Program for Climate, Ecosystem and Fire Applications

Nevada 1999 Wildland Fire and Climate Season Assessment

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Final Report

desert research institute
university and community college system of nevada

Division of Atmospheric Sciences

CEFA Report 00-04

May 2000

Nevada 1999 Season Wildland Fire and Climate Assessment

Forward

This report describes the climate factors and impacts associated with the Nevada 1999 wildland fire season. The project was done under Task Order 5 of the Assistance Agreement (1422F915A80010) between the Bureau of Land Management Nevada State Office and the Desert Research Institute Program for Climate, Ecosystem and Fire Applications. For further information regarding this report or the project, please contact:

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NEVADA 1999 SEASON WILDLAND FIRE AND CLIMATE ASSESSMENT

by

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EXECUTIVE SUMMARY

This report provides an assessment of the climate factors associated with the Nevada 1999 wildfire season, the largest on record in terms of acres burned. The year also ranked second in the number of fires. Temperature, precipitation, relative humidity, wind speed and dry thunderstorms were all highly relevant factors regarding the season's outcome. These factors were examined in context of the fire season, and the primary findings of this study are as follows:

- A precipitation deficit in July (following a near to slightly above average winter and spring season) induced a rapid decline in live fuel moisture, setting up potential fire conditions for the remainder of the season.
- La Niña and its climatological associated precipitation patterns in Nevada may have played a role during late spring and early summer, but without some numerical modeling work it is difficult to say definitively that La Niña played a significant role in the season's outcome.
- Above average temperature from September through November contributed to the above average number of fires during these three months.
- Relative humidity was not an overall climate factor in August (though it may have contributed to some daily fire behavior). However, below average relative humidity was a contributing factor to September's active month.
- Except for August, wind speed does not appear to be a climatological factor in the season's outcome.
- Lightning activity was much below average in the northern portion of Nevada during July and September, but above average across the state in August. For this month the above average counts increased the probability of fire starts, though many areas with below average counts also had a substantial number of fire starts.
- Dry thunderstorms were a prevalent part of the season's fire activity – approximately 70% of all fire starts were naturally caused.
- A trough off of the northern California coast in conjunction with a very strong southwest monsoon was responsible for most of August's activity. September's above average number of fires is more related to low fuel moisture values due to above average surface temperature and below average relative humidity.
- The important climate factors found in this study have some predictability at various time scales. This implies that forecasts of these variables can be made for future planning purposes, though more applied research will be needed for some forecast variables.

INTRODUCTION

The 1999 Nevada wildfire season had the largest number of acres burned (approximately 1.9 million) within the past 30 years of record keeping, and probably since settlement began in the 1800s. In terms of number of fire starts within the same 30-year period, the season ranked second. Of the 833 starts reported in the Bureau of Land Management (BLM) 1202 data base, approximately 70% were caused by lightning.

As will be described below, climate played an important role in the season's activity. This should not be surprising as climate is a driving factor in the outcome of any fire year. However, for a particular year it is likely that only certain climate factors will be relevant. For 1999, precipitation, relative humidity, wind speed and dry thunderstorms were the most relevant factors regarding the season's outcome. This report describes some of the specific climate impacts on the 1999 Nevada wildfire season.

DATA DESCRIPTION

Five data sets were used to perform the analyses in this study. A basic description of the data used in the project is described below. In addition, some representative seasonal examples of live and 1-hour fuel moisture are also provided.

Precipitation

Precipitation anomalies were examined using the National Climate Data Center (NCDC) divisional precipitation data archived at the Climate Prediction Center (CPC). Given the typically low precipitation amounts that occur in Nevada during the summer months, monthly values were considered appropriate for the descriptive study. Great Basin live vegetation response to soil moisture typically occurs over longer periods (weekly to monthly) rather than daily. Precipitation is closely linked to live fuel moisture, and thus an important factor in fire start potential and behavior.

Temperature, relative humidity, wind speed

Remote Automatic Weather Station (RAWS) temperature, relative humidity and wind speeds were used to perform the analysis of surface climate characteristics associated with the fire season. Hourly values of these variables were obtained from the Western Regional Climate Center (WRCC) for 126 sites in and near Nevada. Long-term daily station climatologies were developed for each site using a minimum of 3 years data. At least 18 hours of data for the day had to be present for incorporation into the climatology. Monthly long-term means of maximum and minimum temperature and relative humidity were calculated, providing a baseline to compute monthly and daily anomalies. Temperature and relative humidity were further processed in a harmonics time series procedure to compute daily maximum and minimum climatologies. A monthly wind speed climatology was determined for the two periods 1200-1800 local time and 0200-0800 local time representing daytime and nighttime winds, respectively. These RAWS surface variables were selected as most important for fuel moisture characteristics and fire behavior.

Upper atmosphere variables

Geopotential height, relative humidity and wind direction are variables considered to be the most relevant for the upper atmosphere component of the descriptive study. Geopotential height gives an indication of ridge and trough patterns. Wind direction provides an indicator of source regions for upper-level atmospheric moisture and the overall mean flow (wind direction is directly linked to geopotential height patterns). Upper-level relative humidity provides an indicator of thunderstorm occurrence. In particular, dry thunderstorms can occur when moist air aloft is present with a dry lower troposphere. For example, positive relative humidity anomalies at 600 and 500 mb (approximately 15000-18000 feet) with below or near average anomalies at the surface up through around 700 mb (approximately 10000 feet) would suggest conditions appropriate for dry thunderstorm occurrence. Data for the upper atmosphere were provided by the NOAA-CIRES Climate Diagnostics Center.

Lightning

The cloud-to-ground lightning strike occurrence data set used in the study was provided by Global Atmospherics, Inc. This is based on the National Lightning Detection Network™ for the period 1994-99. The Automated Lightning Detection System data set from BLM for the period 1985-93 was also used in the establishment of a lightning climatology. All of the archived data consists of the time and location (latitude and longitude) of each strike. These data allow for an analysis of lightning occurrence in relation to natural fire start activity, and to compare the lightning season historically.

Fuel Moisture

Live and 1-hour fuel moisture data were used in the study as an indication of fire potential, and to determine their relation to climate variables. Representative sites in northern Nevada (3 each for live and 1-hour fuel moisture) were used in the analysis. These data were provided by the BLM Nevada State Office.

RESULTS

The results described below show that climate played an important role in the 1999 Nevada wildfire season in several ways. An analysis of each variable is provided in its respective section.

Using data from the BLM DI 1202 Individual Fire Report database for both human and natural caused fire starts, the significant fire season in Nevada began in the latter part May and ended in November. The number of fires from January through April was close to average. Nevada experienced an above average number of fires in May with the largest ones occurring in the southern Ely district. June’s fire count was slightly below average. July’s fire count was also below average, with those occurring mostly in the Elko and Ely districts. August was an extremely active month and well above average. It was also the most devastating in terms of acres burned - five of the nation’s largest fires of the year occurred in Nevada during this month. September continued to be quite active and well above average. October and November were also above average. In terms of strictly natural fire starts, July was about half of average, August three times the average, and September nearly four times the average.

The key question related to these statistics is what was the role of climate in creating a "slow" July, but a very active August and September?

Precipitation and live fuel moisture

Figure 1 provides a sequence of precipitation anomaly maps for the period November 1998 through November 1999. Standardized anomalies for climate divisions in the U.S. are given. These values are calculated by subtracting a long-term mean (1950-95) from the observed values and dividing by the standard deviation for the same 1950-95 period. It can be seen that much of Nevada was below average in precipitation during the winter season November 1998 through March 1999, though the western portion was near average. The winter season dry pattern reversed briefly during April in eastern and southern Nevada, but was average statewide during May. June's state pattern was similar to April. In July the pattern changed significantly such that the northern portion of the state was below average. August and September were back to near average, which is little precipitation anyway. October and November were below average. The anomalies for these two months contributed significantly to a late-ending fire season.

The precipitation anomalies can be directly linked to live fuel moisture (LFM), and the patterns shown in Figure 1 correspond to LFM measurements taken during the 1999 season. Figure 2 shows 1999 and long-term average LFM for the Panther, Wells and Fish Springs sites. These curves are fairly representative of other sites in the Battle Mountain, Carson City, Elko, Ely and Winnemucca districts during the 1999 season. The blue curve with solid triangle symbols represents the long-term LFM average (see bottom of graph for number of years), and the red curve with solid square symbols indicates the 1999 bi-weekly measurements.

The near to below average winter precipitation contributed to the LFM starting out at near or below average in early April (Panther and Wells). The near to above average April and near average May precipitation caused the LFM to increase during these months to near and slightly above average values. The LFM began declining in June even though the month was above to near average in precipitation depending on the location within the state. During June the precipitation anomalies kept the LFM near average, except for Wells which remained above average despite the decline. Of particular interest is the sharp decline in LFM during the latter half of June and throughout July. This was an important factor in establishing an increased risk of fire potential. The rapid decline can be attributed to the below average precipitation in the northern portion of the state. From August through the end of season the LFM remained fairly level in association with near average precipitation through September and below average during October and November.

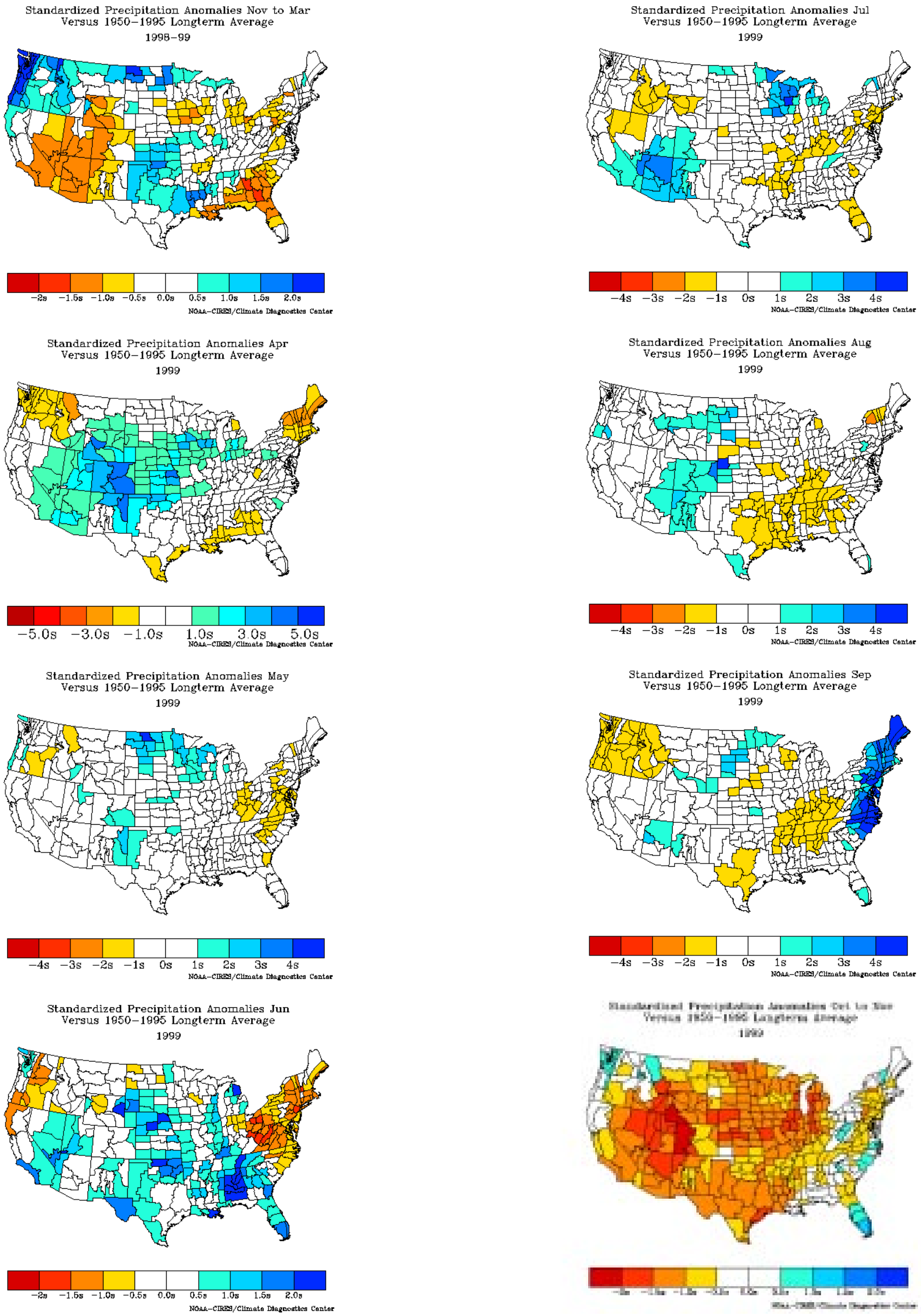


Figure 1. Standardized precipitation anomalies by climate division for the November 1998 through November 1999 period. Warm and cool colors represent below and above average precipitation, respectively (see color bars).

