A Climatology of High Wind Warning Events for Northern and Central New Mexico: 1976-2005

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Introduction

High wind events frequently plague northern and central New Mexico due to synoptic, seasonal, and diurnal processes. These high wind events pose significant challenges to forecasters, and they can often have significant effects to life and property within New Mexico. High wind warnings are issued for northern and central New Mexico by the Albuquerque forecast office for non-convective wind events reaching standardized thresholds for speed. These thresholds are defined as winds having sustained speeds of 40 mph or greater and/or instantaneous gusts of 58 mph or higher. Thus, a thorough assessment of climatological wind data across northern and central New Mexico would benefit forecasters by providing supplemental knowledge of the synoptic regimes and frequency of high wind events.

Therefore, the first objective of this wind study will be to determine a climatology of high wind events for Albuquerque and seven additional sites across northern and central New Mexico. As this first objective is completed, any preconceived forecaster assumptions may be confirmed or refuted, ultimately aiding the overall forecast and warning decision-making processes. A few generalized hypotheses will be discussed in anticipation of results of the study, along with the methodology of both acquiring the data set as well as the statistical analyses performed to generate this climatology. Documented high wind events will then be partitioned into subsets, and will be interrogated before a classification of synoptic settings is applied in order to equip forecasters with conceptual models for recognizing such events.

Data and Methodology

Surface observations from the National Climatic Data Center were first obtained for a 30-year climatological record for the Albuquerque International Sunport, with data sets for additional sites added after preliminary analyses of the Albuquerque data. This complete data set spanned a timeframe from 1976 to 2005 and included both hourly surface observations and any special interim surface observations. More than two million total observations for Albuquerque and other sites were tallied, sorted, and parsed using *Excel*© software. As previously defined, all individual observations meeting the 40 mph (35 kt) sustained wind speed threshold and/or the instantaneous 58 mph (50 kt) gust threshold were considered for a preliminary high wind event. By definition, high wind warnings require only one observation to verify a non-convective high wind event, however rigorous quality assurance was performed to eliminate contamination of shorter duration high wind events that were induced by convection. Any preliminary event that did not contain at least three consecutive hourly observations of sustained wind speeds of at least 31 mph (including the initial observation meeting high wind criteria) was deemed as a short duration convective event, and thus was irrelevant to the study. This lower bound wind speed threshold of 31 mph for preceding and trailing observations was chosen based on the premise of another local office policy, which defines sustained wind speeds of 31 mph (27 kt) as hazardous, yet not life-threatening and thus worthy of an advisory product. In addition, reports of thunder as well as precipitation groups within individual observations were examined to aid in determining if events were induced from nearby convection.

It should also be noted that the Automated Surface Observing System (ASOS) was commissioned at Albuquerque circa 1994, and for the purposes of this study it is assumed that no quality degradation occurred during this transition from fully manned surface observations to occasional human augmentation of the ASOS wind data.

Results are first presented for Albuquerque, and are followed by similar results for seven additional sites in northern and central New Mexico.

Albuquerque

After parsing and quality checking the complete data set, a total of 55 high wind days or events were found at Albuquerque during the 1976 to 2005 time frame. This gives a yearly distribution as depicted in Fig. 1 with less than two non-convective wind events occurring per year on the average. Further analysis of temporal distributions will be elaborated upon in following sections, but first wind direction will be investigated in order to classify additional event characteristics.

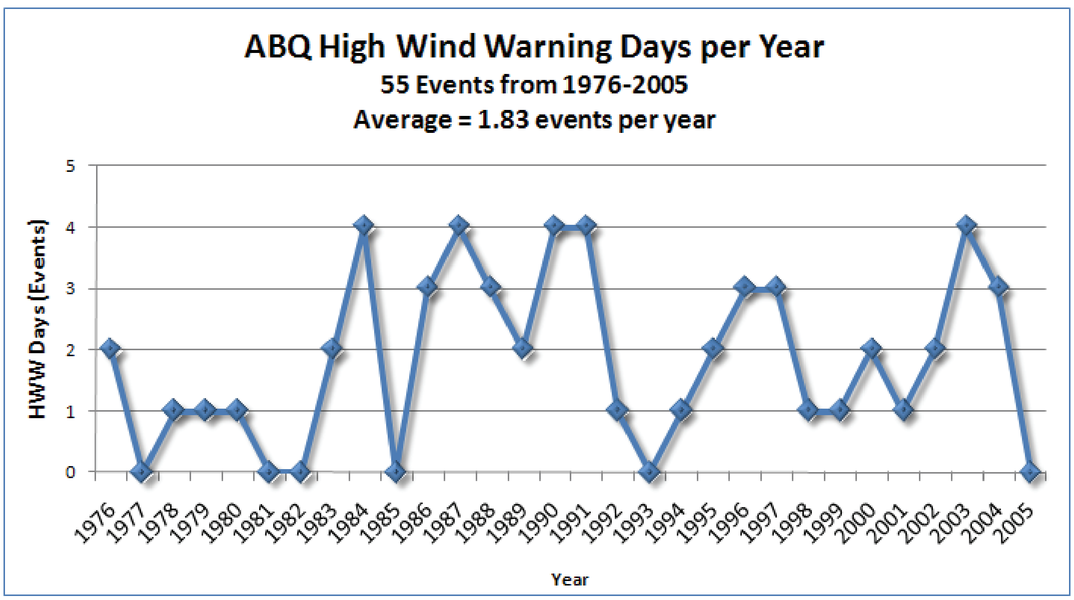


Figure 1. The frequency of high wind events at the Albuquerque Sunport from 1976 to 2005

Two Subsets for Albuquerque

An initial hypothesis was considered before analyzing the directional tendencies of high wind events at Albuquerque. Although strong east wind events are common in Albuquerque, it was hypothesized that high wind events would be predominantly from a westerly and southwesterly direction. Qualitative analysis of each of the 55 high wind days (events) quickly revealed a sharp distinction between two different types of high wind events for Albuquerque. With wind direction as the sole deterministic variable, a sharp contrast was defined between easterly high wind events versus westerly high wind events. Figure 2 depicts the partition of the frequency of high wind observations by wind direction.

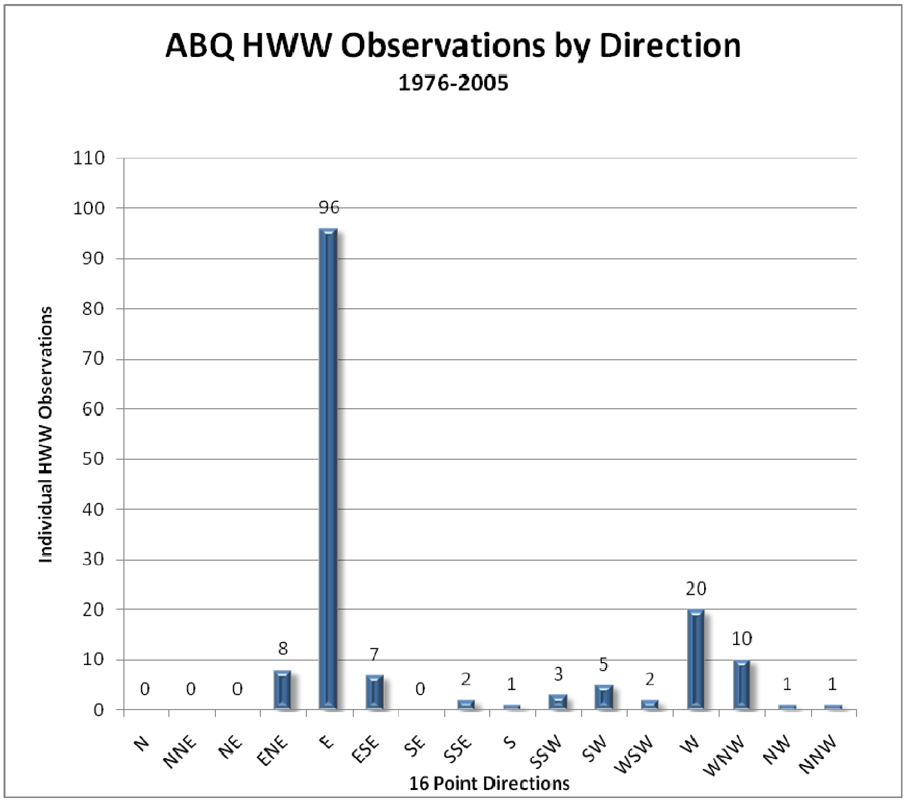


Figure 2. Frequency of high wind observations by wind direction at the Albuquerque Sunport.

Contrary to the initial hypothesis, the dominant type of high wind event was clearly the easterly event (Fig. 2). Of all the individual high wind observations, 96 (61.15%) were composed of an easterly wind direction (090º). Common forecaster knowledge from the local area associates these easterly high wind events with the local gap effect, or increased wind speeds associated with local topographical channeling from the Tijeras Canyon east of the city of Albuquerque. Noted in Fig. 2, a second cluster is evident among events occurring with a westerly directional component. From other recurring trends known to forecasters, these westerly events are generally associated with the more dynamic weather events that affect New Mexico, most frequently in the winter and spring months as deep upper level troughs of low pressure sweep across the southwestern states. Because the two distinct maxima from both easterly events and westerly events are each artifacts of two sharply different weather mechanisms, a decision was made to divide the data into two subsets of westerly and easterly events which could then be independently analyzed. With easterly events centered about a directional mode of 090º, this first easterly subset was broadly defined by any observations hosting wind direction from an azimuthal range of 000° to 179° on the compass rose. Those deemed as westerly high wind events were centered on a directional mode of 270°, and thus were defined by observations hosting wind directions from an azimuthal range of 180° to 359° on the compass rose. After partitioning the events into two subsets, easterly events outnumbered westerly events 36 (65.45%) to 19 (34.55%).

Additional surface data for the Albuquerque Metro area came into existence when an Automated Weather Observation Site (AWOS) was installed at the Double Eagle Regional Airport (AEG) on the western side of Albuquerque. Unfortunately, archived data is sparse and intermittent through the last quarter of 2001, and only became consistent by late January 2002. This left only a small window of less than 4 years available for comparison with Albuquerque Sunport data. Between January 2002 and December 2005, only 2 westerly high wind events were recorded at the Albuquerque Sunport, and high westerly winds were observed on both of these days at the Double Eagle airport. Although other high wind events were recorded at each airport site, these were the only two dates that coincided. Details are listed in the table below.

ABQ vs. AEG High Wind Correlation

Date	ABQ	AEG	Orientation
4/27/2002		YES	WESTERLY
6/20/2002	YES		EASTERLY
8/1/2002	YES		EASTERLY
1/6/2003	YES		EASTERLY
2/2/2003		YES	WESTERLY
4/15/2003	YES	YES	WESTERLY
5/20/2003	YES		EASTERLY
11/22/2003	YES	YES	WESTERLY
3/11/2004	YES		EASTERLY
4/3/2004	YES		EASTERLY
5/11/2004		YES	WESTERLY
6/3/2004	YES		EASTERLY

Temporal Distribution for Albuquerque

As was expected, Fig. 3 illustrates that easterly high wind events were less frequent through the summer months (July, August, and September). This will be investigated from a more in-depth standpoint later, but a lack of synoptic cold fronts in the eastern to northeastern parts of the state is assumed to be the sole culprit for this result. Substantial easterly gap or canyon wind events are documented frequently during the summer months, however these wind events are typically induced by remnant summertime convection and associated mesoscale boundaries propagating westward through the Tijeras Canyon. In addition, data suggest these convectively induced easterly events are predominantly weaker than their synoptically driven counterparts, rarely exceeding high wind criteria. Recall that the focus toward non-convective wind events will be retained for the purposes of this study.

