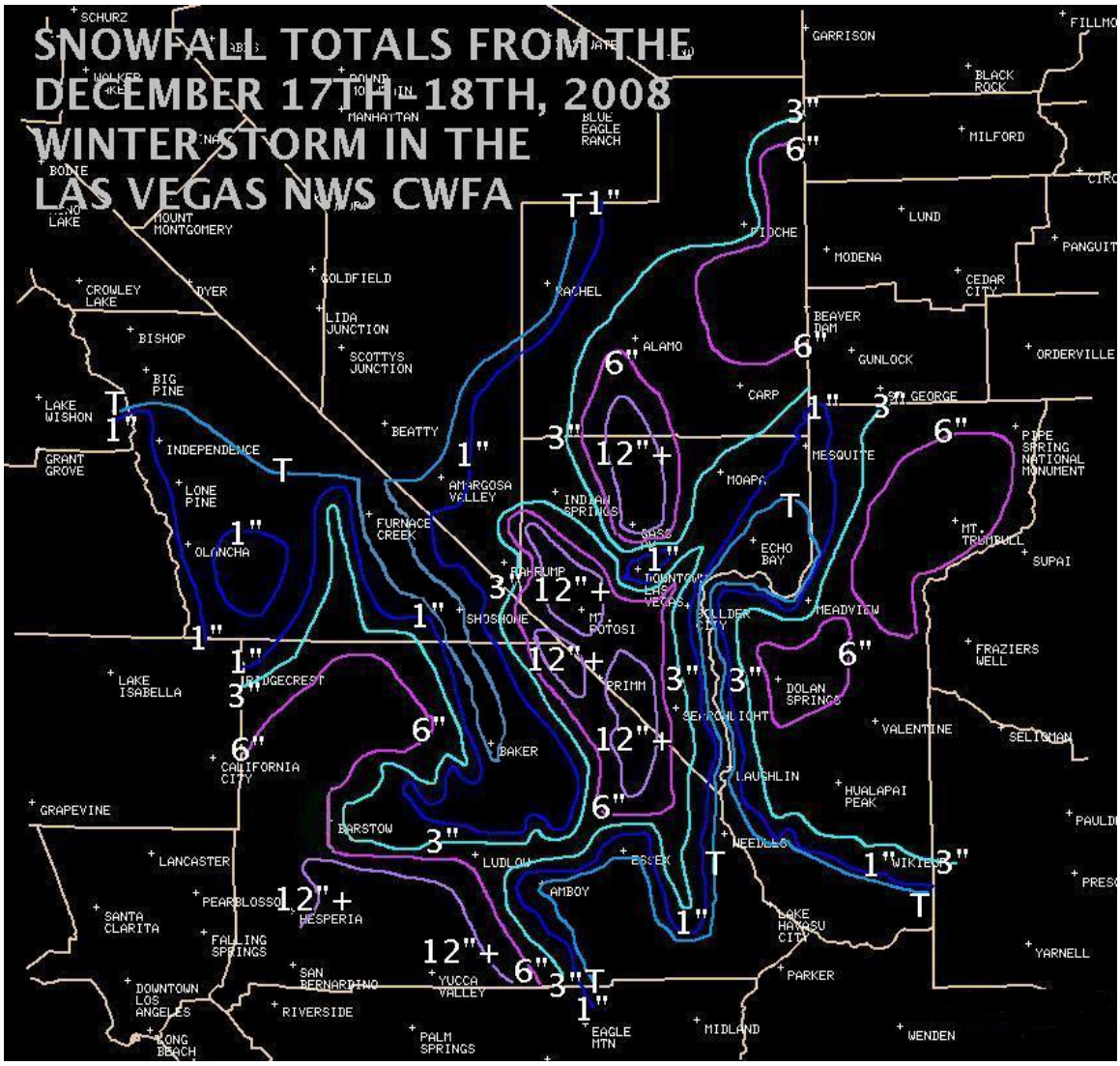

Figure 15 – Plot of snowfall totals across the Las Vegas National Weather Service County Forecast and Warning Area. Note the axis of heavier snow extending from near Yucca Valley, California northeastward towards the Mount Trumbull area of Arizona. Although increases are noted within this area due to elevation, an overall trend of heavier snow reports exists along an axis in this area, suggesting an area of heavy snow. The southeastern part of the Las Vegas Valley was within this area and saw much higher snow amounts than other parts of the Las Vegas Valley.