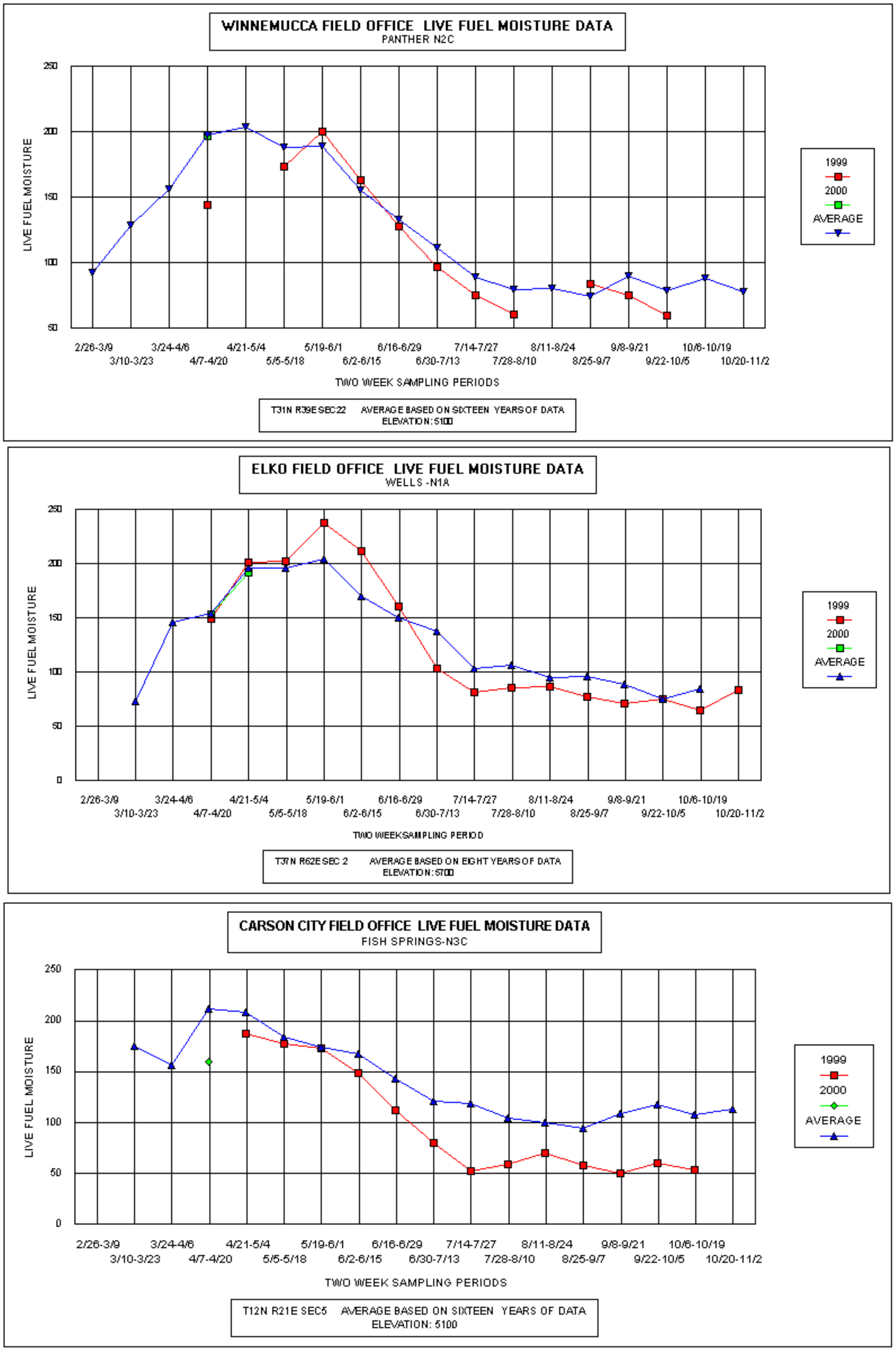


Figure 2. Bi-weekly live fuel moisture for the Panther, Wells and Fish Springs sites for 1999 (red curves) and a long-term average (blue curves).

1-Hour Fuel Moisture

Because of the fine fuel characteristics of Nevada, the 1-hour timelag fuel moisture (FM) is an important part of fire danger, especially the ignition and spread components. Relative humidity and temperature are two key weather variables that make up the 1-hour FM. Thus, from a climatological perspective relative humidity and temperature anomaly patterns determine the persistence of the 1-hour FM. For example, if relative humidity remains below average for longer periods such as a week, month or even season, then the 1-hour FM would remain at lower levels throughout the corresponding period.

Figure 3 shows 7-day periods of 1-hour FM for three sites in Nevada (Antelope Lake, Beacon and Coyote Wash) for the period May through October 1999. The minimum, maximum and average values are given by the red, blue and purple curves, respectively. The 1999 season is shown as the black curve, which for most of the season is at or below average. This pattern can be attributed largely to the temperature and relative humidity patterns described below. The relevance of the persistent below average 1-hour FM was an increased risk of ignition and spread throughout the season.

Temperature

Figure 4 shows RAWS monthly maximum and minimum temperature anomalies across Nevada for May through October 1999. These values are in degrees Fahrenheit. Some of the larger anomalies may be due to a short climatological baseline period (e.g., only 3 to 5 years versus a desired 15-30 years) and therefore not as extreme as first appears. Though not shown in this report, RAWS temperature values have been compared to divisional climate temperature data (similar to precipitation) which contains a long period of record. The adjective terminology used in this section refers to divisional standardized anomalies. Looking at maximum and minimum temperature separately is important to determine if the overall monthly anomalies are based primarily on daytime or nighttime values or both.

Spring and early summer temperature does not appear to be a particularly important factor in the season's fire activity. May, June and July were slightly above average (approximately 3˚F) for both maximum and minimum temperature. This encouraged fuel drying during June and July (Figure 2), but probably not to an unusual extent. However, it did contribute to the below average 1-hour FM in Figure 3.

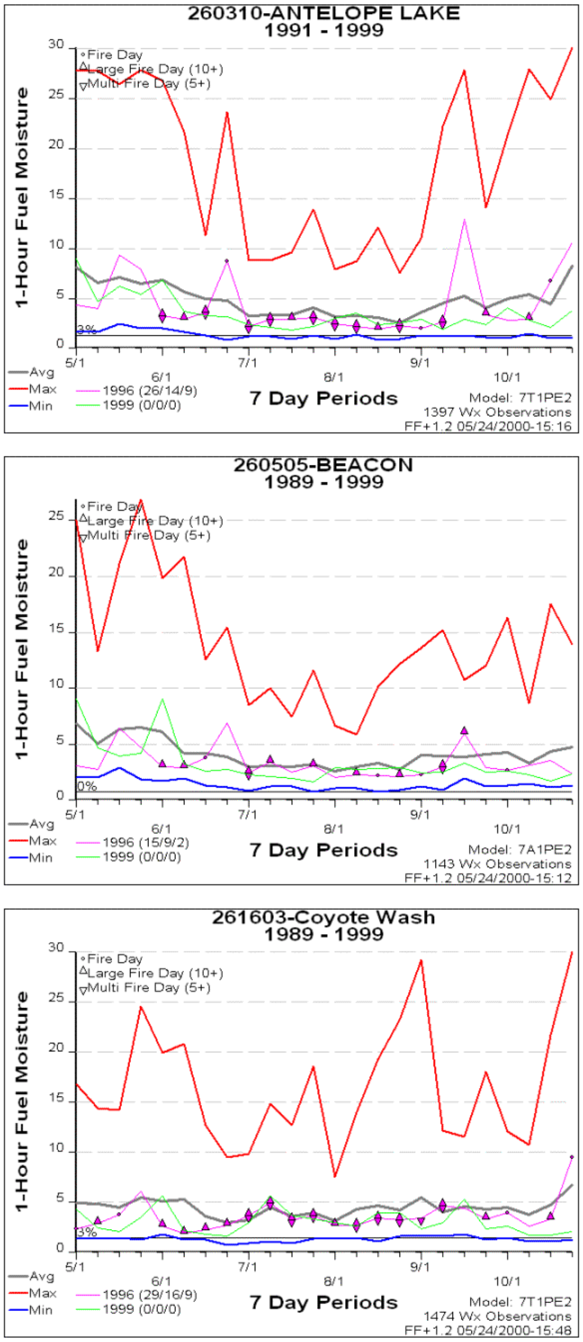


Figure 3. 1-hour fuel moisture for 7-day periods at the Antelope Lake, Beacon and Coyote Wash sites in Nevada. Line and symbol definitions are given on each graph.

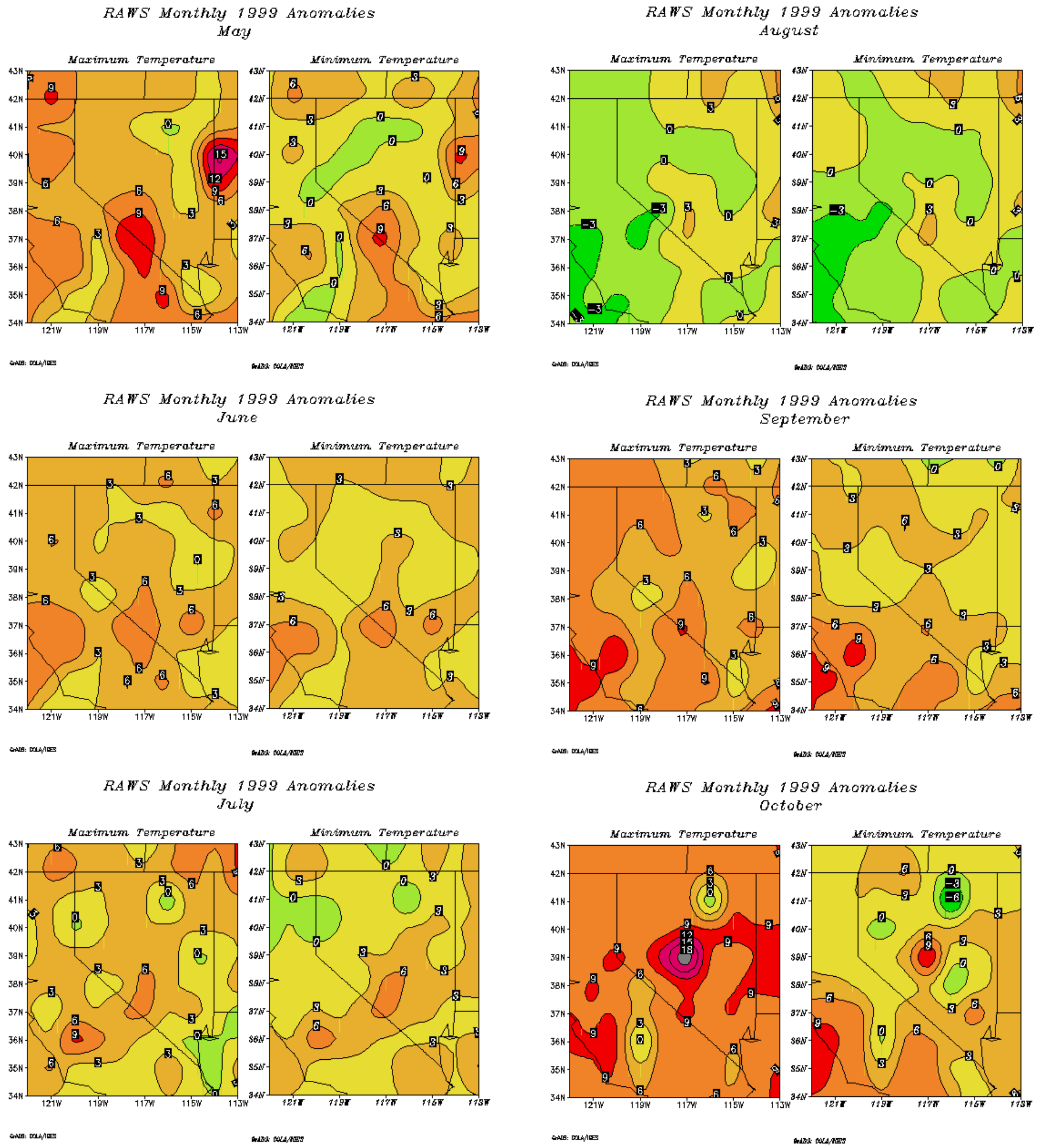


Figure 4. RAWS monthly maximum and minimum temperature anomalies for May through October 1999. Warm and cool colors represent above and below average temperature, respectively. Contour interval is 3˚F.

August was slightly below to near average going across the state from west to east. Above average cloudiness, particularly in western Nevada, contributed to the below normal temperature anomalies. Thus, temperature does not appear to be an important factor during the most active month of the season. Even the 1-hour FM in Figure 3 increased to the long-term monthly average.