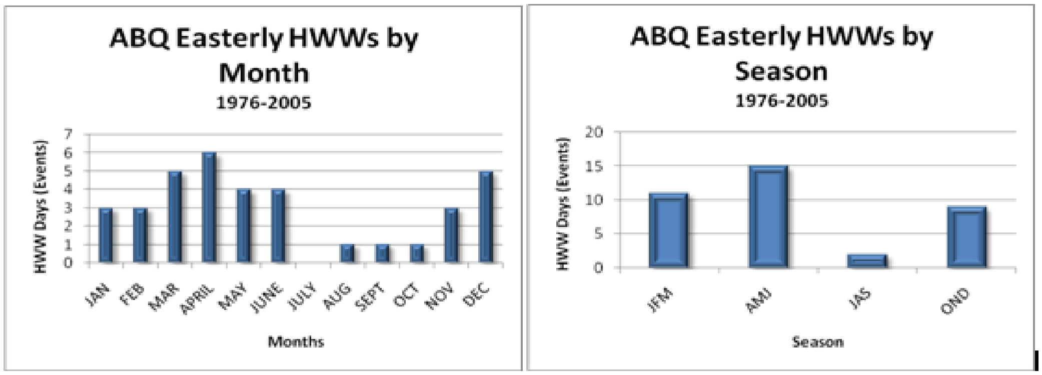


Figure 3. Frequency of easterly high wind events by month (left panel) and by season (right panel) at the Albuquerque Sunport.

Westerly high wind events (Fig. 4) favored the winter to spring months with slightly fewer events noted in the fall season. No westerly events were recorded during the summer months (JAS), as can be expected due to the seasonal lack of westerlies aloft.

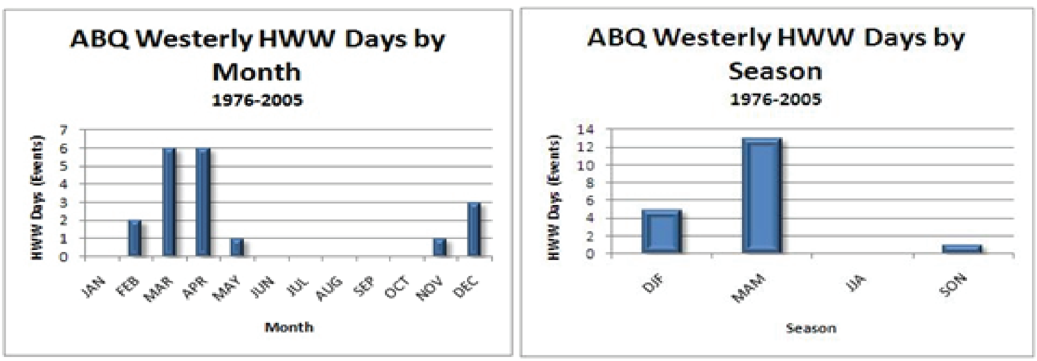


Figure 4. Frequency of westerly high wind events by month (left panel) and by season (right panel) at the Albuquerque Sunport.

Data were also analyzed to develop trends regarding the time of day in which high wind events occur. Easterly high winds have been observed at all hours of the day, but these events seem to undergo a lull or weakening near the hours surrounding both dawn and dusk, as evidenced by the two minima occurring at 0700 MST and 1600 MST in Fig. 5. The wide variability in the timing of these easterly high wind events corresponds fittingly to the high variability in the timing of frontal passages in the eastern to northeastern sections of New Mexico.

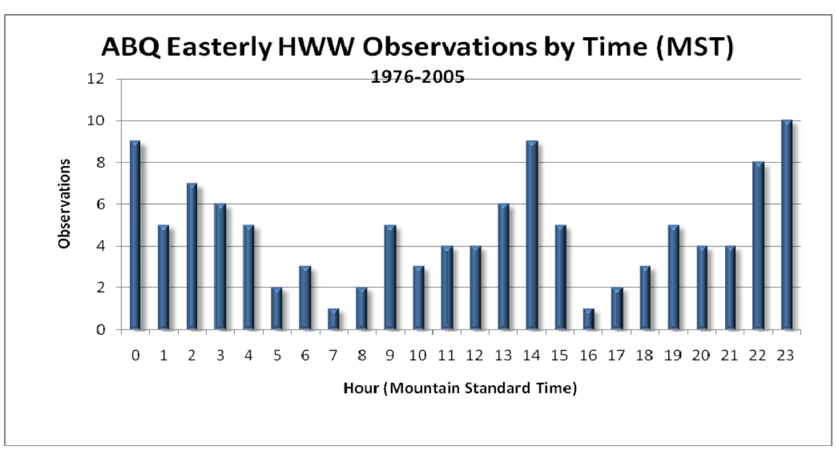


Figure 5. Frequency of easterly high wind observations by hour for the Albuquerque Sunport.

In contrast, westerly events are confined to a much narrower spectrum regarding time of day with events favoring the mid to late afternoon hours, as shown in Fig. 6.

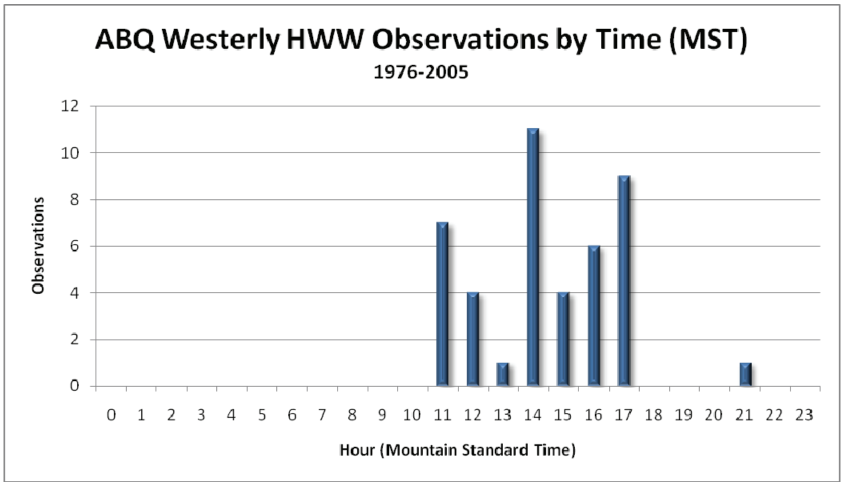


Figure 6. Frequency of westerly high wind observations by hour for the Albuquerque Sunport.

There is an initial assumption or hypothesis that these westerly high wind events are diurnally driven, due to a dependence upon vertical atmospheric mixing at peak heating hours. This hypothesis was explored further by interrogating temperature lapse rates from atmospheric soundings recorded on these westerly high wind event days. This was acomplished by recreating individual soundings from the University of Wyoming web site at: http://weather.uwyo.edu/upperair/sounding.html.

Because soundings are recorded twice a day at 0000 UTC and 1200 UTC, the data closest to the high wind observations were chosen, all of which turned out to be 0000UTC soundings recorded in the afternoon. Temperature lapse rates within the boundary layer were then individually scrutinized for the presence of an adiabatic to superadiabatic lapse rate rate (— -9.8°C/km) off of the ground surface. All analyzed soundings revealed such lapse rates, indicative of a well-mixed atmospheric boundary layer (see Fig. 7). Variability was found in the depth of the boundary layer for different events with mixing heights ranging from 750 hPa (approximately 900 m AGL) to 475 hPa (approximately 4,500 m AGL), along with a mean mixing height of 599 hPa (approximately 2,700 m AGL) for all 19 westerly events. Therefore, the conclusion is made that sufficient surface heating and a well-mixed boundary layer is indeed a requirement for stronger momentum aloft to be mixed to the surface for any westerly high wind event at Albuquerque.

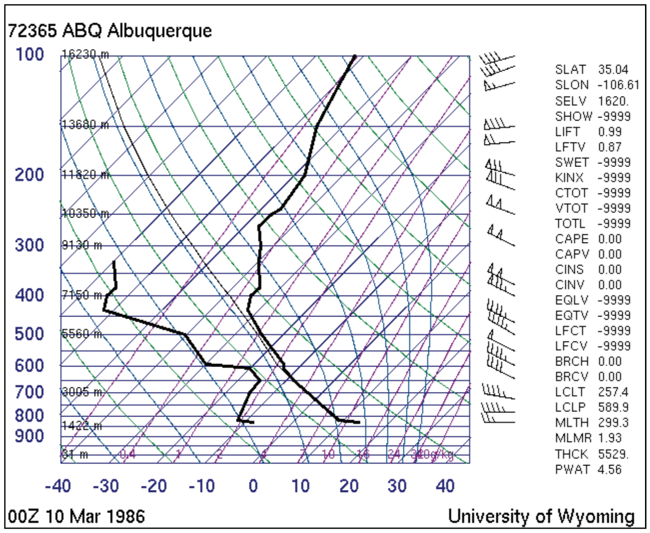


Figure 7. Atmospheric sounding example for March 10, 1986 at 0000UTC indicating a superadiabatic lapse rate within the first several meters above the surface and a subsequent dry adiabatic lapse rate to approximately 610 hPa. Winds in excess of 40 kt are evident within the boundary layer.

Synoptic Regimes for Albuquerque

Synoptic weather analyses were also performed in order to gain a perspective on distinct weather patterns responsible for generating these high wind events at Albuquerque. Conceptual models can then be extracted and applied for future guidance in forecasting and warning descision-making. These analyses will be broad encompassing composite reanalysis charts of pressure at mean sea level along with charts of geopotential height on 500 hPa pressure surfaces. These charts were created using NOAA's Earth System Research Laboratory website. Individual dates for both easterly and westerly events were tallied separately, and then used to construct the composite maps of the mean pressure or geopotential height for all high wind days.

For easterly events, it has been mentioned that the progression of synoptic surface fronts across northern and eastern portions of the state of New Mexico play a pivotal role in the genesis of the easterly gap wind at Albuquerque. This theory is supported by a mean composite sea level pressure using NCEP/NCAR reanalyses. As depicted in Fig. 8, a strong signal of higher sea level pressure values is evident to the north and east of both Albuquerque and the broader state as a whole, indicating a mean placement and progression of southeast to northwest oriented cold fronts just west of this region of greater sea level pressure. More specifically, the 1023 hPa contour is noted just on the northeast corner of the state.

Continuing with the analysis of easterly events, well-defined signals also existed within the 500 hPa geopotential height composite map. The dominant feature appears in the form of a deep upper level trough across the intermountain west. The objective analysis suggests a 575 decameter contour that is evolving to or from a state of closing off into an upper low. This particular synoptic scenario leaves a south to southwesterly flow aloft across New Mexico. This upper "troughing" plays a major, yet seemingly indirect role in the formation of lee side surface cyclones and associated frontal boundaries which often propagate westward and hence drive most of the Albuqueruque easterly gap wind events. Pressure falls aloft are induced by slower moving short wave troughs across the intermountain west, and these pressure falls are coupled to the steering and placement of areas of surface high pressure farther east. As previously noted, the lack of easterly events during the summer months coincides with a lack of synoptic cold fronts affecting areas north and east of the Albuquerque area, which in turn also correlates with the lack of a favorable upper flow regime.

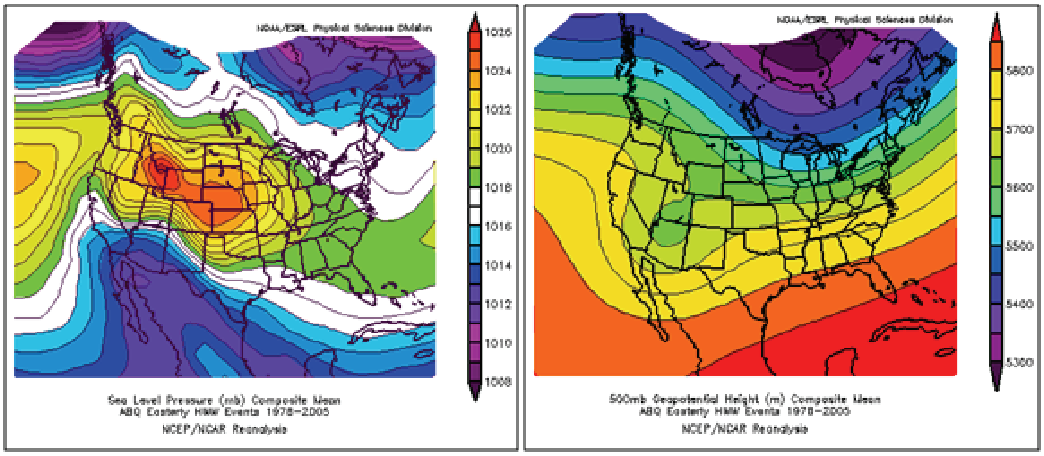


Figure 8. Composite charts of all easterly high wind events at the Albuquerque Sunport with Mean Sea Level Pressure (left) and 500 hPa Heights (right).

After examining hourly distributions and corresponding sounding data of westerly high wind events, it was clearly evident that these events are dependent upon vertical mixing at peak heating hours during the daytime. To elaborate on this regime, the mean composite analyses of all westerly event dates indicated clear synoptic scale features, beginning with the sea level pressure analysis which located a significant lee side surface cyclone centered near the southeastern Wyoming and northeastern Colorado border (mean sea level pressure at 1006 hPa). The pressure falls extend southward into the Texas panhandle and northeastern New Mexico outlining a familiar lee side trough recognized by many local and regional forecasters.

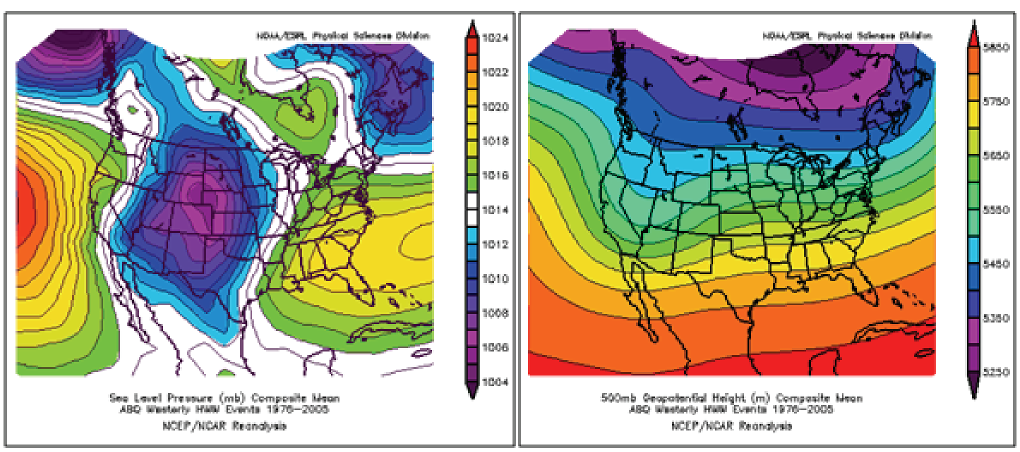


Figure 9. Composite charts of all westerly high wind events at the Albuquerque Sunport with Mean Sea Level Pressure (left) and 500 hPa Heights (right).

For westerly events, the mean flow aloft supplements the aforementioned lee side cyclone/trough at the surface. Mean composite height analysis at 500 hPa suggests gentle longwave troughing in the flow aloft with 555 decameter contours tracing the southern tip of the state of Nevada, also where the trough axis is juxtaposed.

Further analysis of individual 500 hPa height reanalysis data from the National Center for Environmental Prediction suggests that most westerly high wind events occurred within the presence of a deep 500 hPa trough exhibiting heights of two to three standard deviations lower than climatological averages. These troughs were generally located over the southwestern United State (specifially AZ and NM), however some geographical variability was noted with extreme cases involving upper level trough/low placement as far north as the Minnesota-Ontario border. Of the 19 westerly events, six were associated with closed upper level lows with placement ranging from northern Minnesota southward to the Baja peninsula of Mexico. Three of the six closed low events exhibited the feature within a southern Nevada and Utah vicinity, each deepening to two standard deviations below the mean height field for each specific date. One such example is displayed below for a westerly event that occurred on April 11, 1991.

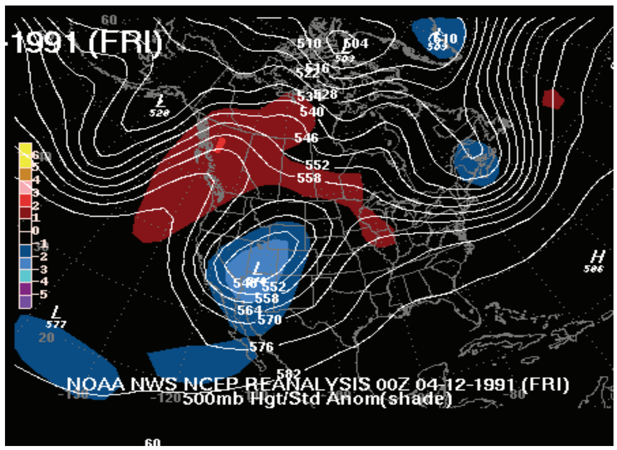


Figure 10. 500 hPa Heights and Standard Anomalies for a westerly high wind event on April 11, 1991.

Upper trough orientation, defined by the slope of the horizontal axis of the 500 hPa trough, was determined for each event. Only 3 westerly events were classified as having a negatively tilted trough axis, and two of these events exhibited only a slight negative tilt. This left a fairly even distribution of both positive and nuetrally tilted axes for remaining events. Jet streak orientation also correlates to trough orientation for individual events, and most events were found to host strongest jet cores to the east southeast of the trough axis, often placing them out of the continental United States and into Mexico. Speed maxima observed at 250 hPa ranged from 70 to 130 kt with spatial variability limiting the recognition of conspicuous jet streak patterns or signals.

Strong pressure gradients over New Mexico are thus inferred from all of these analyses, providing a source region for downward transport of increased momentum and high surface wind speeds and gusts. Again, this vertical mixing is highly reliant on sufficient surface heating and increased lapse rates at the low to mid levels of the atmosphere.

Conclusions for Albuquerque

Hourly surface data from Albuquerque were reviewed for a 30 year record (1976-2005), and a parsed climatological record of high wind events was constructed. This record indicated two subsets of high wind events at Albuquerque: the dominant easterly events generated by the gap wind and the less frequent westerly events caused by strong pressure gradients and momentum aloft mixed to the surface. The temporal distribution of these two subsets were analyzed with easterly events occurring at all hours of the day, favoring the fall to spring months. Westerly events were strictly observed in the late afternoon to early evening hours, and also ommited the summer months. The synoptic setting for easterly events was reviewed and defined by an anomalous signal of higher surface pressures to the north and east of Albuquerque. This signal was predominantly linked to synoptic cold fronts which spill westward through the Tijeras Canyon. In contrast, the westerly events were defined by a lee side surface trough/cyclone in the eastern high plains of New Mexico and Colorado coupled with a short wave trough over the southwestern states. The dependence on daytime heating for vertical atmospheric mixing was linked to this westerly process as well.

Surrounding Sites across Northern and Central New Mexico

Seven additional observation sites were used to expand the climatological record of high wind events across northern and central New Mexico, including Farmington, Gallup, Santa Fe, Las Vegas, Tucumcari, Roswell, and Clayton. A similar methodology was applied for each site, to gain a sense of the seasonal and diurnal distributions of high wind events, as well as other specific characteristics of the events over a thirty year timeframe. An overview of the preliminary findings is shown in Fig. 11.

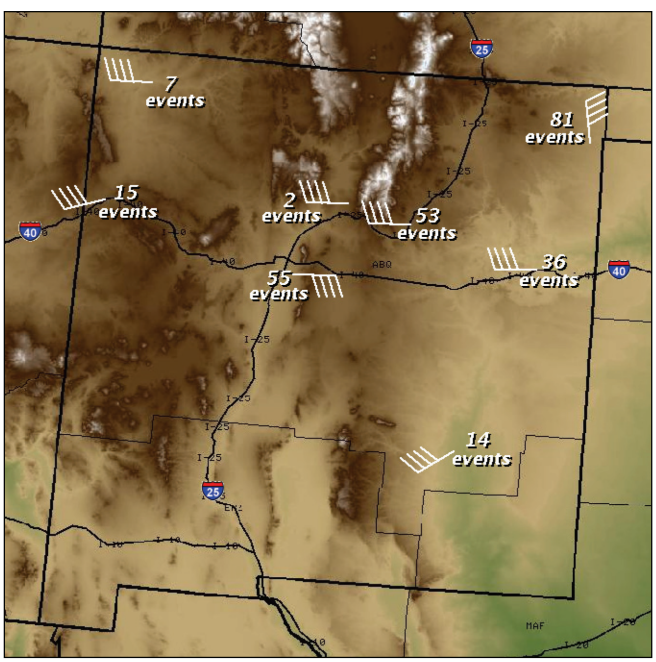


Figure 11. High Wind Events Recorded across the Albuquerque County Warning Area: 1976-2005

In addition to depicting the number of high wind days or events recorded for each site during the 1976 to 2005 timeframe, the following table also displays the primary wind direction, the months and the hours that these events occurred under. A brief synopsis of the findings for each site will then follow.

SITE	# EVENTS	DIRECTIONAL MODE	OCCUR IN XX MONTHS	OCCUR IN XX HOUR OF DAY (MST)
FMN	7	WEST	J **F** **M** A **M** **J** J A S O **N** D	0 1 2 3 4 5 6 7 8 9 10 11 **12** 13 **14** **15** 16 17 **18** 19 **20** 21 22 23
GUP	15	WEST SOUTHWEST	J **F** **M** **A** **M** J J A S O **N** D	0 1 2 3 4 5 6 7 8 9 10 **11** **12** **13** **14** **15** **16** **17** 18 19 20 21 22 23
ABQ	55	EAST	**J** **F** **M** **A** **M** **J** J **A** **S** **O** **N** **D**	**0** **1** **2** **3** **4** **5** **6** **7** **8** **9** **10** **11** **12** **13** **14** **15** **16** **17** **18** **19** **20** **21** **22** **23**
SAF	2	WEST	J **F** **M** A M J J A S O N D	**0** 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 **17** **18** **19** 20 **21** **22** **23**
LVS	53	WEST	**J** **F** **M** **A** **M** **J** J A **S** **O** **N** **D**	0 **1** **2** **3** **4** **5** **6** 7 **8** **9** **10** **11** **12** **13** **14** **15** **16** **17** 18 19 20 21 **22** **23**
TCC	36	WEST	**J** **F** **M** **A** **M** J J A S O **N** **D**	0 1 2 **3** 4 5 6 **7** **8** **9** **10** **11** **12** **13** **14** **15** **16** **17** 18 **19** **20** 21 **22** 23
ROW	14	WEST SOUTHWEST	**J** **F** **M** **A** **M** J J A S O N D	**0** 1 2 3 4 5 6 7 8 9 **10** **11** **12** **13** **14** **15** **16** 17 **18** **19** 20 21 22 23
CAO	81	NORTH	**J** **F** **M** **A** **M** **J** J A **S** **O** **N** **D**	**0** **1** **2** **3** **4** **5** **6** **7** **8** **9** **10** **11** **12** **13** **14** **15** **16** **17** **18** **19** **20** **21** **22** **23**

Farmington (FMN - Northwest New Mexico)

A fairly consistent record of 24 hour observations was obtained from the National Climatic Data Center (NCDC) for Farmington. Although, the station site was apparently moved a couple of times within the selected 1976-2005 period, one of which was in 1981 where overnight observations were missing from August 4, 1981 through September 19, 1981. Only seven non-convective high wind events were recorded between 1976 and 2005 (average 0.23 events per year) as shown in the table above and in Fig. 12a. Winds were predominantly westerly during these seven high wind events with some high wind observations exhibiting a southerly to southwesterly direction (Fig. 12b).