September's maximum temperature was above average, and the minimum was slightly above. The above average temperature and below average relative humidity (to be discussed in the next section) during this month were contributing factors to the above average number of fires by keeping the 1-hour FM below average.

October and November (not shown) were above average in temperature over virtually all of the state. These anomalies in conjunction with below average precipitation were strong contributing factors to the extended fire season. The 1-hour FM remained below average at least through October (Figure 3).

Relative Humidity

Figure 5 shows RAWS monthly maximum and minimum relative humidity (RH) anomalies across Nevada for the May through October 1999 period. Maximum and minimum values are distinguished to indicate potential nighttime fuel moisture recovery versus the driest portion of the day. This analysis shows that RH played an important role during much of the fire season.

RH in May was also above average in the central and northeastern portion of the state, but below average elsewhere. The anomalies were larger during the nighttime period. The number of fires in May was above average, and most occurred in the areas of below average RH. The below average RH contributed to a below average 1-hour FM for most of the month (Figure 3). Also in May, there was considerable lightning activity across much of the state, especially during the last week. Thus, the combination of substantial lightning occurrence and below average 1-hour FM was a significant contributor to the above average number of fire starts.

During June the nighttime humidity was below average while the afternoon RH was near average. This maintained a below average 1-hour FM for most of the month (Figure 3). However, the lack of lightning and human causes kept the month below average in the number of the fires.

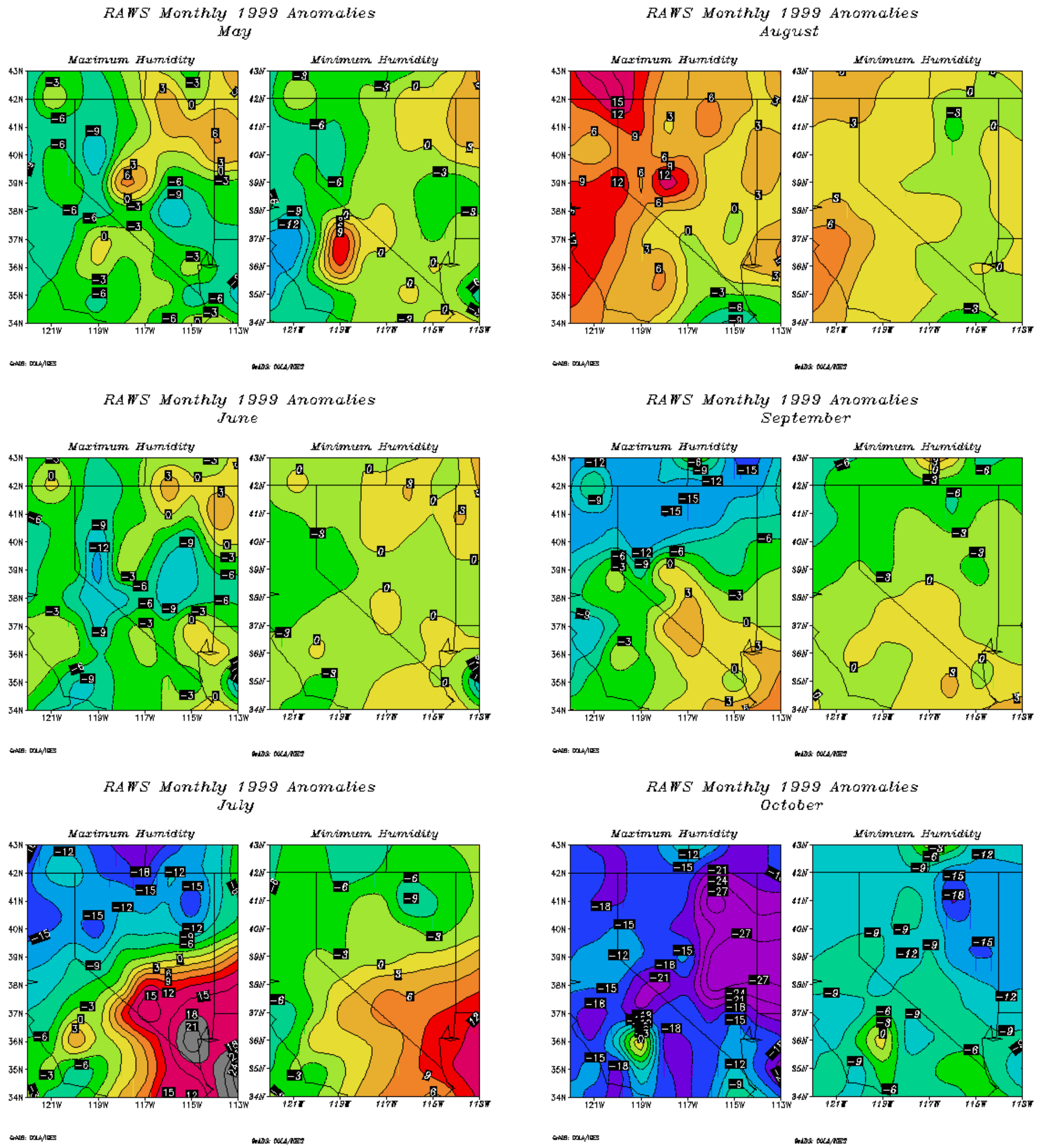


Figure 5. RAWS monthly maximum and minimum humidity anomalies for May through October 1999. Warm and cool colors represent above and below average humidity, respectively. Contour interval is 3%.

A very interesting pattern emerges in July, especially the maximum RH. Nevada is clearly divided by above average RH in the southern portion and below average in the north. This reflects the occurrence of the southwest monsoon over the southern portion during July with the dry conditions over the north associated in part with below average precipitation and slightly above average temperature. This pattern also appears with the minimum RH, but with less magnitude. For much of northern Nevada, the 1-hour FM remained below average during July (Figure 3). Though the number of human caused fires was near average for the month, the natural caused starts was below average. This was partially due to that the lightning activity in northern Nevada was below average during the month (Figure 9).

During August the afternoon RH is near average, while much of the northern portion of the state is above average during the night. This is probably a reflection of numerous thunderstorms during the month with virga and some precipitation increasing low-level RH. The 1-hour FM in Figure 3 did increase to around the monthly average values. However, RH during August probably contributed less to the fire activity than during other months.

September's RH pattern was similar to July – the state is divided with below average RH in the north two-thirds and above average RH in the southern one-third. The pattern is strongest for the nighttime (maximum) RH. Combined with above average temperature, the 1-hr FM was below average for most of the month (Figure 3). Most of the fires during the month were located in the areas of below average RH even though these areas corresponded with below average lightning strikes (Figure 9).

Wind

Figure 6 shows the RAWS monthly May through October 1999 wind anomalies for the periods 1200-1800 and 0200-0800 local time. These times represent the typical occurrence of the maximum and minimum temperature. Since maximum wind speeds in Nevada during the summer correspond to the time of maximum daytime heating, and vice versa for the minimum wind speed, these time periods will generally capture the diurnal cycle of wind. It is also relevant to note here that wind discussed from a monthly climatological perspective may be different from that on a daily fire behavior perspective. Wind is particularly important for the spread component of fire danger.

May wind speed was below average and June was slightly below average. Thus, wind did not act as an unusual drying factor during the spring and early summer months.

In July, daytime wind speed anomalies were slightly above average, and this may have aided in drying along with the below average precipitation and slightly above average

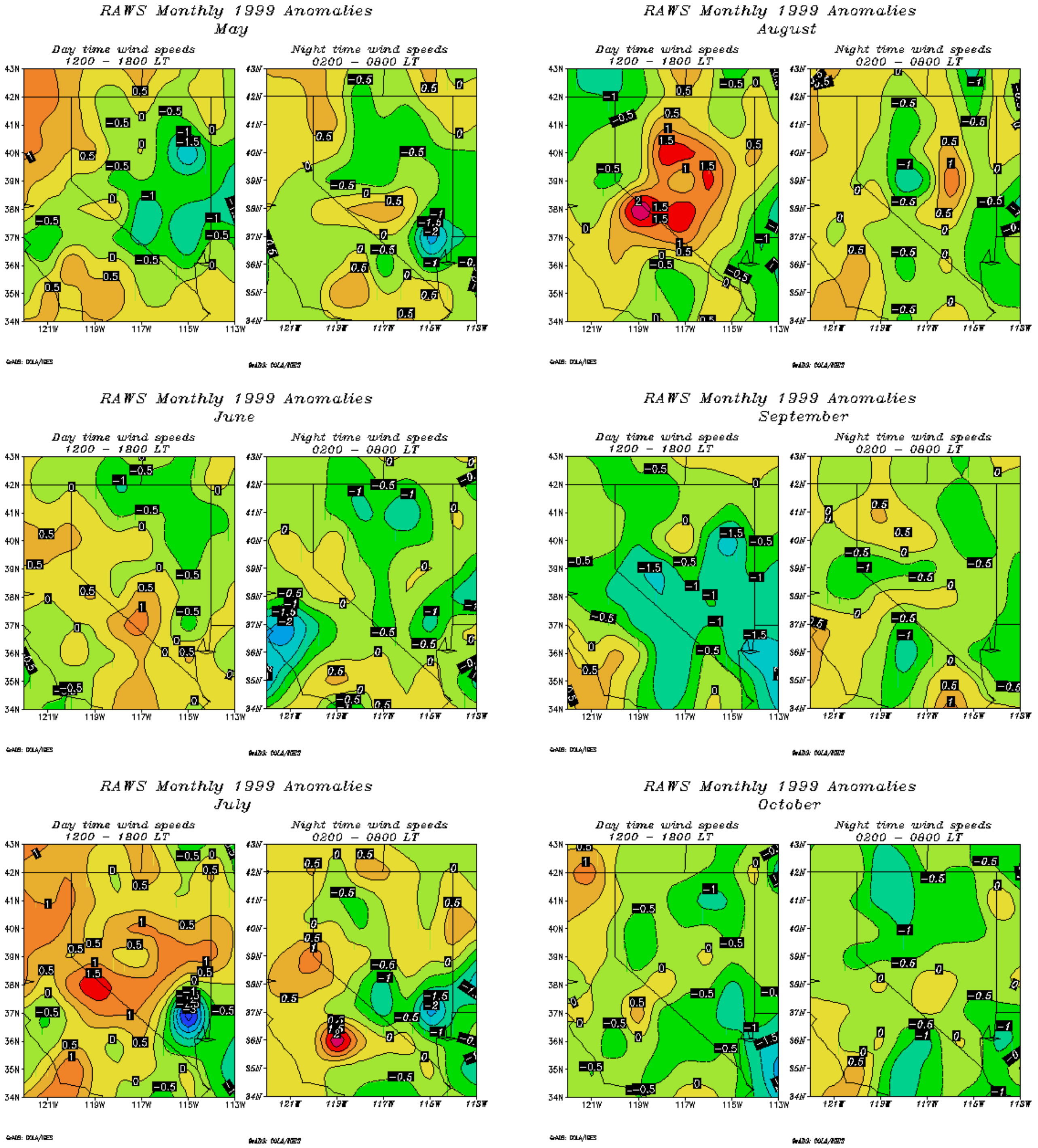


Figure 6. RAWS monthly wind speed anomalies (mph) for May through October 1999. Warm and cool colors represent above and below average wind speed, respectively. Contour interval is 0.5 mph.

temperature anomalies. At Antelope Lake and Beacon there was a decease in the 1-hour FM during July of which wind could have been a contributing factor.

In August a large portion of the state had above average daytime wind speed, but near average during the night. This may be due in large part to extensive thunderstorm activity during the month creating microbursts and outflows. The positive daytime wind anomalies during August would have likely aided in large fire growth.

In September the daytime wind anomalies were below average and the nighttime near average. Thus, wind probably did not play an overall significant role during this month. However, it is likely that above average wind speed did play a role in some of the large fire growth that occurred during the month. One problem in using a sparse data network such as RAWS is the large distances that can occur between the observation and event locations.

Upper air

The upper air circulation patterns are largely responsible for determining surface anomalies. In particular, focus is placed on three variables in association with the fire season – 500 mb geopotential height, *u* and *v* wind streamlines, and relative humidity. The geopotential height indicates ridge and trough patterns, the streamlines provide wind flow and moisture flux sources, and relative humidity an indication of available moisture. These factors are most relevant to natural fire starts, which will be the focus of the discussion in this section.

Figure 7 shows the 500 mb geopotential heights and height anomalies for May through September 1999, representing the most significant part of the natural fire start season. For the western U.S., May was dominated by a deep trough centered over the British Columbia coast. During the last week in May when most of the natural fires occurred, the trough deepened over southern Nevada providing the necessary dynamics for thunderstorm activity. As a result, May wound up having an above average number of natural fires.

In June the trough persisted over the West. Despite this, there was not sufficient upper-level moisture and dynamics to generate thunderstorms. Thus, June was well below average in the number of natural fire starts.