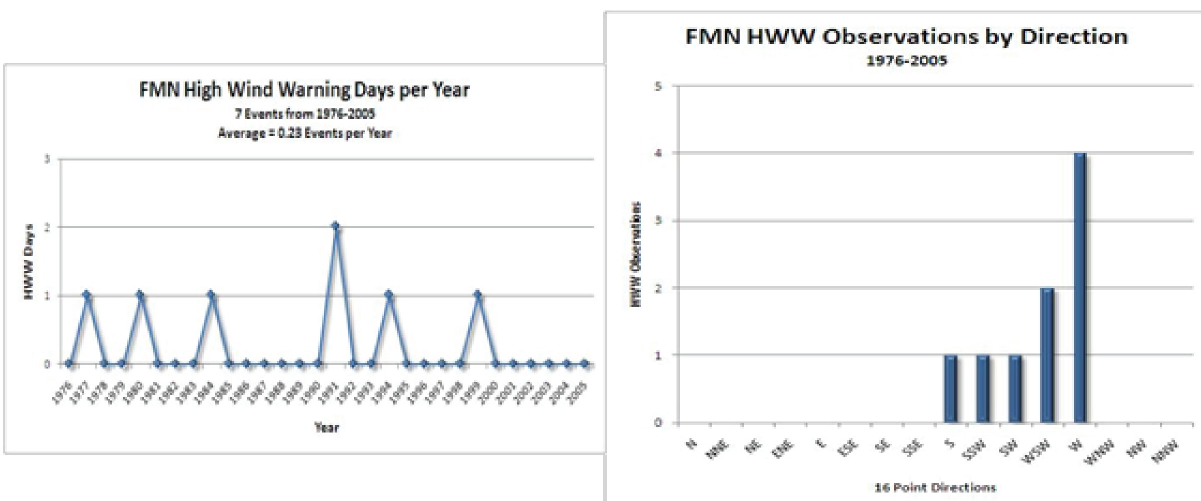


Figure 12. Number of high wind events per year at Farmington (FMN) Airport (left) and high wind events partitioned by direction (right).

Similar to other sites, the majority of these events occurred in the spring months of March, April, and May (Fig. 13a). No matter the time of year, all high wind events at Farmington were recorded during the afternoon and early evening hours when strong winds aloft were juxtaposed with peak heating and sufficient vertical mixing (Fig. 13b).

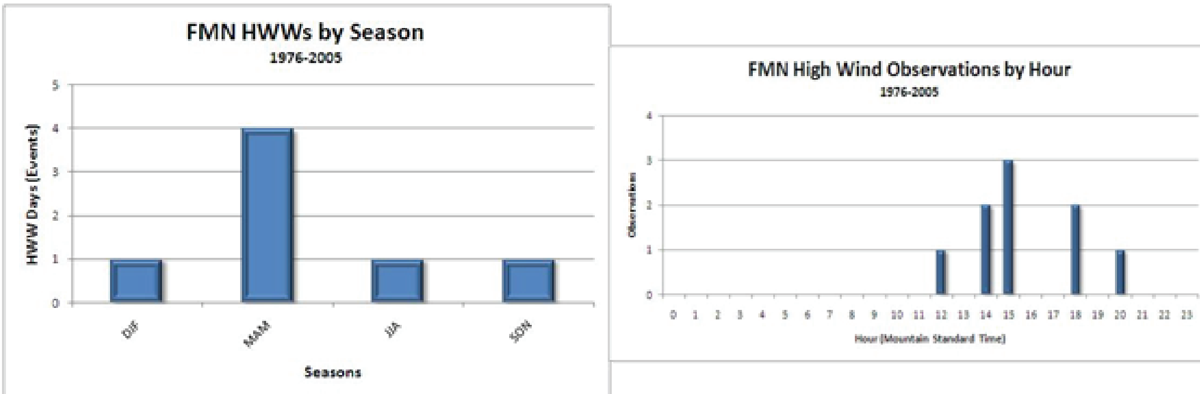


Figure 13. Frequency of high wind events by season (left) and by hour (right) at Farmington Airport

Of the seven high wind events recorded at Farmington, four events were driven by closed upper level lows evident in geopotential height fields at 500 hPa. Three of these closed low events displayed heights of 3 standard deviations lower than average. The remaining events that displayed open wave troughs rather than closed lows were shown to have strong jet cores present at 250 hPa which perhaps overcame the lack of a stronger mid tropospheric perturbation. An example of such an event occurred on March 11, 1991, and standard height fields were reconstructed of this event utilizing reanalysis data from NCEP (National Center for Environmental Prediction).

Gallup (GUP – West Central New Mexico)

A thorough dataset was available for Gallup, with 24 hour observations recorded throughout the full 30 year record. During this period, a total of 19 events were recorded, with no more than two in a year. High wind events occurred primarily with west southwest winds.

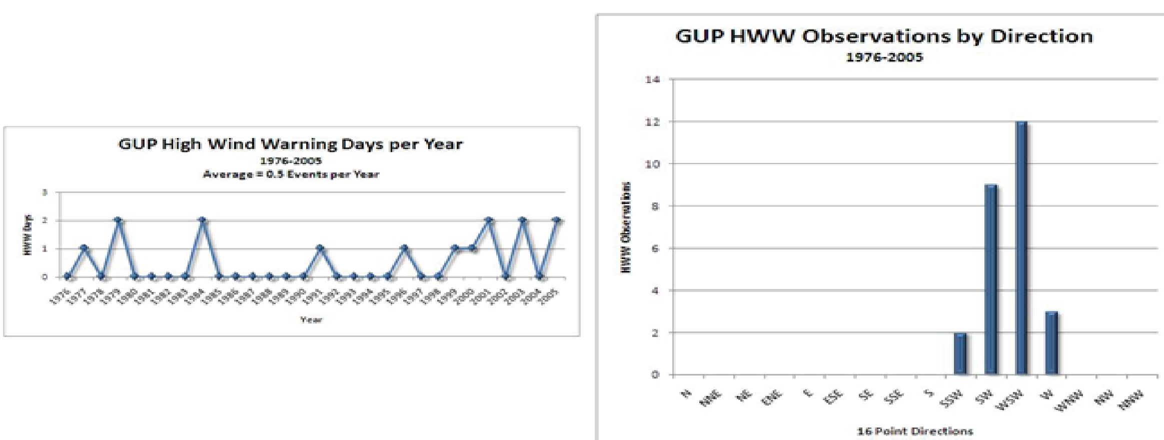
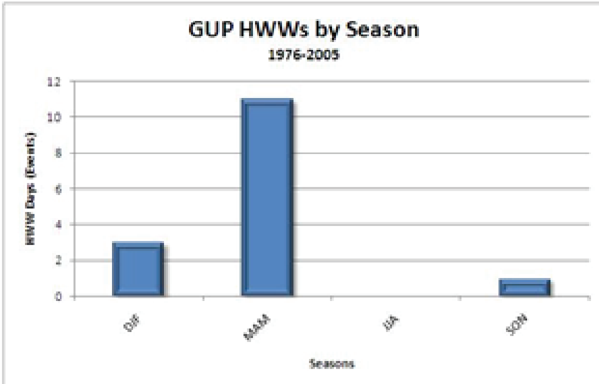


Figure 14. Number of high wind events per year at Gallup (GUP) Airport (left) and high wind events partitioned by direction (right).

The overwhelming majority of events took place within the spring months at Gallup, and no events were recorded in the summer months that follow. All events recorded at Gallup occurred in the daytime with most events distributed in the afternoon hours.



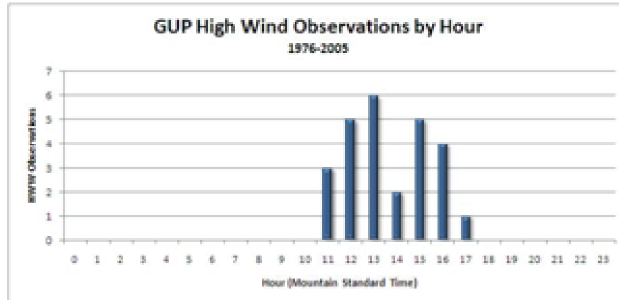


Figure 15. Frequency of high wind events by season (left) and by hour (right) at Gallup Airport.

Similar to the trend of other sites recording westerly high wind events, the presence of a mid tropospheric perturbation was present for all events recorded at Gallup between 1976 and 2005. The characteristics of these perturbations displayed wide variance for different events from closed lows to open short wave troughs. Interestingly, almost every event displayed a neutrally tilted trough or closed low. Reanalysis data for a sample event on April 19, 2001 can be seen in Appendix 2.

Santa Fe (SAF – North Central New Mexico)

During the 30 years of data analyzed, only three events were recorded at Santa Fe, however one caveat should be mentioned. It was found that from June 16, 1977 overnight observations were not recorded through the next 20 years leading up to October 3, 1997 when full 24 hour observations were reinstated. All three events recorded at Santa Fe were comprised of westerly winds favoring the late afternoon and evening hours in the months of February and March. An example is listed in Appendix 3.

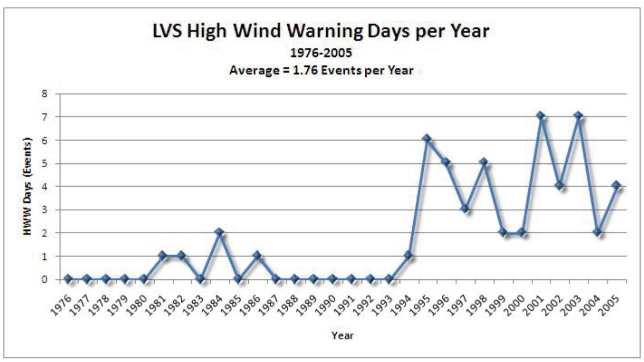
Las Vegas (LVS – Northeast New Mexico)

Surface data during the overnight hours was repeatedly missing for many segments of the Las Vegas climatological record. Most of the surface data was observed manually, and there was likely no justification for employing observers for all hours of the day at an airport with relatively undemanding aviation traffic. The table below summarizes these periods when overnight observations were unavailable.

24 hour Observations Present	Missing Overnight Observations
1/1/1976 through 6/15/1977	6/16/1977 until 1/1/1981
1/1/1981 through 6/18/1983	6/19/1983 until 10/30/1983
10/30/1983 through 5/31/1984	6/1/1984 until 10/12/2000
10/12/2000 through 12/31/2005	

Figure 16a below reveals that nocturnal high wind observations were recorded at Las Vegas, despite the many segments of missing data during the overnight hours. Thus, it is assumed that the total count of high wind events at Las Vegas, as well as the details of the distribution of these events, are likely unrepresentative. This could also account for the erratic year to year distribution of events as indicated in Figure 16a.

Fifty-three events were recorded at Las Vegas from 1976 to 2005, however overnight observations were missing from large partitions of the dataset. In particular, from late May in 1984 to October 2000, no overnight observations were recorded, and this could likely account for an inaccurate reflection of the distribution of these high wind events from year to year, as well as the diurnal distribution of high wind events at Las Vegas. Most high wind events at Las Vegas were westerly, but a small number of observations meeting high wind criteria were recorded from the north and north northeast.



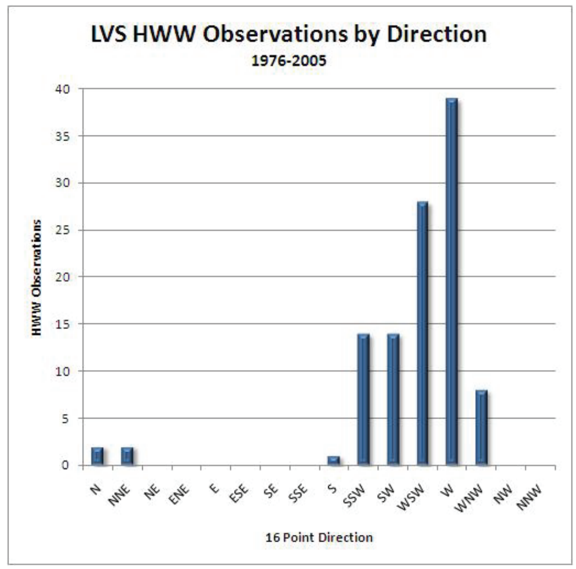
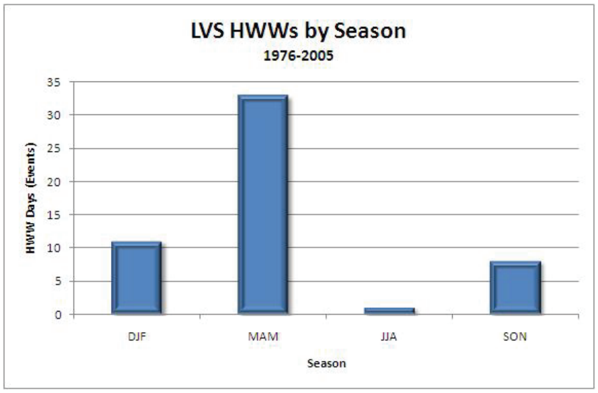


Figure 16. Number of high wind events per year at Las Vegas (LVS) Airport (left) and high wind events partitioned by direction (right).

Trends were noted in the seasonal distribution of high wind events at Las Vegas, similar to those of other previously discussed observation sites, with a maximum noted in the spring months and a minimum during the summer months.

One distinction of the data analyzed at Las Vegas versus other sites is the temporal distribution throughout a 24 hour day period. At Las Vegas high wind observations were recorded in the late night and early morning hours leading to a hypothesis that diurnal heating is not necessarily a lone requirement of all high wind events at this location. With so many observations missing during the overnight hours of the data set, it is also suspected that a significant count of undocumented events occurred during these data-void times.



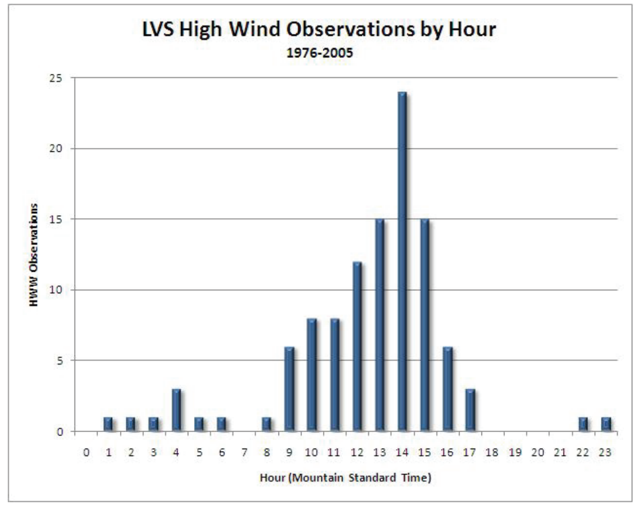


Figure 17. Frequency of high wind events by season (left) and by hour (right) at Las Vegas Airport.

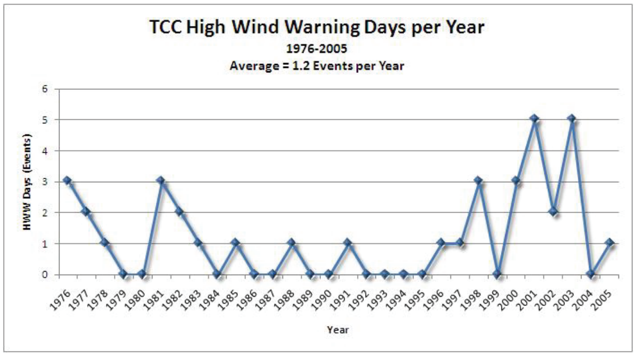
Appendix 4 reveals a typical westerly high wind event at Las Vegas where a substantial upper level low pattern is present with heights of 2 standard deviations below average. Most events at Las Vegas were characterized by this type of regime with an open trough or upper low remaining neutrally tilted with a strong jet streak present on the southern and eastern periphery of the feature in most cases. A significant surface trough or cyclone was also present to the lee of the Rocky Mountains for the entire domain of high wind events for Las Vegas.

Tucumcari (TCC – East Central New Mexico)

Similar to other sites in northeast New Mexico, many segments of data were missing overnight observations at Tucumcari, yet observations were still recorded every day within the selected 30 year period, making it a worthy site to evaluate. The table below summarizes the missing data segments at Tucumcari, and could account for some of the findings listed in figures 18 and 19.

24 hour Observations Present	Missing Overnight Observations
1/1/1976 through 6/28/1980	6/29/1980 until 10/5/1980
10/5/1980 through 10/4/1982	10/5/1982 until 9/7/2000
9/7/2000 through 12/31/2005	

An average of 1.23 events per year was recorded at Tucumcari with a total of 37 events. Note that data at Tucumcari was not recorded during overnight hours from October 1982 through September 2000, leaving some void and potentially unrepresentative areas in the data. Similar to Las Vegas, data at Tucumcari reveals high wind events primarily were of a westerly direction with a few observations reported from the north and north northeast as seen in Figure 18b.



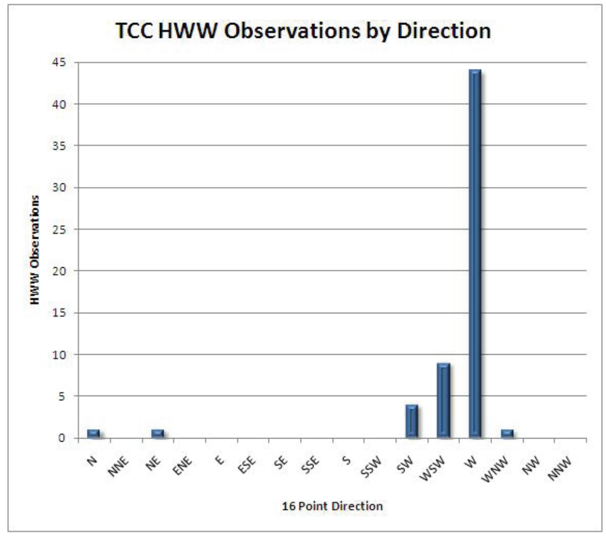
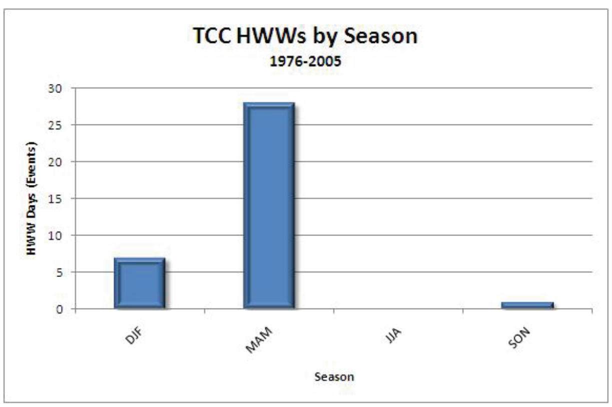


Figure 18. Number of high wind events per year at Tucumcari (TCC) Airport (left) and high wind events partitioned by direction (right).

The majority of high wind events occurred during the spring months at Tucumcari with no high wind events documented during the summer. A small quantity of high wind observations were recorded in the early morning and late night hours, however the early to mid afternoon hours were the more common time frame.



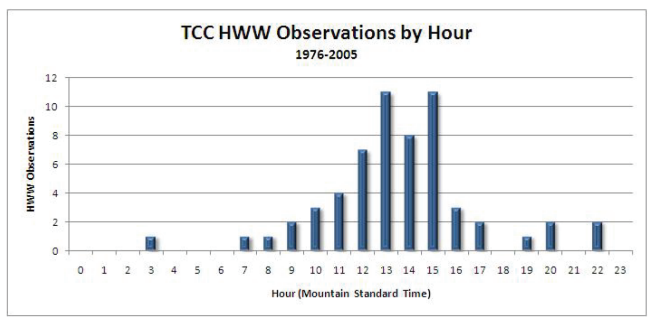


Figure 19. Frequency of high wind events by season (left) and by hour (right) at Tucumcari Airport.

Synoptic regimes for high wind events at Tucumcari displayed similar characteristics to those analyzed for Las Vegas events. Most events were driven by an upper level trough or closed upper low where a strong mid to upper level pressure gradient was present. While analyses of most events also revealed a surface low or trough, the placement and orientation of these surface features varied considerably for many events. See Appendix 5 for the synoptic regime of one such example at Tucumcari.

Roswell (ROW – Southeast New Mexico)

Data from Roswell was consistent for all but one year from June 4, 1994 until June 2, 1995 when overnight observations were not recorded. Only 14 high wind events were recorded at Roswell during this time frame. These events were predominantly from the southwest and west southwest with a few events hosting northerly wind observations.

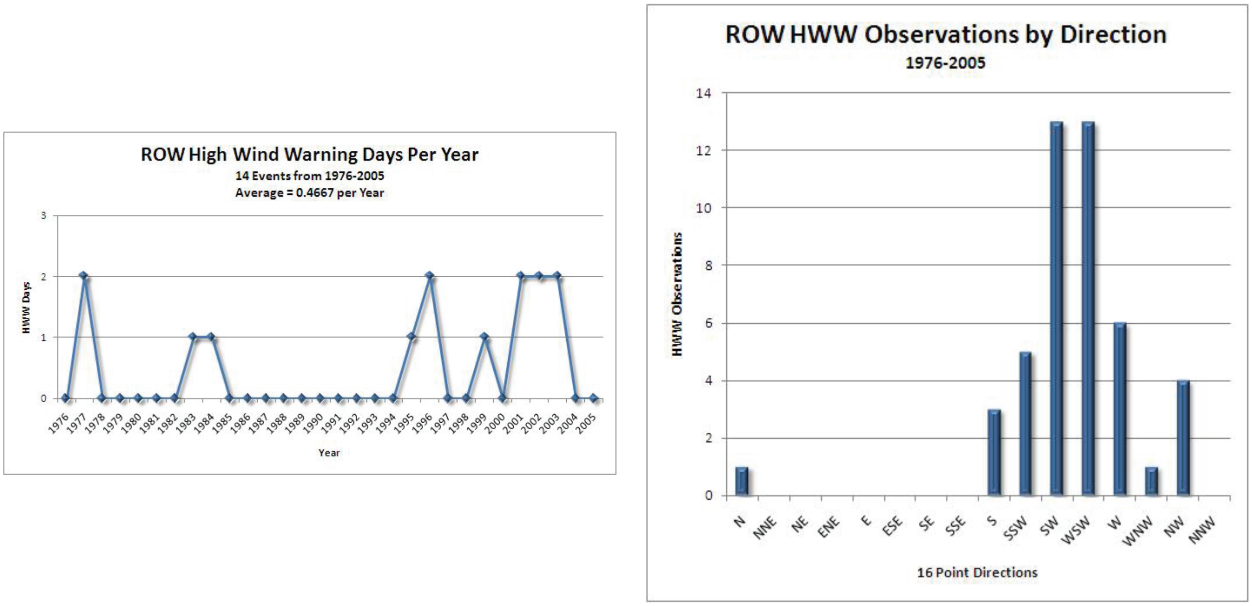


Figure 20. Number of high wind events per year at Roswell (ROW) Airport (left) and high wind events partitioned by direction (right).

All events at Roswell were confined to the winter and spring months with the spring months accounting for the majority of events, similar to most other sites in the study. Also, most events were found to have occurred in the late morning to early afternoon hours.

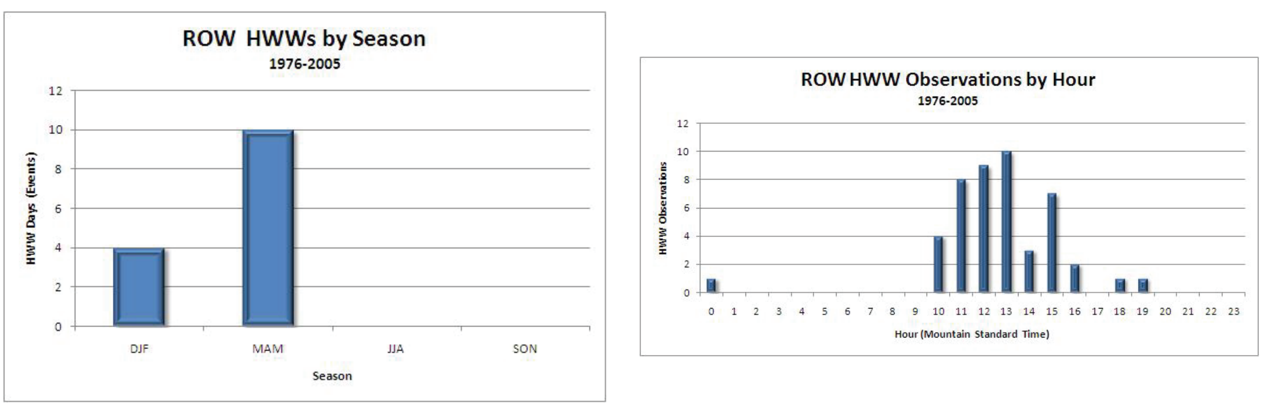


Figure 21. Frequency of high wind events by season (left) and by hour (right) at Roswell Airport.