July was below normal in natural fire starts as well. During the month a weak trough was present off of the northern California coast and a weak ridge was situated over the Midwest. This lead to a generally southwest flow pattern aloft, which is not conducive to thunderstorms and natural starts as will be discussed later. However, the southwest monsoon did extend into southern Nevada during much of the month, yielding above average lightning counts (Figure 12).

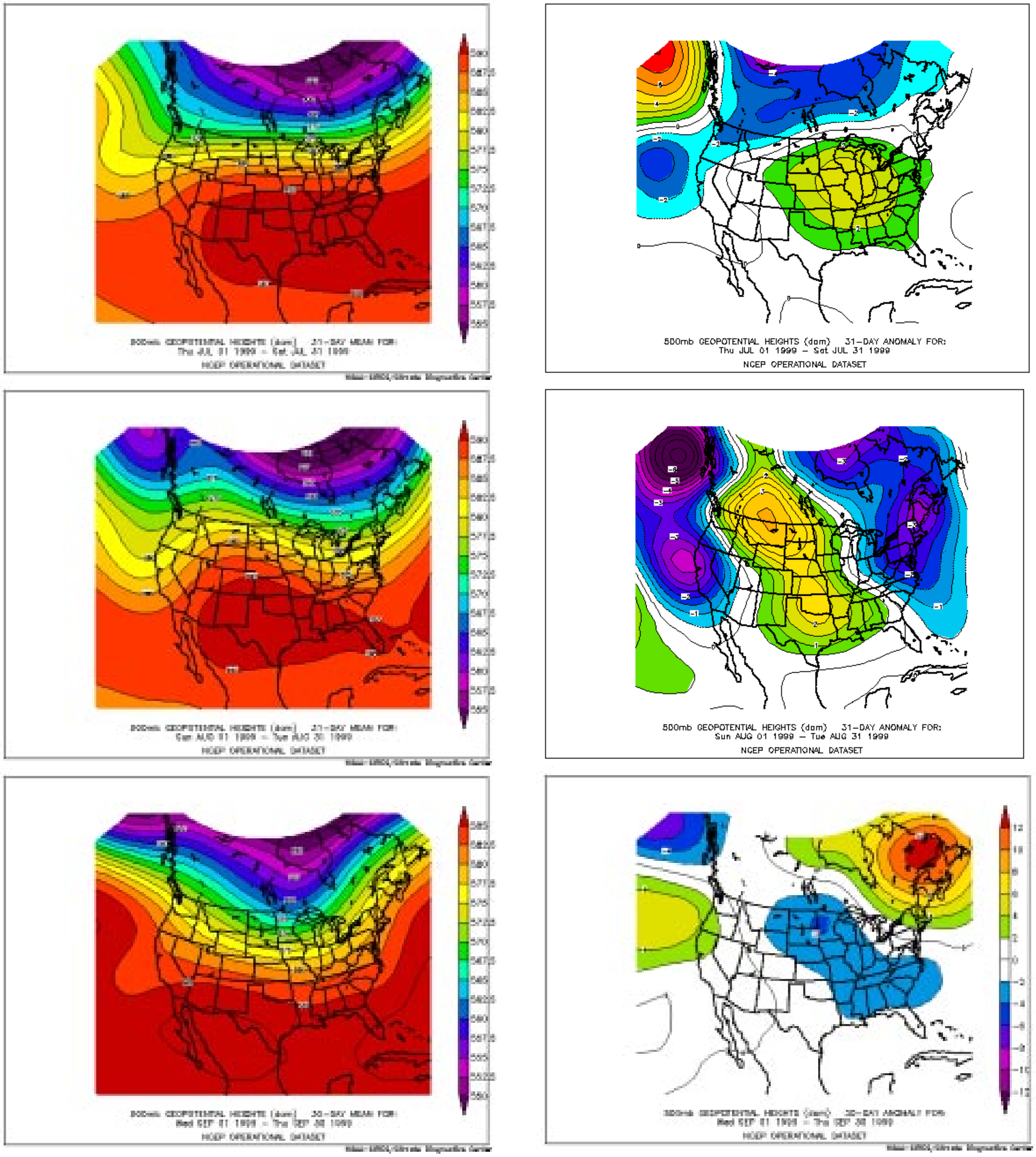


Figure 7. 500 mb geopotential heights (left column) and height anomalies (right column) in decameters for July through September 1999. Warm and cool colors as indicated on the color bar are higher and lower heights, respectively.

In August the trough off of the coast deepened considerably and a ridge formed over the Rocky mountains and western plains. This pattern encourages flow from the southwest monsoon region, provides the necessary dynamics for convective development and thus increases the chances of thunderstorm activity over Nevada. Indeed, much of Nevada did have substantial lightning activity during the month (Figure 12), and in combination with low 1-hour FM caused a well above average number of natural fires for the month.

The mean flow in September was more west-northwesterly across Nevada, reducing the influence of the monsoon, but allowing for more shortwave disturbances to cross the state. Thunderstorm activity was below average in the northern portion of the state (Figure 12), but above average in the south, due in part to available moisture in the monsoon region. However, the influence of the upper-level circulation during September on natural fire starts was not so much from dynamics and thunderstorms, but rather allowing for above average surface temperature and below average RH, and consequently below average 1-hr FM. Thus, even reduced lightning activity could still cause a substantial number of fires.

It is desirable to have a basic understanding of the upper-level circulation pattern appearance during typical active and non-active fire start years. Figure 8a through c shows composites of July through September 500 mb wind streamlines for active and non-active natural fire start years. These were constructed by sorting and ranking the years for the period 1970-99 for each month based on the number of natural fire starts. Winds, by separating out the *u* and *v* components, are then combined and averaged for the top and bottom ten years of the ranked list, and plotted as streamlines to create a typical wind flow pattern and moisture source region associated with above and below average natural fire start years. This work is based on the results of the thesis work by Hall (1998).

At first glance the two July composites in Figure 8a appear quite similar. However, the key difference is during active years when the wind flow coming into Nevada is more southerly compared to southwesterly during non-active years. Since the streamlines can be traced back to an origin point, the beginnings of upper-level moisture during active years is from the warmer and more convective eastern Pacific region compared to the cooler and less convective Pacific region during non-active years. This southerly flow is also indicative of the southwest monsoon as being a substantial component of the Nevada fire activity during July.

The composites are similar in appearance for August (Figure 8b) as they are for July. The only obvious difference is that during non-active years, the southwest high pressure center is shifted closer to Texas. The southwest monsoon typically continues to be active during August, and would also have a significant influence on Nevada fire starts during the month.

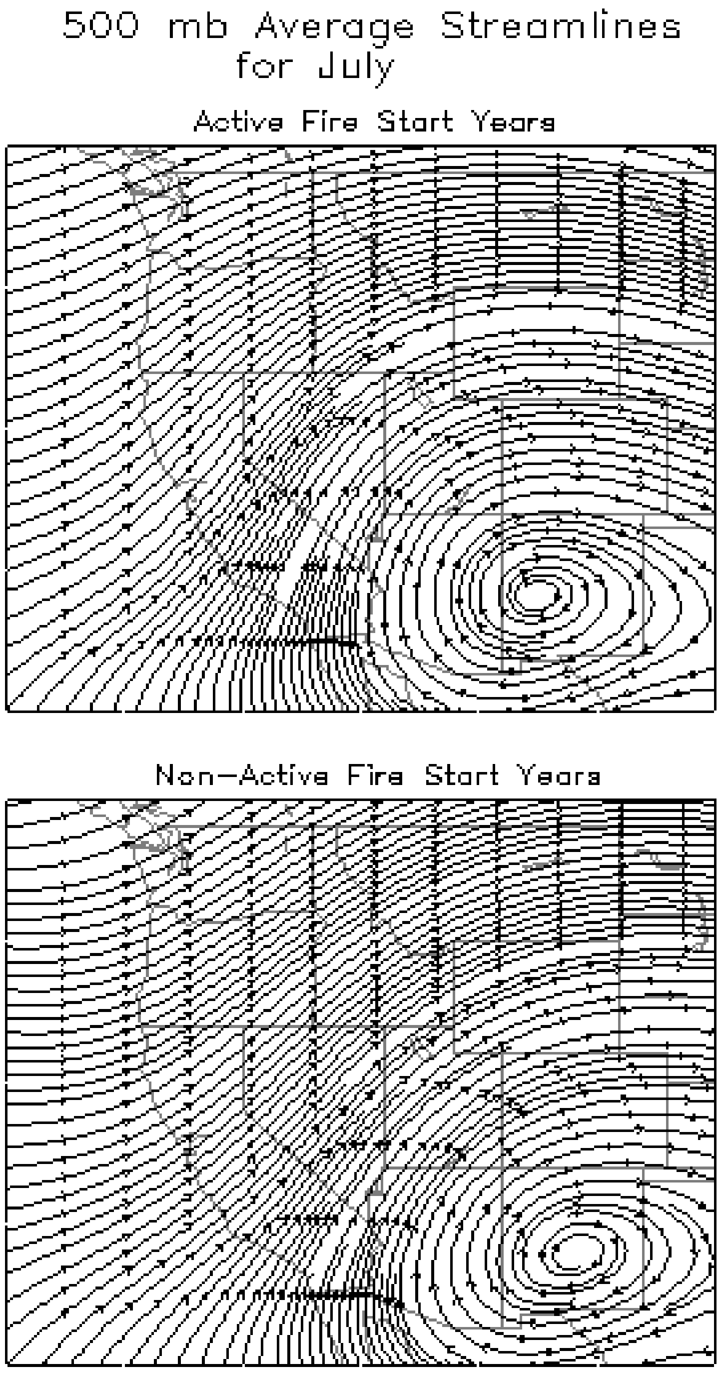
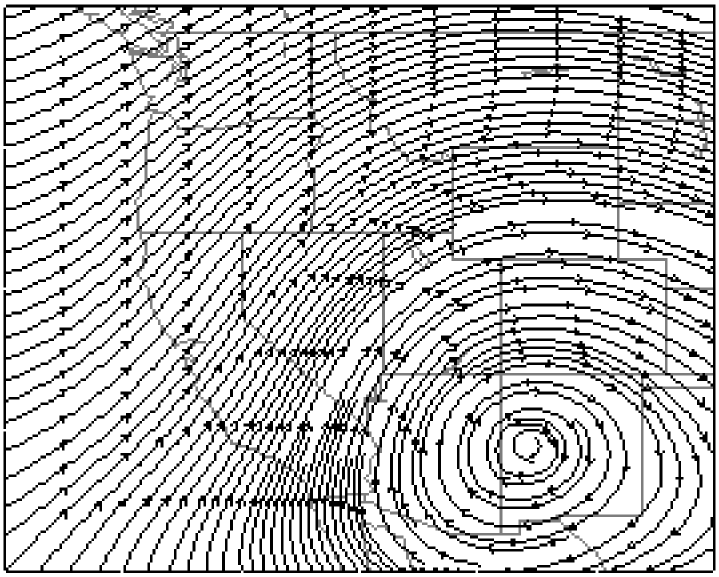
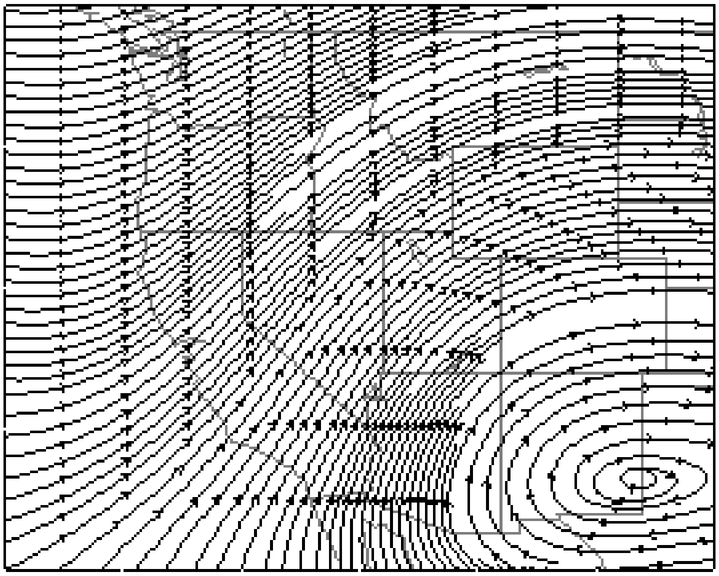


Figure 8a. Composite 500 mb *u* and *v* wind streamlines for July active natural fire start years (top) and non-active years (bottom).



500 mb Average Streamlines
for August

Active Fire Start Years

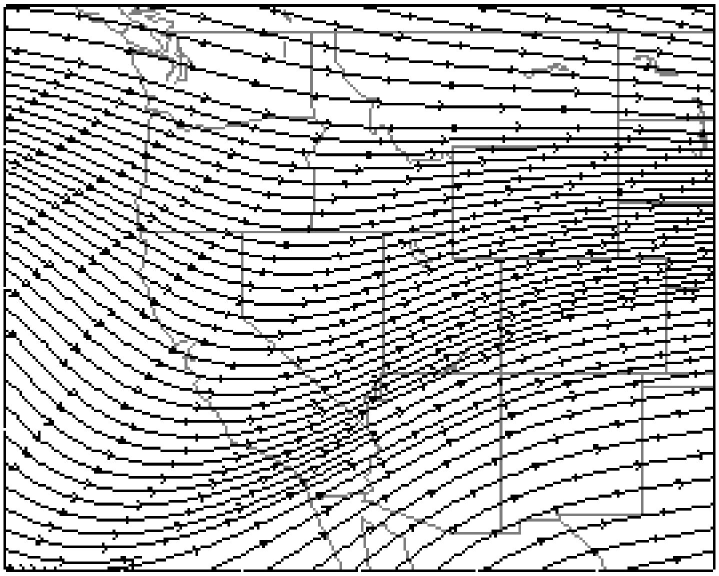


Non-Active Fire Start Years

Figure 8b. Composite 500 mb *u* and *v* wind streamlines for August active natural fire start years (top) and non-active years (bottom).

500 mb Average Streamlines
for September

Active Fire Start Years



Non-Active Fire Start Years

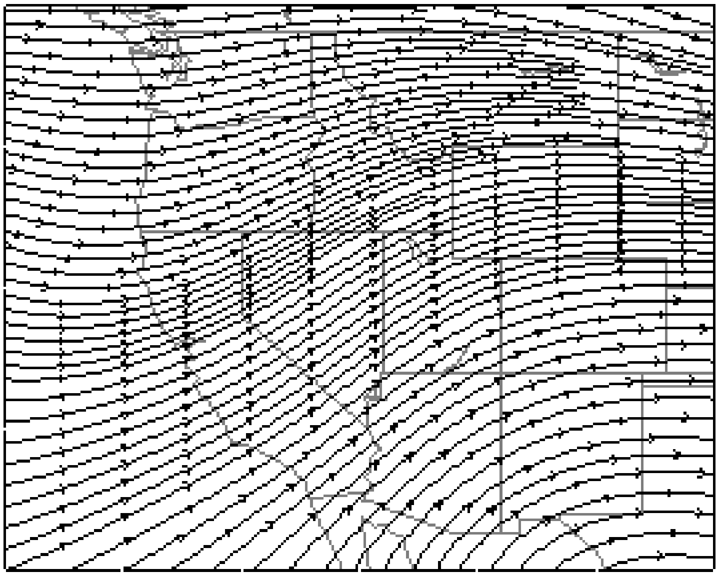


Figure 8c. Composite 500 mb *u* and *v* wind streamlines for September active natural fire start years (top) and non-active years (bottom).

The flow changes considerably in September to more west-northwesterly during active years, while remaining southwesterly during non-active years (Figure 8c). During active years the more northwesterly flow typically would bring with it cooler air aloft and the development of short waves in association with the weak trough over California and the eastern Pacific. This would provide for the necessary dynamics for some thunderstorm development, while at the same time keeping the surface and lower levels relatively warm and dry (and thus reducing 1-hr FM).

Similar types of composites can be done with 500 mb RH anomalies. RH anomalies at this level are an important indicator of the potential for dry thunderstorms as upper-level moisture with dry lower levels is a necessary condition. Of course other dynamics must be in place for convection formation to begin with, such as shortwaves. Figures 9a through c show RH anomaly composites constructed using the same active and non-active years as the streamlines above, except anomalies are combined instead of actual values. Blue contours denote below average RH and red contours above average RH. The green shaded areas indicate regions of small interannual variability (reduced variance associated with the median of the composites; Brown and Hall 1999).

In July (Figure 9a) positive RH anomalies typically occur during active years and negative anomalies during non-active years. That is, above average RH during active years and below average during non-active years. During active years, RH increases by as much as 5%, which on a daily basis may seem insignificant, but on a monthly scale is quite large. The pattern of the positive RH anomalies during active years suggests the southwest monsoon region as being a primary source. The reduction of RH during non-active years suggests a less strong monsoon, and/or perhaps more confined over New Mexico.

The August active year composite pattern (Figure 9b) is similar to July, except there is more year-to-year variability. RH values are typically around 5% above average. The non-active years is somewhat different from July in that over much of the southwest the RH anomalies remain positive, except over Nevada where RH values are typically near or slightly below average.

In September the patterns for active and non-active years are different from the previous two months. During active years, positive anomalies of around 3% occur, but this in only the northern portion of the state. This pattern matches the northwest flow seen in the streamlines, which defines a boundary between the cooler north and warmer south. The southern portion may still be under some slight influence of the monsoon region, but it is not a strong pattern. During non-active years, there are negative RH anomalies over south-central Nevada, but the northern portion of the state is not too different in appearance from active years. This indicates that there

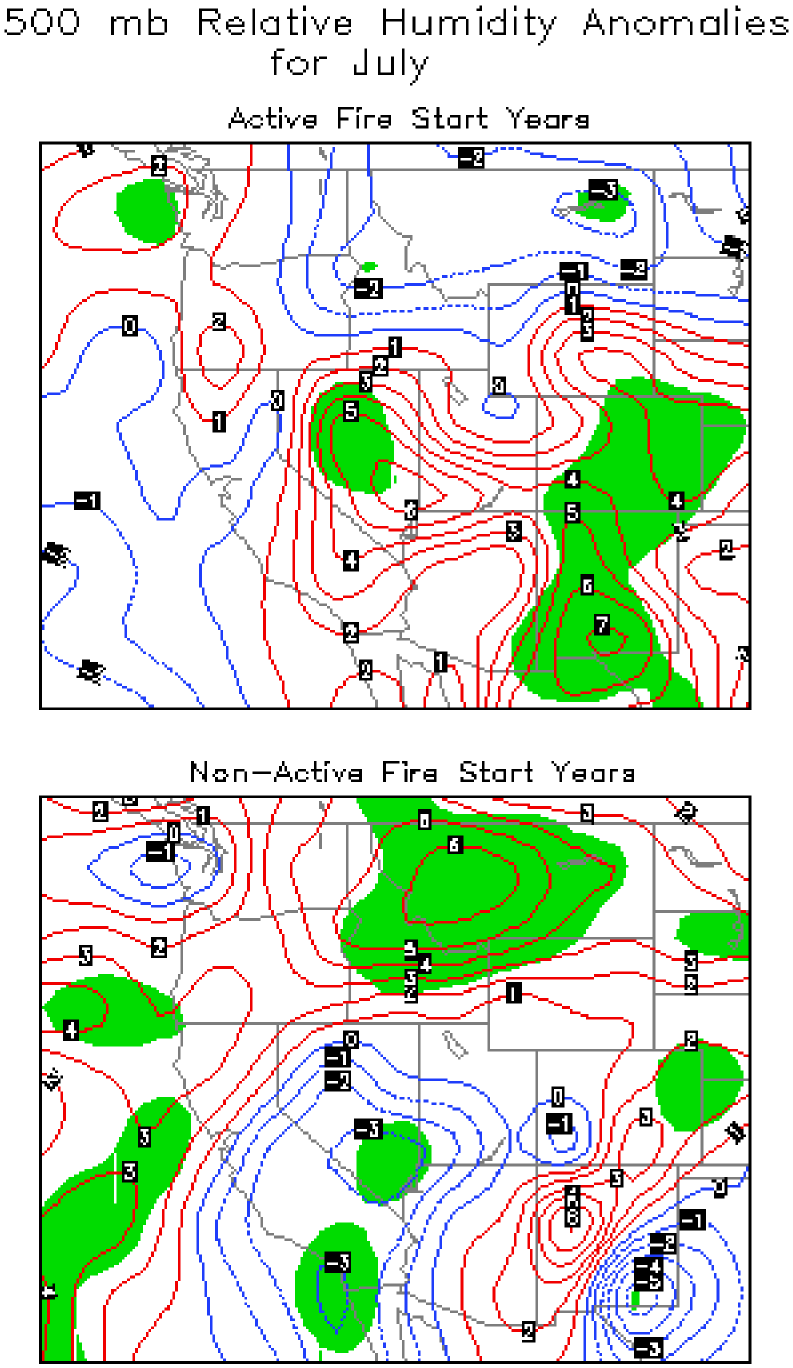
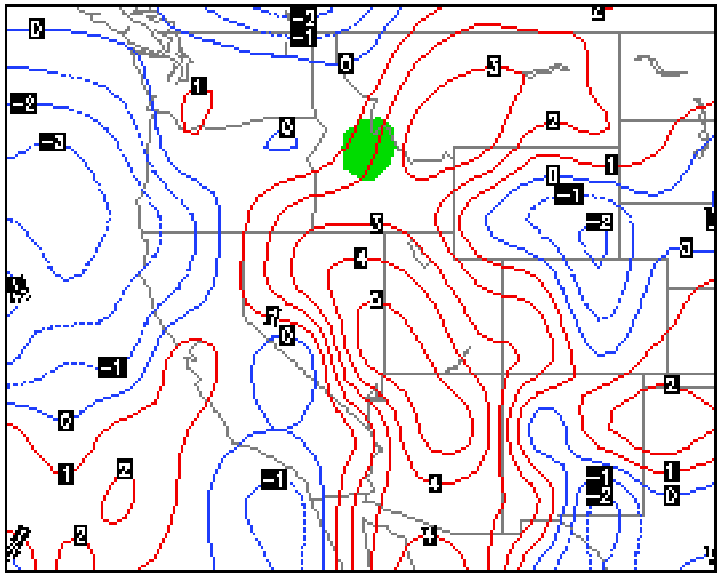


Figure 9a. Composite 500 mb relative humidity anomalies for July active natural fire start years (top) and non-active years (bottom). Red lines indicate positive humidity anomalies and blue negative. Green areas are indicators of generally less interannual variability.

500 mb Relative Humidity Anomalies
for August

Active Fire Start Years



Non-Active Fire Start Years

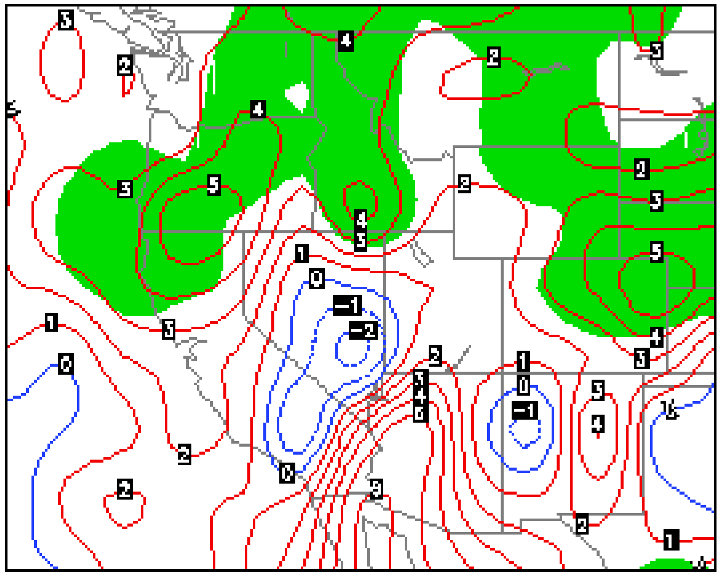


Figure 9b. Composite 500 mb relative humidity anomalies for August active natural fire start years (top) and non-active years (bottom). Red lines indicate positive humidity anomalies and blue negative. Green areas are indicators of generally less interannual variability.

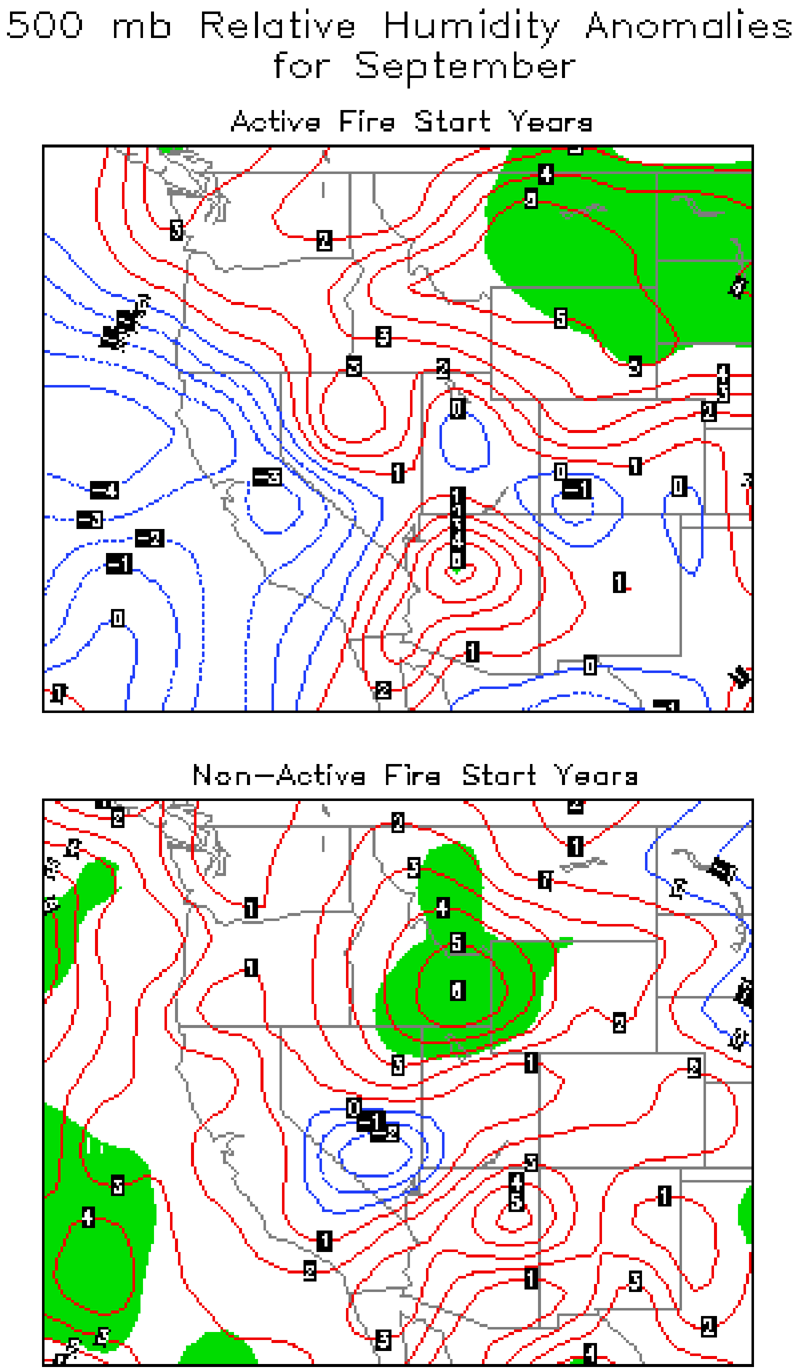


Figure 9c. Composite 500 mb relative humidity anomalies for September active natural fire start years (top) and non-active years (bottom). Red lines indicate positive humidity anomalies and blue negative. Green areas are indicators of generally less interannual variability.

is either a lesser role for upper-level humidity and dry thunderstorms in September, or that closer regional examination needs to be taken.

It is of interest to examine the 1999 streamline and RH anomaly patterns, and compare them to the composites and another recent very active fire year, 1996. Figures 10a through c shows both the 1999 and 1996 streamlines for July through September.

During July (Figure 10a) 1999, the streamlines were more southwesterly and similar to the non-active year composite (Figure 8a). However, in 1996 the southwest high pressure center had shifted to eastern Arizona, with strong southerly flow curving up and over southern California and then into Nevada. In August (Figure 10b) 1999, the combination of southerly flow from the monsoon region and the California coast trough is readily apparent. The flow pattern for August 1996 was similar to that of July 1996. For September (Figure 10c) both years resemble the composite active year pattern with the west-northwest flow over Nevada, except that the trough over California is highly amplified during 1999.

Monthly 500 mb RH anomalies for both years can be examined in a similar manner for comparison (Figures 11a through c). During July (Figure 11) 1999 the positive RH anomalies are confined to the southern portion of the state, suggesting that the monsoon encroached the state but not far enough up to increase lightning strike activity in the northern portion (Figure 12). In 1996, the monsoon moisture was spread over nearly the entire state. In August (Figure 11b) 1999 there is evidence of moisture advection from the monsoon region, but also from the California trough. August 1996 looks similar to July 1996 as the monsoon moisture continued to dominate the state. In September (Figure 11c) 1999 the positive anomalies are centered over Nevada, but during 1996 are spread over nearly the entire West.

Comparing these two years suggests there are some general similarities between the two years and with the composites, but there are also some substantial differences. The differences between the two years is a good example of interannual variability. In general, the important upper atmosphere factors are the moisture supply from the southwest monsoon region, and a trough of off California during July and August, and a west-northwesterly flow pattern in September to bring in shortwaves that provide the dynamics for thunderstorm development.

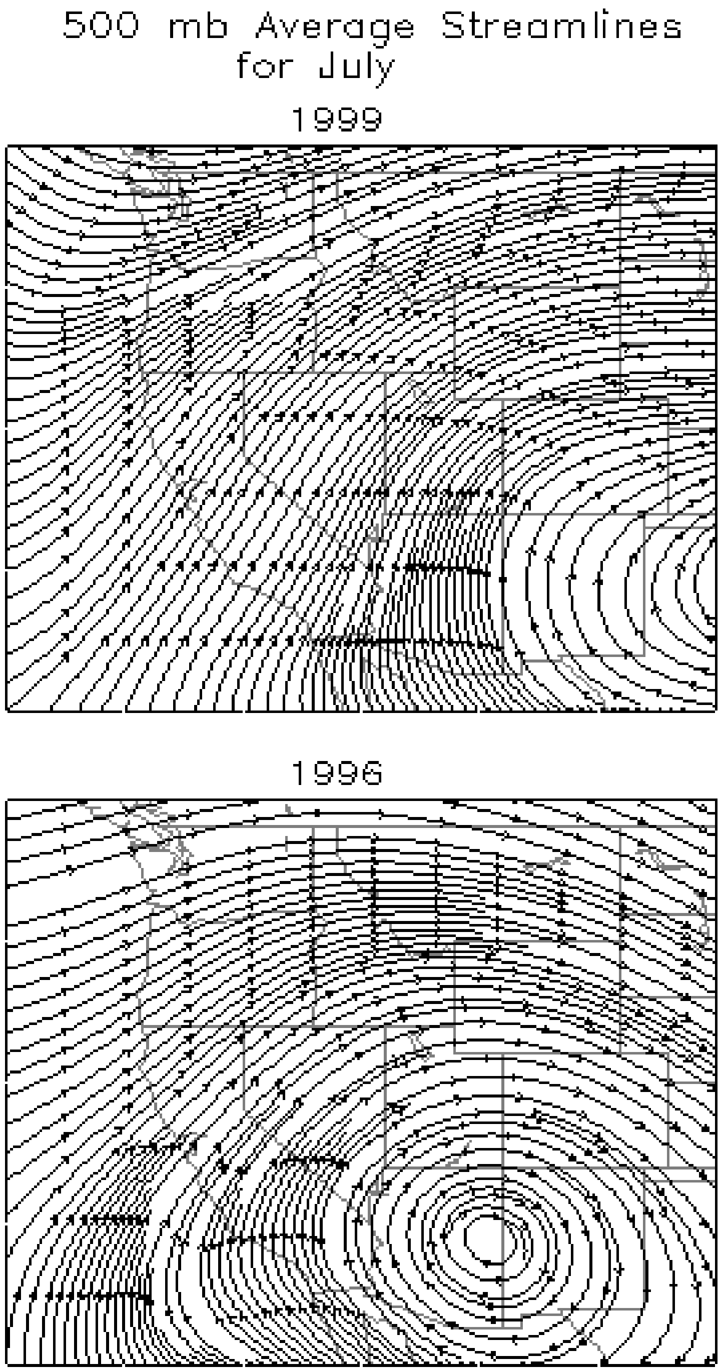


Figure 10a. 500 mb *u* and *v* wind average streamlines for July 1999 (top) and 1996 (bottom).

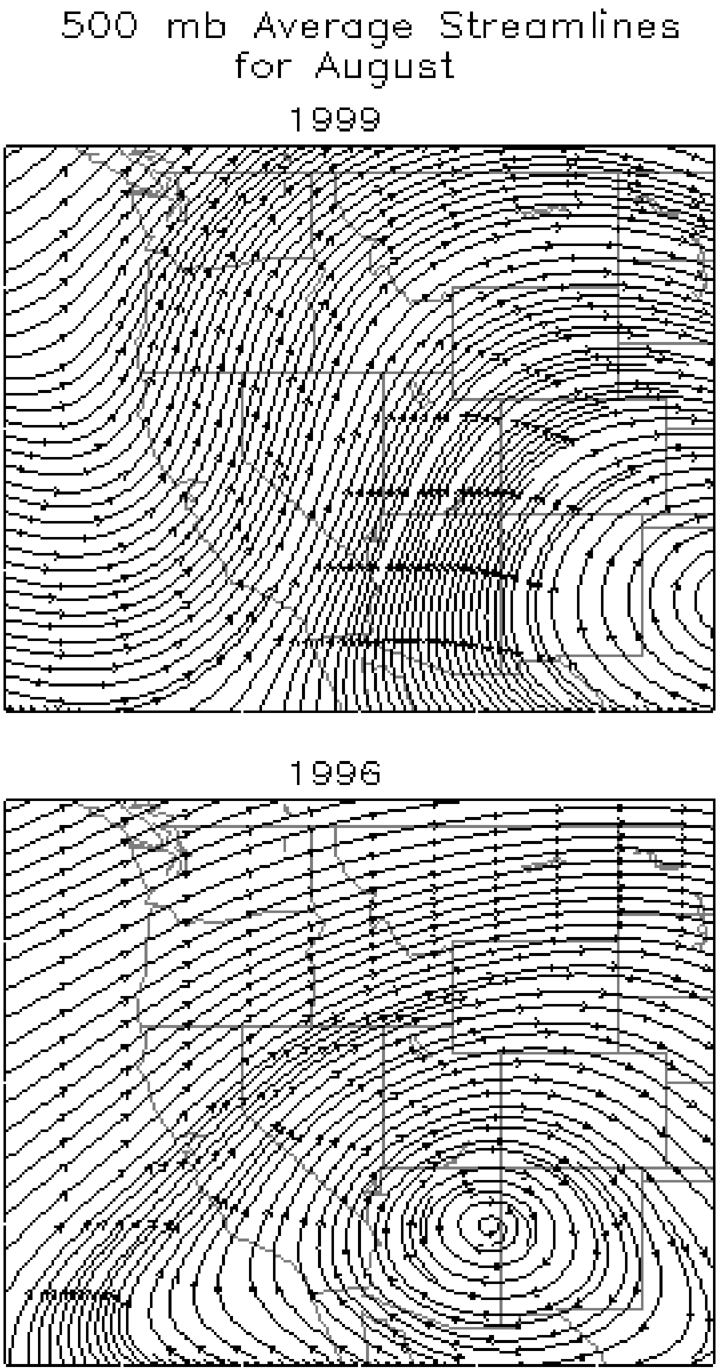
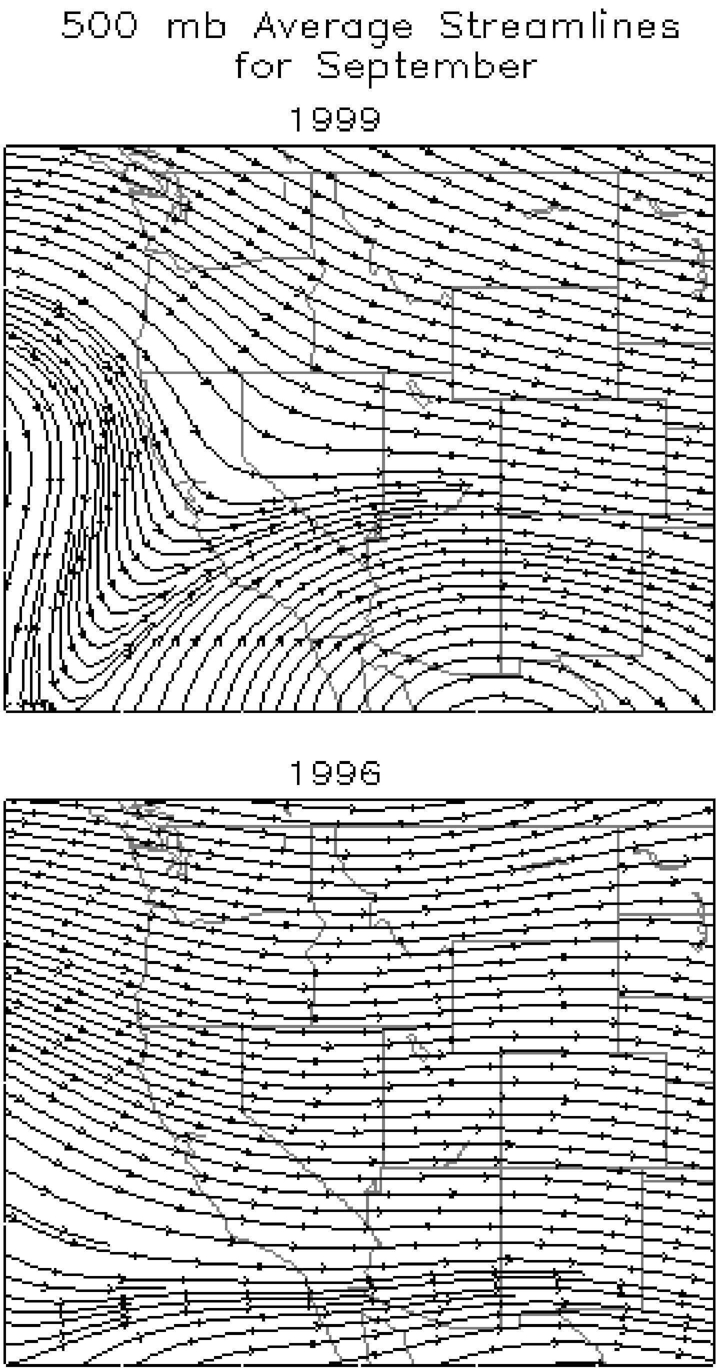


Figure 10b. 500 mb *u* and *v* wind average streamlines for August 1999 (top) and 1996 (bottom).



500 mb Average Streamlines for September

1999

1996

Figure 10c. 500 mb *u* and *v* wind average streamlines for September 1999 (top) and 1996 (bottom).

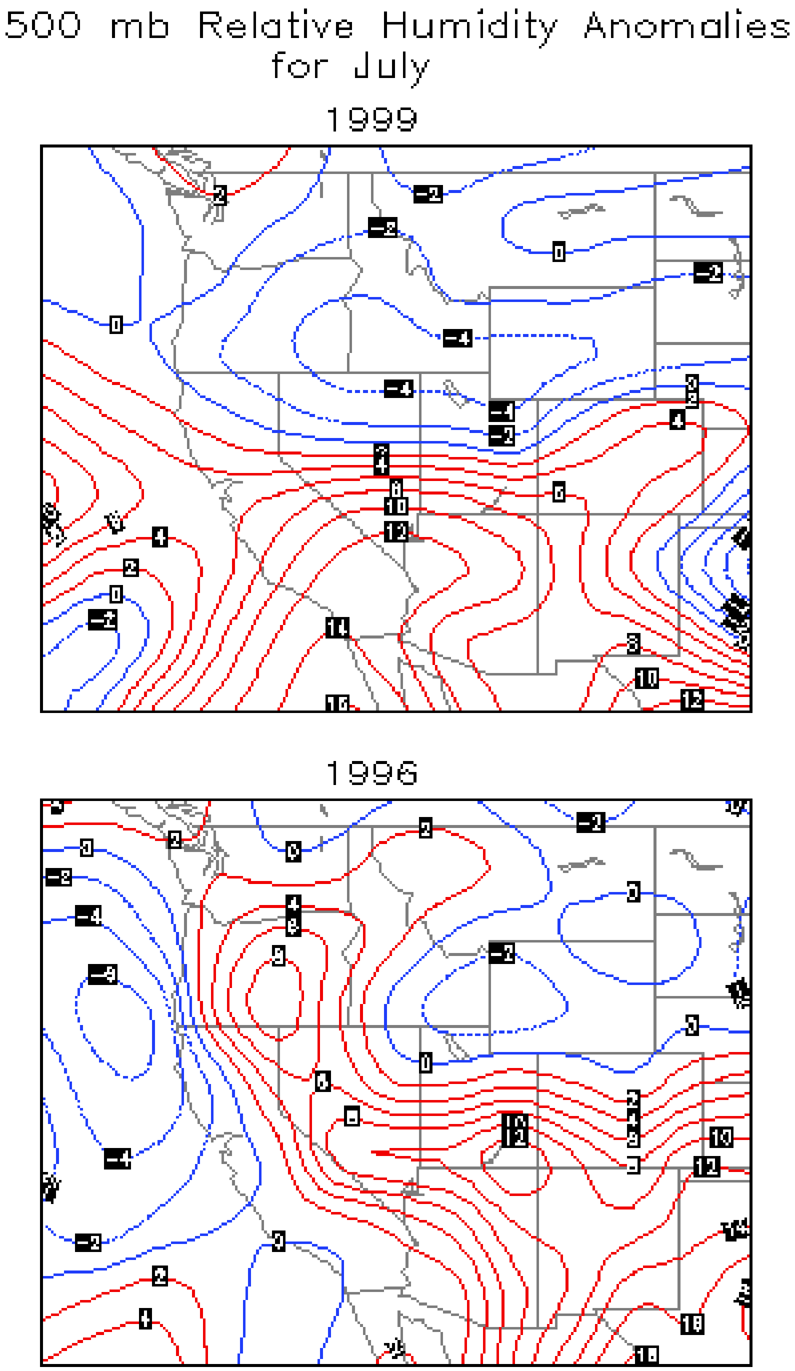


Figure 11a. 500 mb RH anomalies for July 1999 (top) and 1996 (bottom). Red lines indicate regions of positive anomalies, and blue lines negative anomalies.

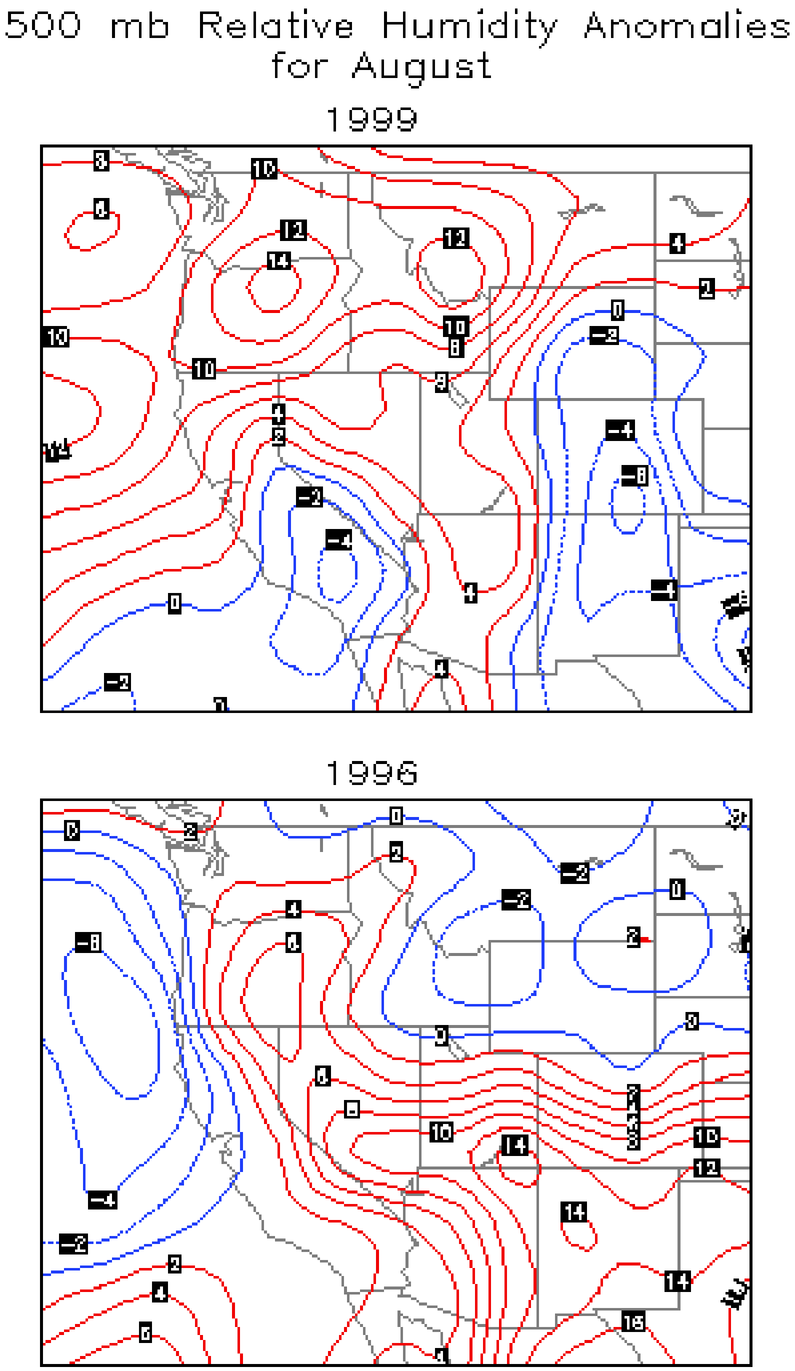


Figure 11b. 500 mb RH anomalies for August 1999 (top) and 1996 (bottom). Red lines indicate regions of positive anomalies, and blue lines negative anomalies.

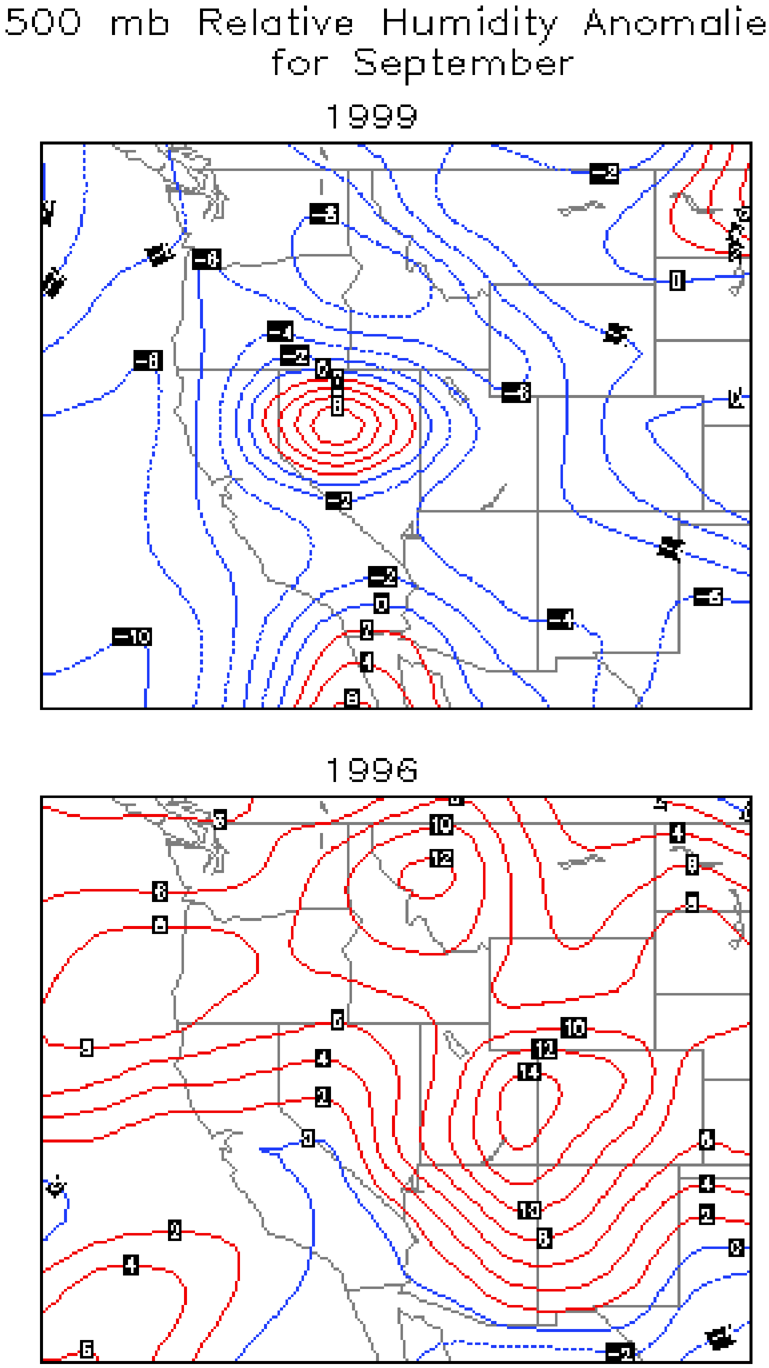


Figure 11c. 500 mb RH anomalies for September 1999 (top) and 1996 (bottom). Red lines indicate regions of positive anomalies, and blue lines negative anomalies.

Lightning

Lightning strike activity is examined using the 1999 archived National Lightning Detection Network™ (NLDN) data and comparing historically to an Automated Lightning Detection System (ALDS) and NLDN combined climatology. Latitude and longitude values were placed in 0.5x0.5 degree bin for analysis and contouring.

Figure 12 shows percent of average plots of lightning occurrence across Nevada for July through September 1999, along with locations of individual lightning strikes. In July across the northern portion of the state, lightning strikes were well below average which accounts in part for such a below average natural fire start month. However, most of the fire starts did occur in the same area as below average lightning. The southern portion of Nevada shows above average strikes by 150% and more in association with the southwest monsoon discussed earlier. Only a few fire starts occurred in the southern Elko district.

As much as 200% of average and more occurred over much of central and western Nevada in August where there were also a large number of natural fire starts. There was a also a large number of fire starts in eastern Nevada where lightning strikes were near to below average.

September appears somewhat similar to July, with most of the lightning activity in the southern half of the state, while the northern half shows well below average number of strikes. The locations of natural fire starts shows that most of these occurred in the below to near average strike areas. Thus, anomalous lightning counts were not important for this particular month.

Even though August had above average strike counts for much of the state, the eastern portion of Nevada along with northern half during July and September were below average, which suggests that abundant lightning activity is not a requirement for natural fire starts. If fuel conditions are satisfactory for ignition, then in theory only one strike is needed for a fire start.

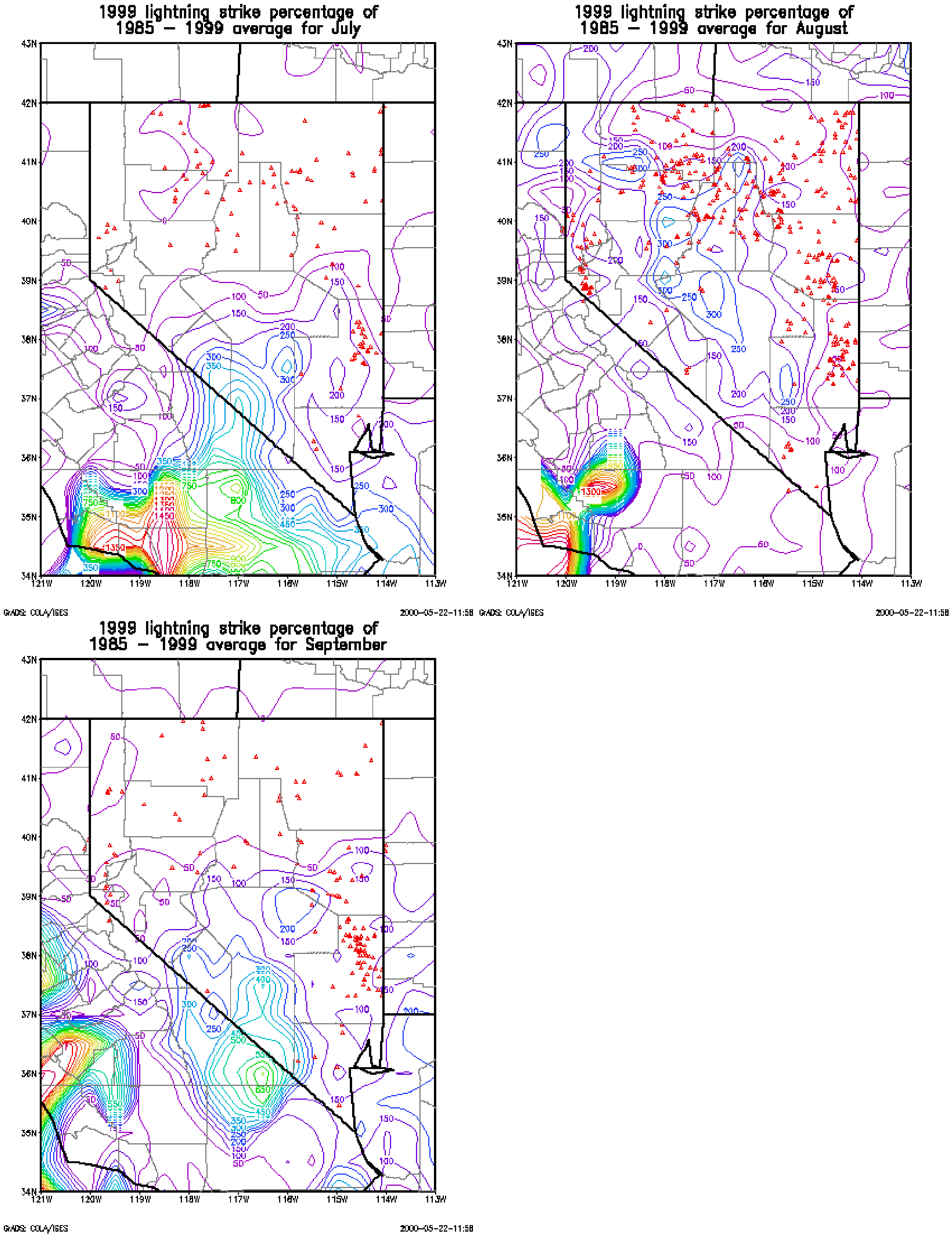


Figure 12. NLDN monthly average lightning strike counts for July through September 1999. Red symbols indicate location of natural fire start.

CONCLUSION

The key climate elements related to the 1999 Nevada fire season were precipitation, temperature, relative humidity, wind speed and dry thunderstorms associated in part with a very active southwest monsoon. Associated with these factors was a persistent below average 1-hr FM during much of May through October.

Climate Summary

The below average precipitation during July, a typical dry month anyway, caused a rapid decline in live fuel moisture. La Niña may have played a role early in the fire season by reducing precipitation (Figure 13a). Figure 13b shows the observed standardized precipitation anomalies by climate division for May through July 1999. During the typical primary fire season (July – September) there is no statistical relationship between La Niña and precipitation in Nevada.

The 1-hr FM was below average during much of the season (May through October). This was related to below average relative humidity and slightly above average temperature during all months except August, which was above average due in large part to extensive thunderstorm activity across the state. Relative humidity does not appear to have played a significant role in August overall, though low RH on individual days may have contributed to fire behavior affects.

Wind speed from a climatological perspective appears to have been important only during August, which had above average daytime wind speeds. That is, monthly wind speed anomalies do not suggest a contribution to unusual fuels drying. The August anomaly was most likely caused by microbursts and outflows from extensive thunderstorm activity. Above average wind speed likely played a role in fire spread on some days, but it is difficult to quantify this from historical data given the relative sparse distribution of the RAWS network compared to the fire locations.

The analysis of 500 mb relative humidity and geopotential height anomalies, and wind streamlines indicates that the southwest monsoon was a major factor during the fire season, especially August. In July, the upper level circulation was not conducive to natural fire starts. However, in August the circulation supported the advection of monsoon moisture into the state. A combination of one of the strongest southwest monsoons on record and an anomalous deep trough off of the northern California coast led to extensive lightning activity across the state and an unusual number of natural fire starts. At least half of the August natural fire starts were in direct association with the monsoon, including large events of early and late August. For other days, shortwaves resulting from the coastal trough provided the necessary dynamics for thunderstorm development. September's pattern switched to a more northwesterly flow consistent, though somewhat amplified, with active year composites. This pattern also allowed for a number of shortwaves to produce thunderstorms across the state. However, because the risk of ignition of fine fuels was so high after four months of below average 1-hr FM, even a few lightning strikes in the right locations caused numerous fire starts.

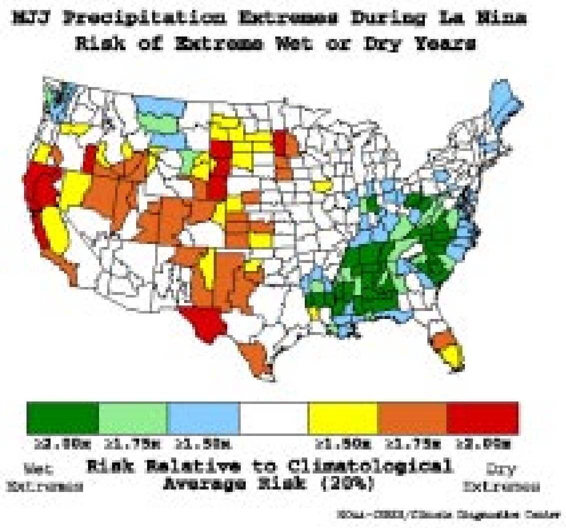


Figure 13a. Risk of having a dry May through July season by climate division as a result of existing La Niña conditions.

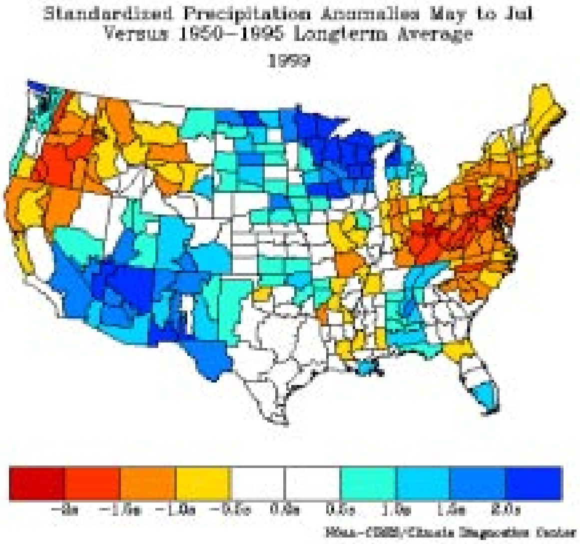


Figure 13b. Standardized precipitation anomalies by climate division for May through July 1999.

Statewide, the 1999 annual lightning strike total was slightly below average. However, the season showed strong intraannual variability. For example, in July the northern portion of Nevada was well below average in strike counts, but the southern portion was slightly above as a result of the southwest monsoon. In August, the monsoon influenced the entire state, and some of central and western Nevada was as much as 300% of average in strike counts. In September, the northern half was again below average while the southern half was above average. Thus, lightning only played a significant role during August.

Evolution of the 1999 Season

Precipitation was only average to below average during the spring and early summer. In May and June, temperature was slightly above average (approximately 3˚F), with corresponding below average relative humidity (approximately 3-9% depending on the location). This caused an early reduction in the 1-hr fuel moisture which remained below average through most of the season. In essence, the fine fuels became conducive for ignition early in the season and remained so through November.

In July below average precipitation, above average temperature and below average relative humidity in the northern half of the state (above average relative humidity in the south) continued to keep the 1-hr fuel moisture below average. However, the 500 mb wind flow was such that only upper level moisture entered the southern portion of the state, and thunderstorm activity was therefore minimal in the north. As a result, below average thunderstorm activity occurred during the month over much of the state. But because of the dry fuels by this time, there were still quite a few natural starts, though below average.

By August a deep trough had formed off of the California coast generating a number of shortwaves across the state. In conjunction, the southwest monsoon had developed to one of the strongest on record. Thus, the combination of the trough and upper-level moisture advection across the state from the monsoon region caused the development of numerous dry thunderstorms and above average lightning strike counts. Having both the trough and strong monsoon is an unusual pattern. In conjunction with the dry fuels already in place, numerous fires occurred just from the probability of having above average lightning strike counts.

In September, above average temperature and below average relative humidity continued to keep the 1-hr fuel moisture below average. The general upper-level flow switched to the west-northwest, allowing for shortwaves to cross the state and generate the dynamics needed for thunderstorm development. The number of lightning strikes was below average for most of the state, but they occurred in fortuitous locations. The biggest issue for September was the continued persistence of dry fuel conditions, and not so much an unusual weather pattern.

Above average temperature and below average precipitation continued through November. The 1-hr fuel moisture also remained below average for October and November. There was nothing unusual regarding natural fire starts during this period, but the dry conditions did allow for a late season in terms of human caused fires.

Discussion

From a prediction perspective, several of the findings from this study can be used to make forecasts of future fire seasons. First, La Niña may cause late spring and early summer precipitation deficits, which would lead to a reduction of live fuel moisture and plant stress. Above average temperature may occur during the spring, which would typically reduce average relative humidity and 1-hr FM. Therefore, a forecast of La Niña conditions is important to begin the resource planning process. Second, a forecast of 500 mb mean flow conditions would determine whether or not a pattern typical of active or non-active natural fire years would be expected. For example, trough conditions along the west coast would provide an indication of a potential increase in shortwaves and weak fronts, but this trough would also increase the southerly flow from the typically moisture laden southwest monsoon region. Third, a forecast of a strong southwest monsoon would indicate an increased risk of natural fire starts because of its being a primary moisture source for potential thunderstorm development. The composite analysis clearly shows that during active fire years, the predominate moisture comes from the southwest U.S. Fourth, for natural fire starts it is necessary to have dry thunderstorms. The initial conditions needed to establish these are sufficient moisture at the 600 to 500 mb levels and near or below average relative humidity at the surface and lower atmosphere Extensive lightning activity is not a necessity for active fire years, but clearly increases the probability of ignition.

It is clear from this type of study that climate conditions play an important role in the extent of Nevada's fire season. Though daily weather drives short-term fire activity and behavior, weekly, monthly and seasonal climate establishes the overall weather pattern and seasonal fire activity. Climate information should become a standard and integral component in fire season planning.

Acknowledgements

Sandy Gregory from the BLM Nevada State Office provided the live and 1-hour fuel moisture plots, and a comprehensive review of the report. The 500 mb geopotential height anomaly images were provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, from their Web site at http://www.cdc.noaa.gov/. Most of the map graphics were generated using the Grid Analysis and Display System (GrADS) from the University of Maryland's Center for Ocean-Land-Atmosphere Studies. The National Lightning Detection Network™ (NLDN) data were provided by Global Atmospherics, Inc.

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