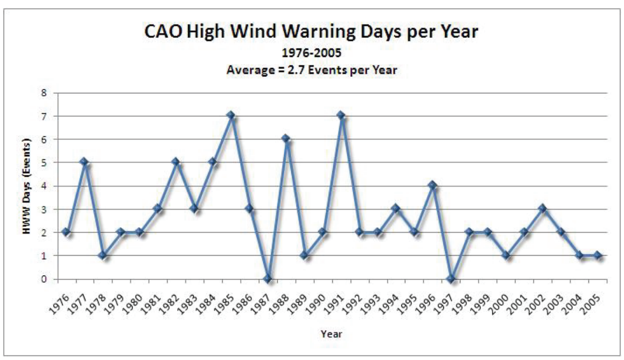
A view of the synoptic settings for a particular high wind event recorded at Roswell can be seen in Appendix 6. Similar to other sites across New Mexico a jet streak aloft, a strong mid troposhperic perturbation and a lee side surface low were analyzed during this event and most others within the dataset.

Clayton (CAO – Far Northeast New Mexico)

The data from Clayton, New Mexico did not encompass 24 hour observations for two relatively short durations as depicted below.

24 hour Observations Present	Missing Overnight Observations
1/1/1976 through 8/2/1977	8/3/1977 until 8/27/1977
8/27/1977 through 9/24/1986	9/25/1986 until 7/9/1987
7/9/1987 through 12/31/2005	

Of all 8 sites analyzed, Clayton recorded the most high wind days throughout the analyzed 30 year timeframe with 81 total events. Contrary to other sites across northern and central New Mexico, the most common direction observed was from the north, yet a substantial amount of observations encompassed westerly and southwesterly directions.



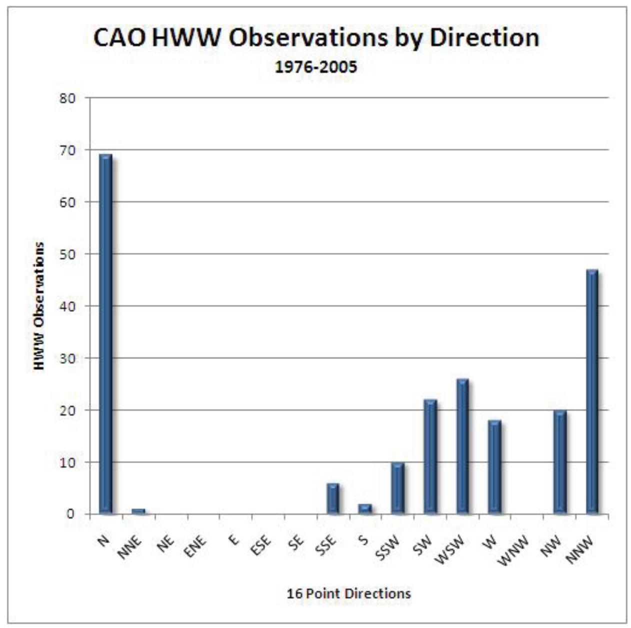


Figure 22. Number of high wind events per year at Clayton (CAO) Airport (left) and high wind events partitioned by direction (right).

High wind data from Clayton demonstrated two arrays of directional orientation, much in the same way that high wind data from the Albuquerque site did. As with the Albuquerque data, it was determined that separate synoptic mechanisms were responsible for events occurring from different directions. Fast moving synoptic cold fronts with a pronounced surface pressure gradient were linked to northerly high wind events at Clayton while the process of boundary layer mixing of strong winds aloft was generally associated with southerly to westerly high wind events. Therefore, high wind events were segregated according to directional orientation. As seen from Figure 22 there were no west northwest high wind events within the dataset (just northwest and west), and this offered an intuitive place to divide the dataset. Thus, those events defined as northerly high wind events fell within a 300° to 040° azimuthal range leaving the remaining southerly and westerly events within a 150° to 299° azimuthal range.

Events were still found to favor the spring months at Clayton, for both northerly and westerly events, and northerly events are more common in the fall than westerly events.

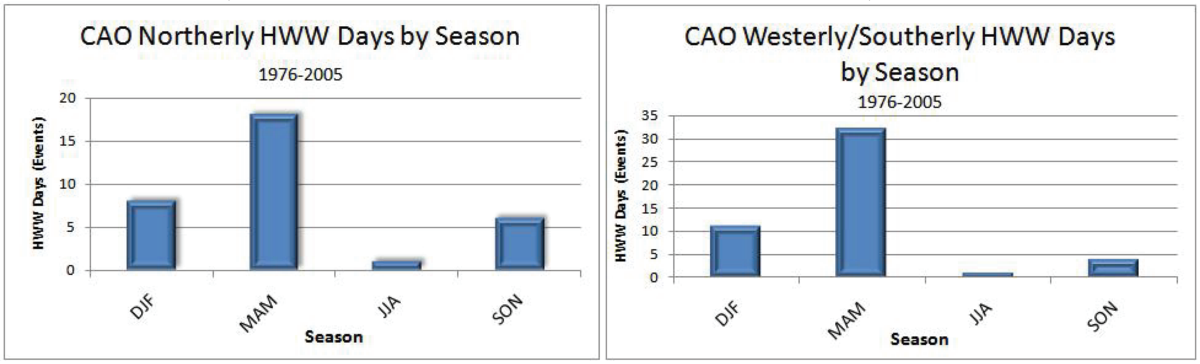


Figure 23. Frequency of high wind days by season for northerly events (left) and westerly/southerly events (right) at Clayton Airport.

Northerly events were distributed throughout all times of day with a maximum recorded in the late morning as seen by Figure 24a. The occurrence of these northerly events at all times of day corresponds to the variable arrival times of synoptic cold fronts generating high winds. The remaining events correspond with westerly events from other sites across northern and central New Mexico with most events occurring in the mid afternoon during peak heating and mixing.

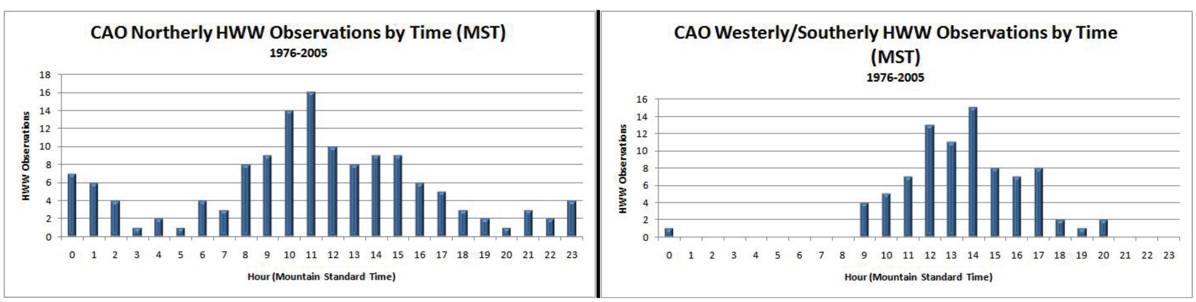


Figure 24. Frequency of high wind days by hour for northerly events (left) and westerly/southerly events (right) at Clayton Airport.

A sample northerly high wind event from April 21, 1984 can be seen in Appendix 7. Similar to other northerly high wind events at Clayton the mid tropospheric perturbation is displaced east of the site as is the surface low. This placement and orientation induces pressure rises over the site, indicative of the passage of a cold front with a pronounced surface pressure gradient also visible.

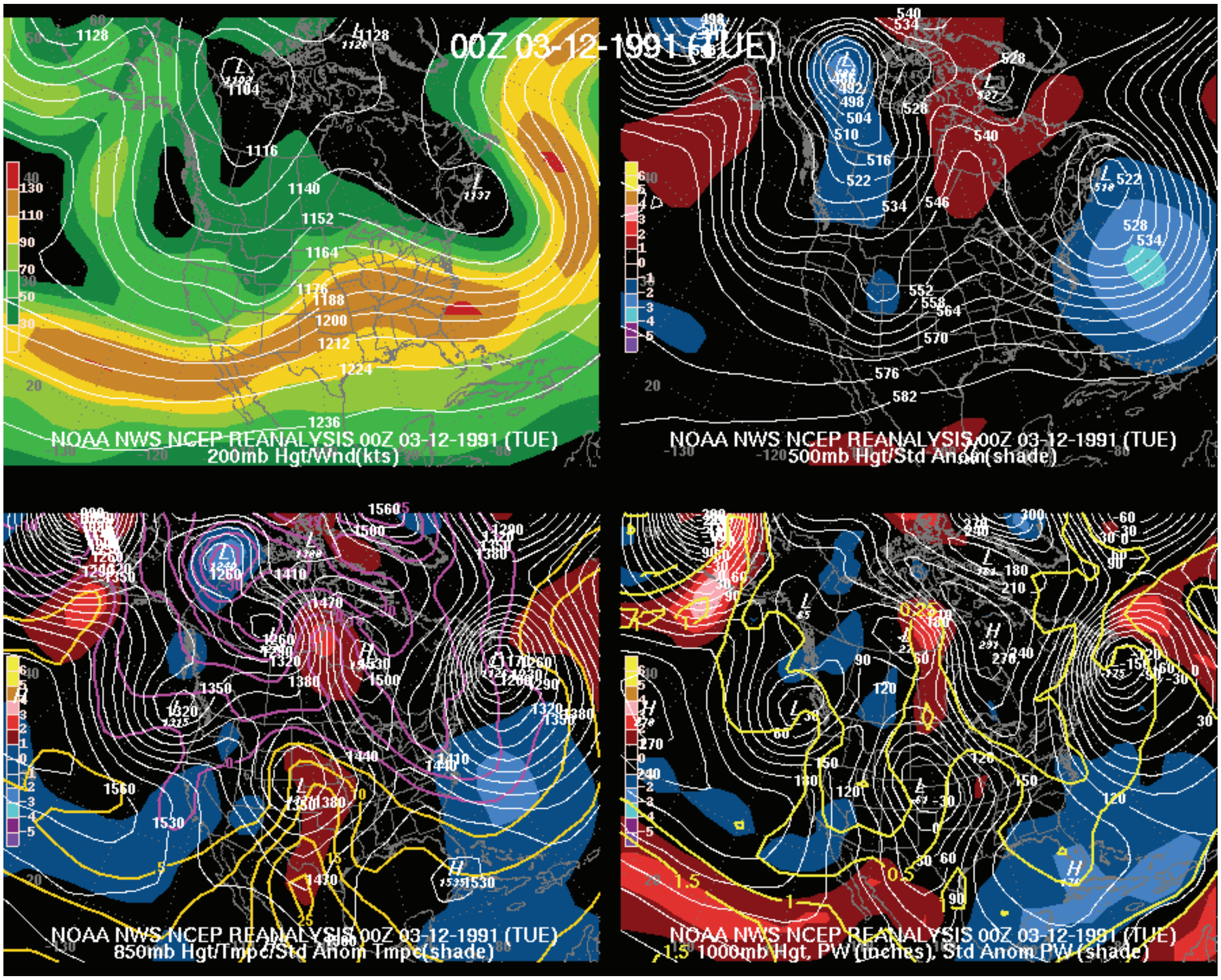
Appendix 8 includes a sample and fairly representative westerly high wind event showing an upper level short wave trough (with trough axis remaining west of site CAO) and an associated surface low (to the north of site CAO). The height fields surrounding the trough fall one standard deviation below average for this particular sample date.

Conclusion

A climatological record of high wind events was built for eight observational sites across New Mexico utilizing a 30 year period of record from 1976 to 2005. Hourly and interim surface observations from these eight sites were reviewed to determine the frequency of high wind events. Among this climatological record, the temporal distributions of high wind events were extracted on hourly, monthly, seasonal, and yearly intervals. Directional distributions were also attained, and reanalysis was performed where it was deemed necessary, such as at Albuquerque where differing and distinct mechanisms triggered high wind events. Synoptic analyses were also performed to obtain conceptual models that will hopefully aid in forecasting and warning decision making. This included a look at composite analyses of mean sea level pressure and geopotential height fields, as well as the synoptic settings responsible for high wind events on a case-by-case basis. Future work will hopefully include the construction of a database that will allow improved methods for inter-site comparisons of events on an individual and collective basis.

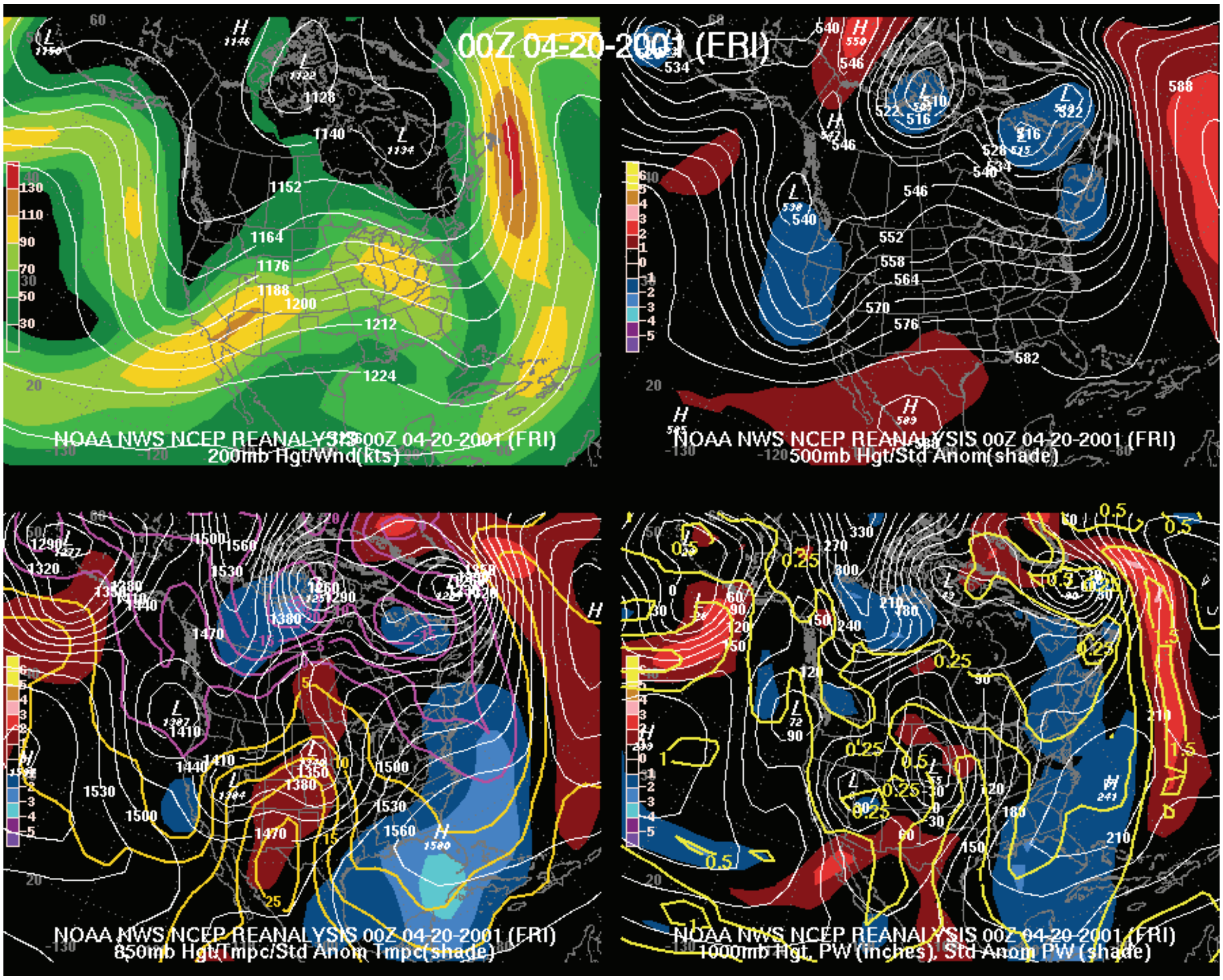
Appendix 1

Farmington Synoptic Example:



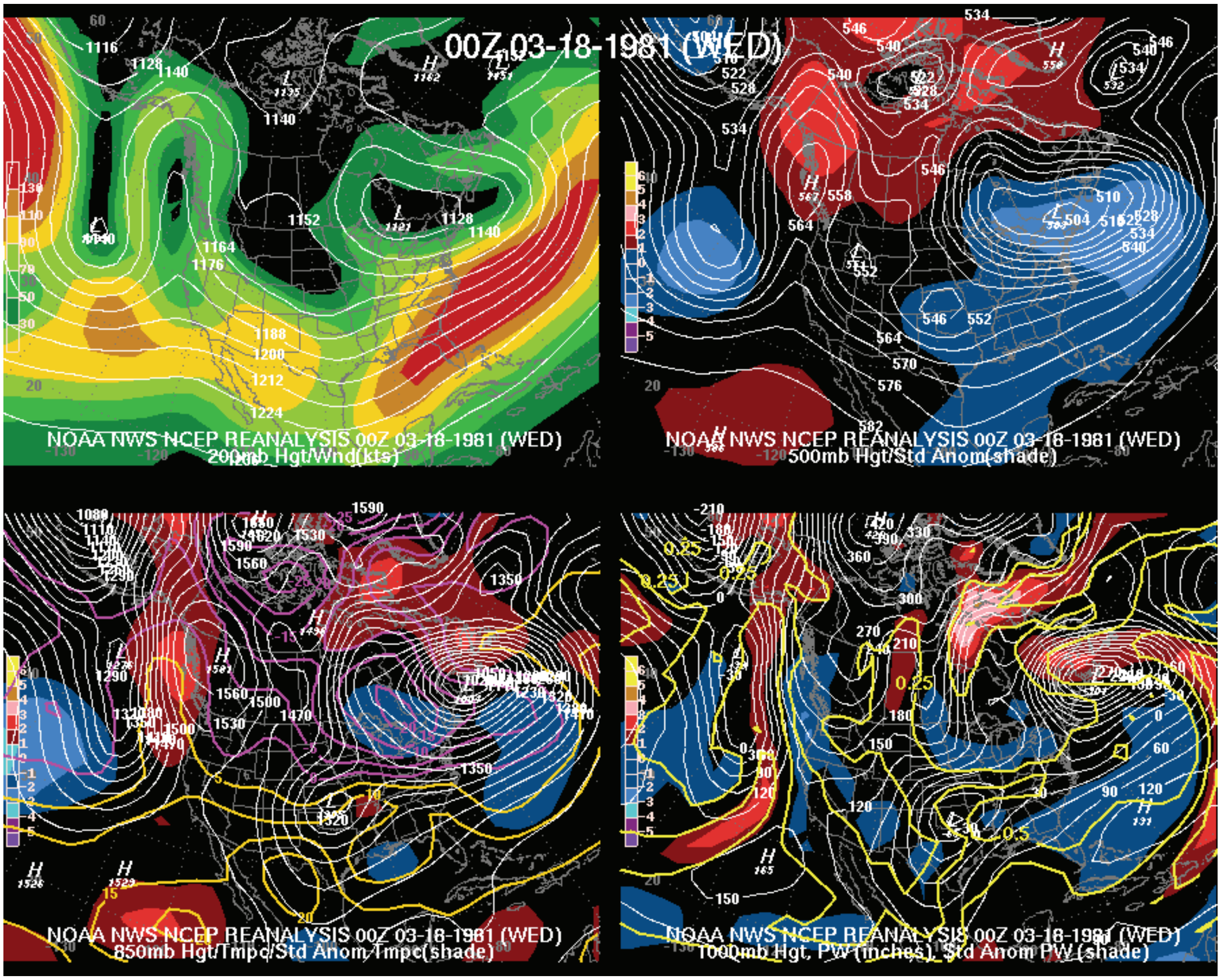
Appendix 2

Gallup Synoptic Example:



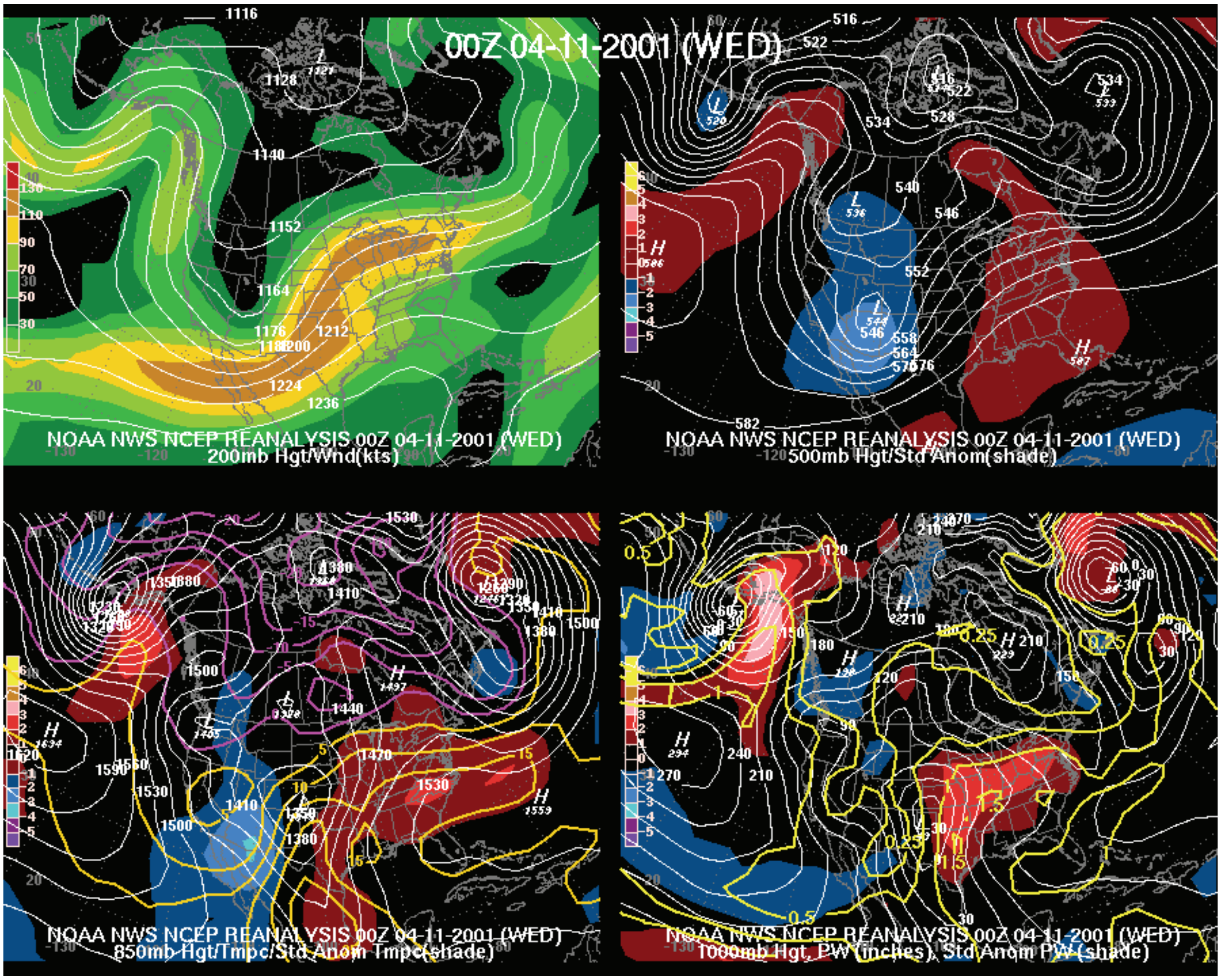
Appendix 3

Santa Fe Synoptic Example:



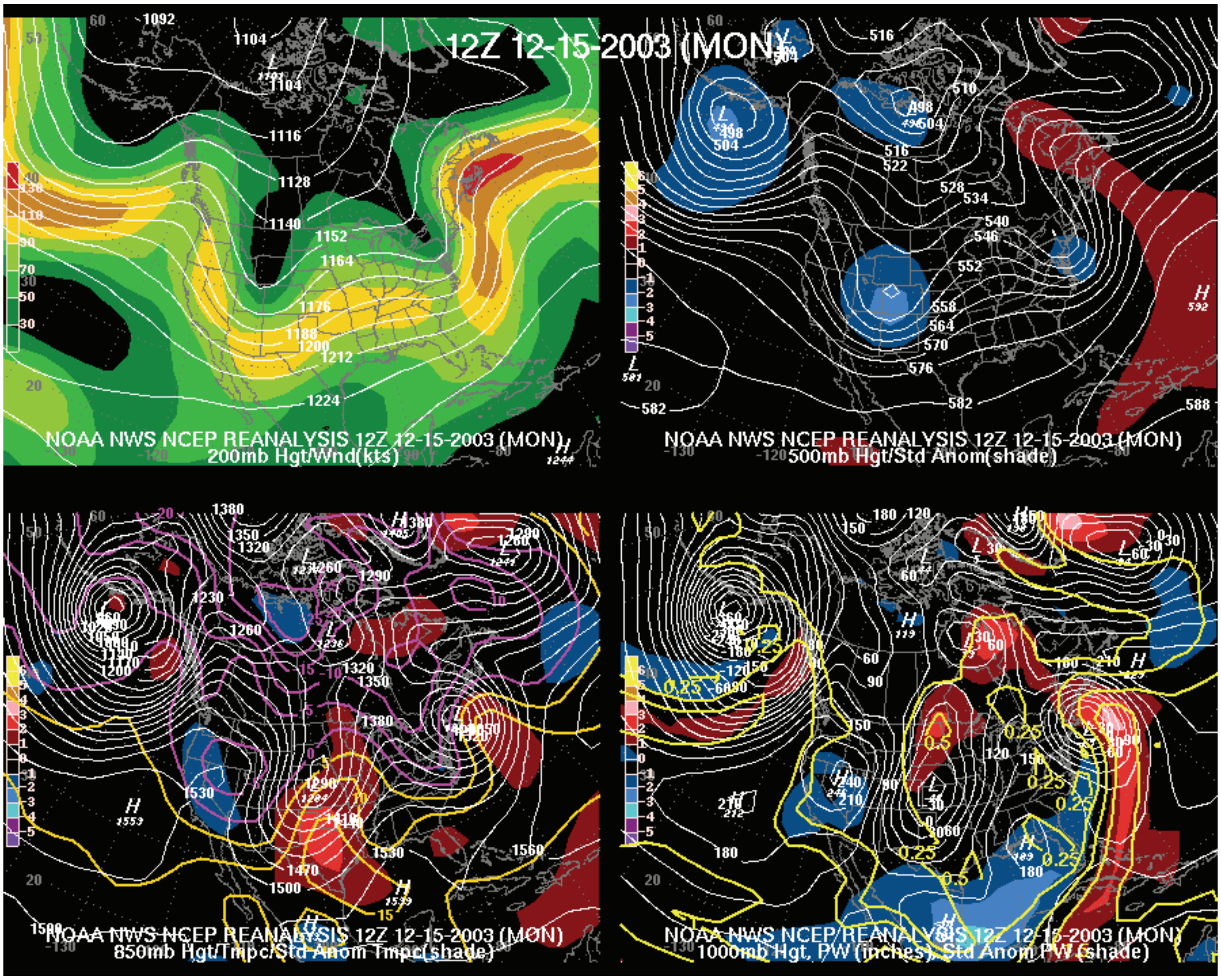
Appendix 4

Las Vegas Synoptic Example:



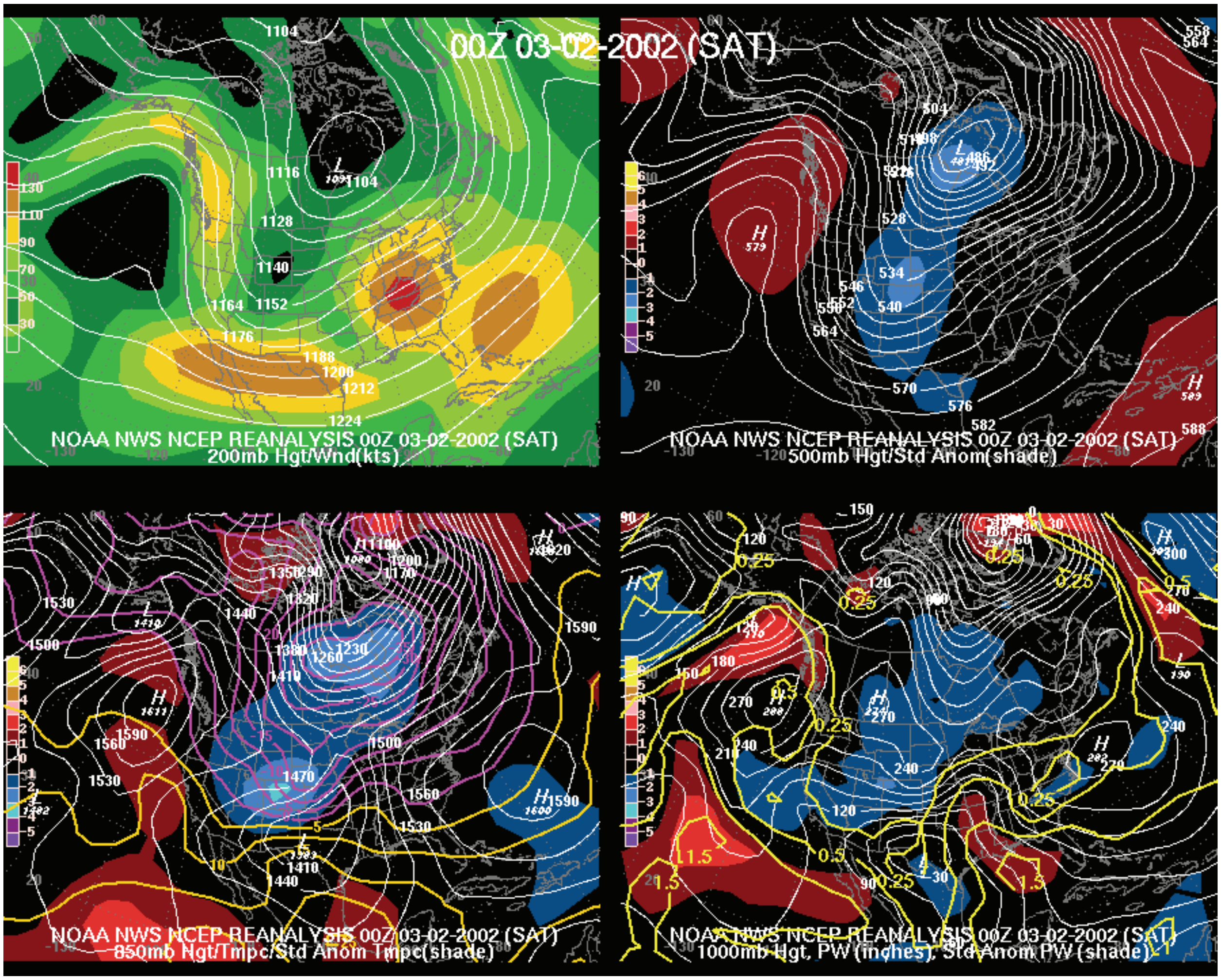
Appendix 5

Tucumcari Synoptic Example:



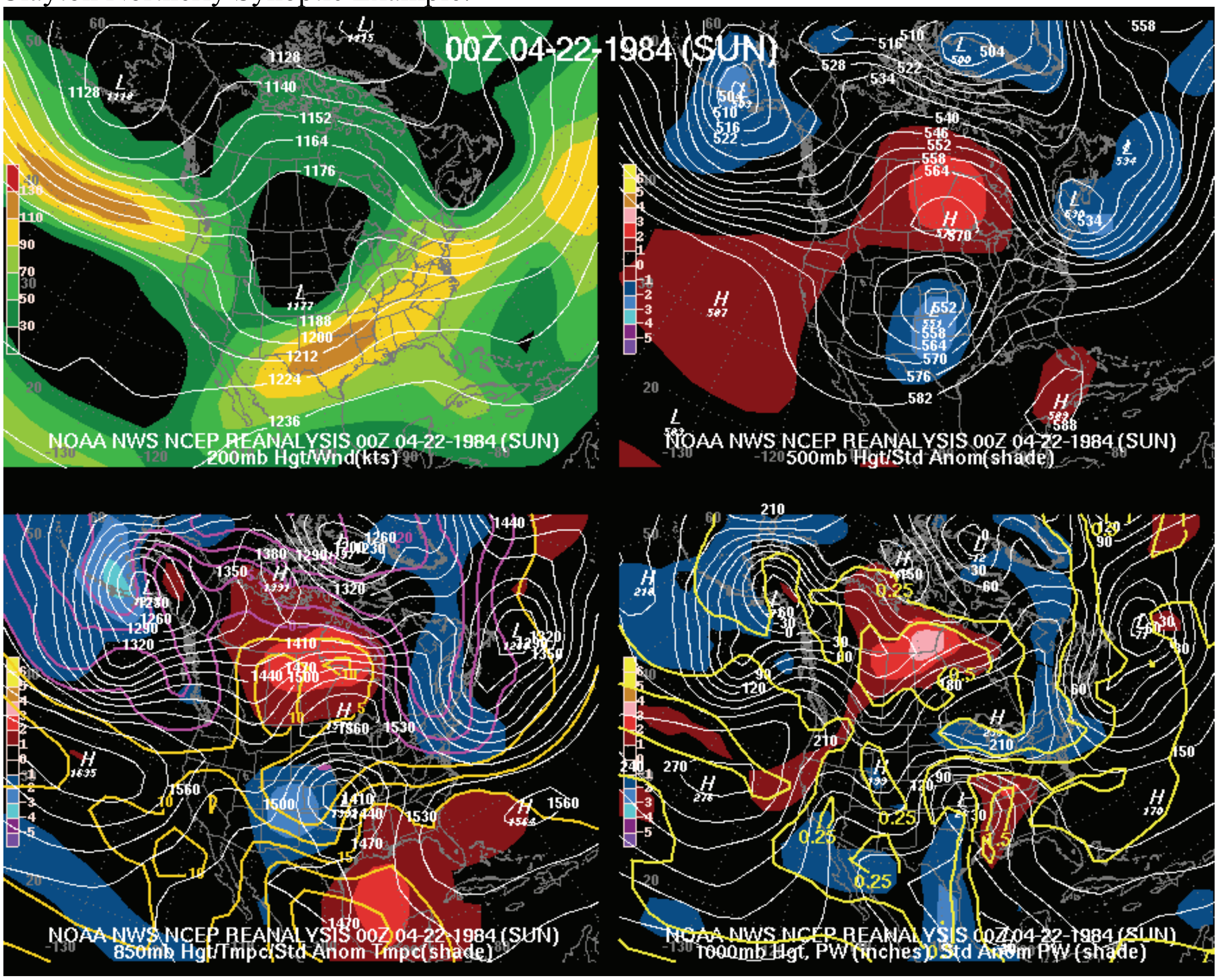
Appendix 6

Roswell Synoptic Example:



Appendix 7

Clayton Northerly Synoptic Example:



Appendix 8

Clayton Westerly Synoptic Example: