THE CLIMATOLOGY OF DEW POINTS AND FIRE WEATHER RELATED PARAMETERS IN THE MISSOURI-ARKANSAS REGION

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Master of Science

by

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December 2010
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THE CLIMATOLOGY OF DEW POINTS AND FIRE WEATHER RELATED PARAMETERS IN THE MISSOURI-AR KANSAS REGION

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A candidate for the degree of Master of Science

And hereby certify that in their opinion it is worthy of acceptance.

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THE CLIMATOLOGY OF DEW POINTS AND FIRE WEATHER RELATED PARAMETERS IN THE MISSOURI-ARKANSAS REGION

Melissa D. Chesser

Dr. Anthony R. Lupo, Thesis Supervisor

ABSTRACT

Forecasting fire weather in the Springfield, Missouri and Little Rock, Arkansas Weather Forecast Offices (SGF and LZK WFO, respectively) across the greater Missouri and Arkansas regions (MoArk) county warning areas has been described as a challenge for wildfire managers. It is known that wildfire managers rely on their local WFO to provide fire weather forecast that are vital in the decision making process for wildfire suppression and prescribe fire management. Many climatic factors that affect fire hazards, including soil moisture, synoptic conditions, dewpoint, temperature and wind are indirectly impacted by ENSO. The climatology of dewpoint, temperature, Palmer Index, and synoptic conditions of fire weather flow regimes are presented here using the synoptic station observation network covering the MoArk region. A statistical analysis was performed in order to find useful interannual variability in the climatology of dew points and fire weather related parameters and their relationship to El Niño and La Niña. The data set used here contains monthly average dewpoint temperatures dating back to 1948 for three sites within Missouri: St. Louis, Columbia, and Springfield and one site in Arkansas: Little Rock. Dewpoint rather than relative humidity was chosen for this research because it is a measure of the actual amount of moisture in the air and is useful for seasonal fire weather
outlooks as the seasonal forecast would allow the forecaster to provide sufficient lead time for the relevant local, state, and federal agencies to plan and prepare for wildfire potential months in advance. In a study by Heilman (1998), dewpoint had the ability to discriminate between normal conditions and large wildfire conditions. An F-Test analyses was performed on the Columbia, MO, St. Louis, MO, Kansas City, MO, Littlerock, AR and Springfield, MO dewpoint linear regression chart. According to the F-Test analyses, all areas showed a significant increase in dewpoint temperatures. For example, in Columbia, MO, there is a significant increase in dewpoint temperatures (at the 95% confidence level). These rises in dew point are consistent with a moisture climate, and may also be part of the reason for increased precipitation in our region (e.g. Karl et al 1997). After examination dewpoint temperatures, syntopic conditions, and soil moisture of La Niña case 1988, it is shown that 3, 617 acres burned in the Missouri area and in the El Niño case 1991, no burned acres were reported.
1 Introduction

Forecasting fire weather in the Springfield, Missouri and Little Rock, Arkansas Weather Forecast Offices (SGF and LZK WFO, respectively) across the greater Missouri and Arkansas regions (MoArk) county warning areas has been described as a challenge for wildfire managers. It is known that wildfire managers rely on their local WFO to provide fire weather forecast that are vital in the decision making process for wildfire suppression and prescribed fire management. This in turn, is a challenge for the National Weather Service in Springfield, MO and Little Rock, AR as they are faced with providing quality decision making information for the wildfire managers. Both entities, The National Weather Service and Fire Managers are also aware that fire weather is both a short-term and long-range prediction problems. As with any short-term and long range predictions, challenges lay within forecasting for a variety of synoptic situations such as snowfalls (e.g., Lupo et al 2005). These, in turn, are important for the behavior and rate of spread of a wildfire.

Natural climate variability has been studied extensively in recent years, including an examination of the El Niño Southern Oscillation (ENSO) as it relates to the variability of Atlantic hurricane activity (e.g., O’Brien et al., 1996; Bove et al., 1998; Lupo and Johnston, 2000; Lupo et al. 2008), sea surface temperatures (SSTs; e.g., Mokhov et al., 1997), climate (e.g., Gershunov and Barnett, 1998; Wunsch, 1999), snowfall events (e.g., Kunkel and Angel, 1999; Berger et al. 2002; Lupo et al. 2005), blocking events (e.g., Wiedenmann et al., 2002), and Midwestern tornado events (e.g., Schaefer and Tatom, 1998; Akyuz et al. 2004). It is well documented that the variability of SSTs in the Pacific Basin can
drastically impact the general circulation of the atmosphere on short (seasonal) and long time (interannual) scales. Specifically, coupled ocean-atmosphere events such as the El Niño Southern Oscillation (ENSO) have been linked to significant interannual variations in local and regional climates.

Although there have been recent successes in producing relatively accurate long-range forecasts which are largely based on improved understanding of the connections between ENSO and global to regional climate changes there are also difficulties. One of the more difficult forecasting challenges for long-range seasonal forecasts is the ability to forecast the climate characteristics of a season better than, for example, some benchmark such as climatology or persistence (Lupo et al. 2007). Additionally, anomalous SST distributions alter the heating distributions of the tropical troposphere which significantly influence the general circulation of the atmosphere. This alteration can produce significant changes in the regional climates by directly influencing the frequency and intensity of extratropical cyclones (e.g., Key and Chan 1999), tropical cyclones (e.g., Lupo and Johnson, 2000) as well as blocking anticyclones (e.g., Wiedenmann et al. 2002). The occurrence or lack of occurrence of blocking during a season will determine the climate characteristics of a region (e.g., warm, wet, cold and dry, etc). Therefore, understanding the nature of these interannual SST variations as well as how interannual variability itself is modulated on even longer time scales, are critical components to consider in long-range seasonal forecasting (Lupo et al., 2005).

Many climatic factors that affect fire hazards, including soil moisture, synoptic conditions, dew point, temperature and wind, will also be indirectly
impacted by ENSO. These factors influence fuel moisture which is critical to fire management. Wind is considered to be the primary weather factor that influences fire spread. The greater a wind, the faster a fire will spread and the more intense it will be. Adding to this examination of fire weather in the MoArk region is the assessment of dew point. Although most research focuses on relative humidity, dew point rather than relative humidity was chosen for this research because it is a measure of the actual amount of moisture in the air.

The El Niño-Southern Oscillation results from changes in weather and climate arising from a joint air-sea interaction involving sea surface temperatures (SSTs) in the eastern equatorial Pacific Ocean, and changes in atmospheric pressure over the equatorial Pacific. At the most basic level, when equatorial sea surface temperatures off the western coast of South America are anomalously warm, the climate is in an “El Niño” phase. El Niño tends to produce wetter than normal conditions for the southeast and southwest U.S. The effect of individual ENSO events on climatic conditions at the regional or local level may vary somewhat, and no two ENSO events are identical. However, certain ENSO related patterns are discernible in the climatic record.

La Niña conditions prevail when there is a significant cooling of sea surface temperatures in the eastern Pacific. The cooler sea surface temperatures, and related patterns of atmospheric pressure, change the pattern of winter storm tracks, and generally result in anomalously dry conditions in the southeast and southwest U.S., but wetter than normal conditions in the Pacific Northwest. Furthermore, La Niña tends to be more persistent than El Niño; typically persisting for 6 months or more. According to a study, published by The Climate
Assessment Project for the Southwest (CLIMAS) Institute for the Study of Plant Earth (2000) states that it is important to keep in mind that El Niño and La Niña are not directly opposite conditions, nor are they entirely linear in their behavioral patterns. This type of behavior was described by Lupo et al. (2007) as well. Rather, ENSO conditions should be viewed in terms of variability in the statistical distribution of likelihood for average, above-average, and below-average conditions. Essentially, El Niño may increase the chance for wetter than normal conditions, while La Niña may increase the chances of being dry. Maps of precipitation patterns in the United States during ENSO-dominated periods illustrate the similarities that exist in the southwest and southeast, both of which tend to be wetter than normal during El Niño and drier than normal during La Niña (Fig 1.1). Furthermore, as is seen in Fig 1.1, the clear dipole over the U.S. Pacific Northwest and the Southwest may be seen; precipitation tends to be higher in La Niña (or lower in El Niño) years, in the Northwest at the same time that dry La Niña (or wet El Niño) conditions exist in the Southwest.

Fire weather, as has been seen in recent years, can cause vast devastation. For example, during the latter part of 2005 to early 2006 (transition from a neutral to La Niña state), areas just to the west of the MoArk region (TX, OK, KS) experienced a severe fire weather season; approximately 256 wildfires occurred covering 17,473 acres burned (NWS, personal communication 2006). These events were fueled by periods of warm, dry conditions and extremely favorable windy conditions including an unstable boundary layer.
Figure 1.1 Composite Precipitation Anomalies
Versus 1950-1995 Longterm Average

Figure 1.1 Composite Precipitation Anomalies 1950-1995 Long term Average (http://www.cdc.noaa.gov/)
The time periods chosen for this study, a span of about 50 years, represent sufficiently long time scales in order to identify and describe significant interannual dew point variability with respect to ENSO phases and then correlated to fire-weather situations, specifically the amount of acreage burned. The dew point temperature dataset was then stratified into ENSO phases (El Niño, La Niña, or Neutral). Berger et al. (2002) described that climatic fluctuations due to natural variability inherent in the earth-atmosphere system have been examined extensively (e.g., Wallace and Gutzler, 1981; Blackmon et al., 1984) in the past. The importance of these studies, according to Berger et al. (2002), is that interannual variability in climates within the United States Midwest have been linked to coupled ocean-atmosphere phenomena such as the El Niño and Southern Oscillation. These phenomena have been shown to influence the mean structure of midlatitude atmospheric circulations on time scales from season to a few years to decades (Berger et al. 2002). As Berger et al (2002) show, “heavy snowfalls are events that typically occur in association with synoptic scale transients. However, these snowfalls often occur on time and space scales more consistent with those of mesoscale phenomena. Therefore, the identification of the common climatic, synoptic-and meso-scale patterns that produce heavy snowfall was essential for the improvement of heavy snowfall forecasting”. This work will take a similar approach.

The climatology of dew point, temperature, Palmer Index, and synoptic conditions of fire weather flow regimes are presented here using the synoptic station observation network covering the MoArk region. A statistical analysis was performed in order to find useful interannual variability in the climatology of
dew points and fire weather related parameters and their relationship to El Niño and La Niña.
2 Data and Definitions

2.1 Data

The data set used here contains monthly average dew point temperatures dating back to 1948 for three sites within Missouri: St. Louis, Columbia, and Springfield and one site in Arkansas: Little Rock. The Kansas City, MO data set begins with 1972. The data used for research were obtained from the Missouri Climate Center (http://climate.missouri.edu/) and the Midwestern Regional Climate Center (http://mcc.sws.uiuc.edu/). The dew point temperatures are measured in degrees Fahrenheit as this represents the current U.S. Meteorological Standard for measuring dew point. As in Lupo et al. (2003) and others the exact units are not germane to the results.

The five stations chosen for this research each met a certain criteria in order to be included.

- For example, each time series must extend back to at least 1978 and the stations must not have moved more than once during the length of the dataset.
- These stations where chosen in order to obtain a broad geographical distribution across the study region (Fig. 2.1).
- With stations that had moved more than once during the length of the dataset, there had to be no evidence found to suggest that these moves resulted in significant changes in climatology.
Figure 2.1: The Map of Missouri and Arkansas (Maps courtesy of Digital Map Store® - Topographic Maps)

- Kansas City, MO: 231791
- Columbia, MO: 231791
- St. Louis, MO: 237455
- Springfield, MO: 237976
- Littlerock, AR: 034248
2.2 Definitions

For all stations, the periods were greater than 30 years, Table 2.1. For example,

- St. Louis, MO (Station ID 237455): 58 years
- Columbia, MO (Station ID 231791): 58 years
- Kansas City, MO (Station ID 234358): 34 years
- Springfield, MO (Station ID 237976): 58 years
- Littlerock, AR (Station ID 034248): 58 years

The time periods chosen represent sufficiently long time scales in order to identify and describe significant interannual dew point variability with respect to ENSO phases. These were then correlated to fire-weather situations, specifically the amount of acreage burned. The dew point temperature dataset was then stratified into ENSO phases (El Niño, La Niña, or Neutral). The ENSO phase stratification was based on the Japan Meteorological Agency (JMA) ENSO index. This definition is a widely accepted definition for ENSO that has been used with many other climatological studies (e.g., Lupo et al. 2005). According to this definition, a particular phase for ENSO (El Niño, La Niña or Neutral) is determined based on a 5 month running mean of spatially averaged sea surface temperature (SST) anomalies contained with an area between 4°S-4°N, 150°W-90°W in the tropical Pacific basin. In order for a particular year to be classified as an El Niño (La Niña) year, the SST anomaly must be 0.5°C (-0.5°C) or more (less) for 6 consecutive months including the months of October, November and December. Alternatively, values between 0.5°C and -0.5°C are classified as a neutral year. The ENSO year is defined to start on October 1st and persists
through the following September. So, for example, the 1997 El Niño year started in October 1st of 1997 and persisted through September 1998. A comprehensive list of ENSO years, defined by ENSO phase, dating back to 1948 are found in Table 2.1. More information regarding the JMA ENSO index can be found on the Center for Ocean and Atmospheric Prediction Studies (COAPS) website (http://www.coaps.fsu.edu).

Dew point rather than relative humidity was chosen for this research because it is a measure of the actual amount of moisture in the air. Dew point is defined as the temperature air would be if it is cooled until the point of saturation at constant pressure (Ahrens, 2008). The vapor pressure may then be obtained by referring to appropriate hygrometric tables. This method depends on the fact that the pressure due to water vapor does not change as the air is cooled but remains the same until saturation is reached. Various types of apparatus’s can be used to determine dew point. All types of apparatus for determining the dew point possess a surface, usually a polished metal mirror exposed to the air so that condensed moisture can be detected that can be cooled several degrees below air temperature and whose temperature can be observed. The exposed surface is cooled slowly until condensation appears, at which time its temperature is observed.

Finally, the analyses used in this study were the global monthly mean extended and reconstructed SSTs and SST anomalies compiled by the National Centers for Environmental Prediction (NCEP) and available through the National Oceanic and Atmospheric Administration (NOAA) online archive (http://www.cdc.noaa.gov/cgi-bin/data/composites/printpage.pl).
SSTs and anomalies are available and these can also be found in the monthly Climate Diagnostics Bulletin (www.cpc.ncep.noaa.gov) and mean SST anomalies in the ENSO region are available from 1864 to the present through the Center for Ocean and Atmospheric Prediction Studies (COAPS – www.coaps.fsu.edu).

According to the National Weather Service-Climate Prediction Center, the “NCEP/NCAR Reanalysis Project is a joint project between the National Centers for Environmental Prediction (NCEP, formerly "NMC") and the National Center for Atmospheric Research (NCAR). The goal of this joint effort is to produce new atmospheric analyses using historical data (1948 onwards) and as well to produce analyses of the current atmospheric state (Climate Data Assimilation System, CDAS)” (http://www.cpc.ncep.noaa.gov/products/wesley/reanalysis.html ). The 500 hPa heights and height anomalies from the NCEP/NCAR Reanalysis project (Kalnay et al. 1996) were also examined and are available via the many of the same sources referenced above.
Table 2.1: Time period 1948-2006 stratified by ENSO phase.

<table>
<thead>
<tr>
<th>La Niña Years</th>
<th>Neutral Years</th>
<th>El Niño Years</th>
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<tr>
<td>1949</td>
<td>1948</td>
<td>1951</td>
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<td>1954-1956</td>
<td>1950</td>
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<td>1988</td>
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<td>1976</td>
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<td>2000-2001</td>
<td>2002</td>
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<td>2003-2005</td>
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3 Climatological Analysis and Methods

3.1 Trends in Dew points

Dew point rather than Relative Humidity was chosen for this research because it is a measure of the actual amount of moisture in the air. Thus, dew point is defined as: the temperature air would be if it is cooled until the point of saturation (Ahrens, 2008). The vapor pressure can be then obtained by referring to appropriate hygrometric tables. This method depends on the fact that the pressure due to water vapor does not change as the air is cooled but remains the same until saturation is reached.

But dew point temperatures are useful for seasonal fire weather outlooks as the seasonal forecast would allow the forecaster to provide sufficient lead time for the relevant local, state, and federal agencies to plan and prepare for wildfire potential months in advance. In a study by Heilman (1998), dew point had the ability to discriminate between normal conditions and large wildfire conditions. Therefore, both long-range and short-term forecasting issues can be addressed simultaneously through the development of statistical and synoptic-dynamic climatologies.

In the Missouri - Arkansas region, fire weather events are favored when the weather is dry, and vegetation is brown and dry. This makes the late fall through the early spring the time of the year when wildfire potential is greatest regionally. Therefore, the yearly averaged dew points were plotted with respect to time and simple linear regression analysis was performed. Starting with the Littlerock, AR and Springfield, MO, the linear regression, (Figs 3.1 and 3.2) imply dew point temperatures rising from about 50°F to 51°F for a 58-year period, thus showing
an upward trend. Next, St. Louis and Columbia, MO (Figs 3.3 and 3.4) shows a stronger upward trend. Kansas City, MO proved to have the strongest upward trends in dew point temperatures for a 34-year period, (Fig 3.5).

An F-Test analyses were performed on the Columbia, MO, St. Louis, MO, Kansas City, MO, Littlerock, AR, and Springfield, MO, dew point linear regression chart. According to the F-Test analysis, all areas showed a significant increase in dew point temperatures. For example, in Columbia, MO, there is a significant increase in dew point temperatures (at the 95% confidence level). These rises in dew point are consistent with a moist climate, and may also be part of the reason for increased precipitation in our region (e.g. Karl et al. 1998).

![Figure 3.1 The Little Rock, AR, average annual dew point temperatures.](image-url)
Figure 3.2 As in Figure 3.1 except for Springfield, MO.

Figure 3.3 As in Figure 3.1 except for St. Louis, MO.
Figure 3.4 As in Figure 3.1 except for Columbia, MO.

Figure 3.5 As in Figure 3.1 except for Kansas City, MO.
In order to determine the impact of the El Niño and La Niña study years along with the amount of dew point in Missouri over a specific time frame, the Wildland Fire Assessment System (WFAS) was used in conjunction with the above mentioned analysis. Although there are other available resources provided by the National Interagency Fire Center (NIFC), the WFAS was chosen as the best resource to determine relative greenness over Missouri. The WFAS is an internet based information system. As stated by the NIFC, the current implementation of the WFAS provides a national view of weather and fire potential including the satellite Normalized Differentiated Vegetation Index (NDVI) derived Relative Greenness map. The Relative Greenness maps portray how green the vegetation is compared to how green it has been historically.

During the months of March-April, 1989, of La Niña year 1988, the average dew point temperature for Columbia, MO, was 36°F, with an average temperature of 60°F, and an average precipitation of 1.84 inches there were 3,617 acres burned in Missouri. Seasonally, the average based on 58 years, for Columbia, MO, the La Niña average dew point was 40.7°F. Based on these numbers, the March-April 1989 months were quite dry, which may have led to a large number of acres burned.

The following figures represent the relative greenness for the state of Missouri. Therefore, Missouri is depicted as red (absence of moisture) and little to no green vegetation is shown. At the beginning of March 1989 (Fig. 3.6), you can see the effects of La Niña set in motion. By the following week, March 08-March 14, 1989 (Fig. 3.7), dryness is setting in over the eastern half of the US as well as for March 22- March 28, 1989 (Fig. 3.8). By the beginning of April, a diminutive
amount of precipitation had fallen, the amount for March and April 1989 (Fig. 3.9) was 1.84 inches.

Figure 3.6 The U.S. Map of Relative Greenness Mar 01-Mar 07, 1989
(http://www.wfas.net/content/view/20/35/)
Figure 3.7 The U.S. Map of Relative Greenness Mar 08-Mar 14, 1989
(http://www.wfas.net/content/view/20/35/)

Figure 3.8 The U.S. Map of Relative Greenness Mar 22-Mar 28, 1989
(http://www.wfas.net/content/view/20/35/)
On the contrary, during the months of March-April, 1992, of El Niño year 1991, average dew point temperature for Columbia, MO, was 41.5°F, with an average temperature of 66.8°F, and the total precipitation of 6.84 inches there were no reported acres burned in Missouri. Seasonally, the average based on 58 years, for Columbia, MO, the El Niño average dew point was 42.1°F. Based on these numbers, the March-May 1992 months experienced a wetter than normal season which again lead to no reported acres burned in the Missouri area.

The following figures represent the relative greenness for the state of Missouri. Therefore, as we progress through the months of March-April of 1992, Missouri is
first depicted as red (no moisture) with a gradual movement to green. At the beginning of April (Fig. 3.10), you can see the effects of a greater amount of moisture in motion. By the following week, April 24-April 30, 1992 (Fig. 3.11), wetness is setting in over the eastern half of the US as well as for May 08-May 14, 1992 (Fig. 3.12). Toward the end of May a vast amount of precipitation had fallen, and is represented in Fig. 3.13. Due to the immense amount of rain, low temperatures and relatively high dew point temperatures, Missouri did not experience any acres burned between March-April, 1992.

Figure 3.10 The U.S. Map of Relative Greenness Apr 10-Apr 18, 1992
(http://www.wfas.net/content/view/20/35/)
Figure 3.11 The U.S. Map of Relative Greenness Apr 24-Apr 30, 1992
(http://www.wfas.net/content/view/20/35/)

Figure 3.12 The U.S. Map of Relative Greenness May 08-May 14, 1992
(http://www.wfas.net/content/view/20/35/)
Figure 3.13 The U.S. Map of Relative Greenness May 15-May 21, 1992

(http://www.wfas.net/content/view/20/35/)
4 Flow Regimes

As we discussed in Chapter 3, in the Missouri-Arkansas region, fire weather events are favored when the weather is dry, and vegetation is brown and dry. This makes the late fall through the early spring the time of the year when wildfire potential is greatest regionally. Since we examined the yearly averaged dewpoints which were plotted with respect to time and simple linear regression analysis was performed, we can examine other variables that can also contribute to fire weather.

First, the evidence of El Niño, 1991 and La Niña, 1988 events are further enhanced by examining Fig. 4.1 below.

![Figure 4.1 The Observed SST anomaly in Nino 3.4 region](http://meteora.ucsd.edu/~pierce/elnino/whatis.html)

By the given definition of the Experimental Climate Prediction Center at UC San Diego, when the difference from average conditions gets above 0.5 Celsius or so
(red areas), you are in a warming period that is an El Niño. Whereas, when the difference from average conditions gets below -0.5 Celsius (blue areas), you are in a “cold phase”, or La Niña.

4.1 La Niña Year 1988; March-April 1989

During the months of March-April, 1989 of La Niña year 1988, average dewpoint temperature for Columbia, MO was 36°F, an average temperature of 60°F and an average precipitation of 1.84 inches there were 3,617 acres burned in the Missouri area. Seasonally, the average based on 58 years, for Columbia, MO the spring was a La Niña year with an average dewpoint of 40.7°F. Based on these numbers, the March-April months were quite dry which may have led to a large number of acres burned.

According to the NOAA’s Drought Information Center (http://www.drought.noaa.gov/plamer.html), the Palmer Index was developed by Wayne Palmer in the 1960s and uses temperature and rainfall information in a formula to determine dryness. It has become the semi-official drought index. The Palmer Index is most effective in determining long term drought- a matter of several months-and is not as good with short-term forecasts (a matter of weeks). It uses a 0 as normal, and drought is shown in terms of minus numbers; for example, minus 2 is moderate drought, minus 3 is severe drought, and minus 4 is extreme drought. The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The negative is that it is not as good for short-term forecasts, and is not particularly useful in calculating supplies of water
locked in snow, so it words best east of the Continental Divide. (http://www.drought.noaa.gov/palmer.html).

According to Fig. 4.2 below, for the month of March in the southern part of Missouri, the Palmer Index was a -2 and for the month of April in southern Missouri (Fig. 4.3), the Palmer Index was again a -2; however, drought conditions worsened over the month due to lack of precipitation and drier air masses. In Fig. 4.4, March and April are combined together to give a two month average of -2.

Figure 4.2 The Palmer Drought Index March 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
The 500mb level was selected for the March-April 1989 case study analysis because it is generally midway between the key levels of divergence; this level is commonly thought of as representative of the steering circulation for surface systems. The flow regime for this area is represented by Fig. 4.5. The flow regime represents little indication of any high or low pressure systems over the study area which is a suggestion of a zonal flow pattern.

Due to the lack of a meridional flow pattern, the study area did not receive flow from the south which may have brought the moisture needed to prevent the outbreak of fires; the zonal flow circulation pattern tends to bring drier air from Canada into the southern and eastern states. There is further evidence in Fig. 4.6 and Fig. 4.7 that indicates a zonal flow. Combined with the 500mb scalar winds (Fig. 4.8), the average wind speed during March-April 1989 was 21 m/s (50mph). Wind speeds at these heights combined with this slight tropospheric ridge and accompanying trough added to the fire occurrences over the southern part of Missouri due to the lack of gulf moisture from the Gulf of Mexico as air dries as it passes over the Rockies.

Wind speeds can affect the direction and speed of a wildfire spread and soil moisture is a valuable tool in determining the potential of fire weather. According to the Western Water Assessment (WWA) (http://wwa.colorado.edu/IWCS/index.html), soil moisture is the amount of water contained in the soil pores above the saturated groundwater zone that is available for plants to use or for evaporation into the atmosphere. In addition, the WWA states that soil moisture is more predictive in temperature forecasts.
Figure 4.3 The Palmer Drought Index April 1989 Composite Mean U.S. Map  
(http://www.cdc.noaa.gov)
Figure 4.4  The Palmer Drought Index March-April 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.5 The 500mb Geopotential Height (m) March-April 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.6  The 700mb Geopotential Height (m) March 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.7 The 500mb Vector Wind Speed (m/s) March 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.8 The 500mb Scalar Wind Speed (m/s) March-April 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
than precipitation alone, and the correlation between soil moisture and temperature is highest in warm months when evaporation is the highest.

According to Mark Zachary Jacobson, the predictions of ground surface temperature and soil moisture are important since ground temperatures and moisture influence wind speeds. He continues to state that low soil moisture increases ground temperature, increases thermal turbulence, and increases wind speeds. Furthermore, low soil moisture contents increase near surface wind speeds by enhancing turbulence transport of momentum from aloft to the surface. On the other hand, higher soil moisture will effectively lower air temperature and possibly prevent the onset of a wildfire. Researchers also found that soil moisture is a good predictor for future precipitation because increased evaporation from the soil and resulting humidity increases the likelihood of future precipitation.

Figure 4.9 represents the amount of soil moisture available in the Missouri region for March-April 1989. Therefore, over the southern portion of Missouri, one would have to excavate 450mm-550mm of soil before reaching any available water as compared to the regions west of Missouri where one would have to excavate 50mm-150mm of soil. Fig. 4.10 represents the March-April 1989, anomaly. As the chart indicates, a broad ridging set-up in the SW Continental United States (CONUS) near the surface and prevented any precipitation to fall. So, the bulk of the moisture to the area had to come in from the Gulf of Mexico or from the north. This is a classic La Niña set-up. The SE and NW CONUS are wetter than normal (as seen from the 4.0-5.5 and sometimes 6.0mm/day) while the NE and SW CONUS are dryer than normal, Fig. 4.11.
Figure 4.9  The CPC Soil Moisture Surface (mm) March-April 1989 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.10  The CPC Soil Moisture Surface (mm) March-April 1989 Composite Anomaly U.S. Map (http://www.cdc.noaa.gov)
Figure 4.11  The Surface Precipitation Rate (mm/day) March-April 1989

Composite Mean U.S. Map (http://www.cdc.noaa.gov)
When combining the geopotential height map, with the Palmer Drought Index map of -2, and soil moisture of 450mm-550mm, all variables aided to the fire occurrences over the southern part of Missouri where 3,617 acres burned

4.2 El Niño year 1991; March-April 1992

On the contrary, during the months of March-April, 1992 of El Niño year 1991, average dewpoint temperature for Columbia, MO was 41.5°F, an average temperature of 66.8°F and the total precipitation of 6.84 inches there were no reported acres burned in the Missouri area. Seasonally, the average based on 58 years, for Columbia, MO the spring was an El Niño year with an average dewpoint of 42.10°F. Bases on these numbers, the March-May months experienced a wetter than normal season which again lead to no reported acres burned in the Missouri area. According to Fig. 4.12, for the month of March 1992 in the southern part of Missouri, the Palmer Drought Index was a 0 indicting normal conditions. In fig. 4.13, for the month of April 1992, the Palmer Drought Index was again 0 indicating normal conditions. The overall mean of the Palmer Drought Index for March-April 1992 was close to zero.

The 500mb geopotential heights during the months of March-April 1992, El Niño year 1991 (Fig. 4.14) showed a more pronounced middle tropospheric ridge over the western half of the United States with an accompanying trough over the eastern United States that resulted in a counterclockwise positive vorticity movement where the winds along with moisture moved from south to north bringing the moisture that accompanied this El Niño event. As the trough set in (Fig. 4.15 and Fig. 4.16), it brought about upward motion, greater
instability, and rain which lead to the 6.84 inches of rain received in Missouri. Combined with the 500mb scalar winds (Fig. 4.17), the average wind speed during March-April 1989 was 18 m/s (40mph).

At these lower wind speeds, the ground did not have the opportunity to “dry out” and maintained the moisture needed to prevent fire occurrences to occur in the southern part of Missouri as was seen in the La Niña event. Again, the 500mb level was selected for the March-April 1992 case study analysis because it is commonly thought of as representative of the steering circulation for surface systems.

By examining Fig. 4.18, the evidence of El Niño is quite apparent. A surface precipitation rate of 3.4mm per day over Missouri combined with low wind speeds, sustained the soil moisture in the region. Fig. 4.19 represents the amount of soil moisture available in the Missouri region for March-April 1992, El Niño year 1991. Therefore, over the southern portion of Missouri, one would have to excavate 400mm of soil before reaching any available water as compared to the March-April 1989, La Niña year 1988, where one would have to excavate 450mm-500mm before any available soil moisture was reached. Although the comparison is small, a difference of 50mm between the El Niño and La Niña event, the addition of the extra precipitation in the El Niño was enough to prevent any fire occurrences from March-April 1992.
Figure 4.12  The Palmer Drought Index March 1992 Composite Mean U.S. Map
(http://www.cdc.noaa.gov)
Figure 4.13  The Palmer Drought Index April 1992 Composite Mean U.S. Map

(http://www.cdc.noaa.gov)
Figure 4.14  The 500mb Geopotential Height (m) March-April 1992 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.15  The 700mb Geopotential Height (m) March 1992 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.16  The 500mb Vector Wind Speed (m/s) March 1992 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.17  The 500mb Scalar Wind Speed (m/s) March-April 1992 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.18  The Surface Precipitation Rate (mm/day) March-April 1992

Composite Mean U.S. Map (http://www.cdc.noaa.gov)
Figure 4.19 The CPC Soil Moisture Surface (mm) March-April 1992 Composite Mean U.S. Map (http://www.cdc.noaa.gov)
5 Conclusions

Fire-weather risk relates to how a combination of weather variables influences the risk of a fire starting or its rate of spread, intensity, or difficulty to suppress. Fire risk is influenced by a number of factors including fuels, terrain, land management, suppression, and weather. We have all seen it in the news—dry atmospheric conditions produced a wayward spark which led to engulfing flames that in turn threatened homes and swiped across landscapes.

Therefore, the purpose of this topic was to examine forecasting fire weather in the Springfield, Missouri and Little Rock, Arkansas Weather Forecast Offices (SGF and LZK WFO, respectively) across the Missouri and Arkansas regions (MoArk) which has been described as a challenge for wildfire managers. Wildfire managers rely on their local WFO to provide fire weather forecast that are vital in decision making for wildfire suppression and prescribe fire management. This in turn, is a challenge for the National Weather Service in Springfield, MO and Littlerock, AK as they are faced with providing these decision making information to the wildfire managers. Regardless of the cause of wildfires in the MoArk region, the occurrence of several wildfires depends to a large degree on the atmospheric conditions present before, during and after the time of ignition.

The time periods chosen for this study, a span of 48-50 years, represent sufficiently long time scales in order to identify and describe significant interannual dewpoint variability with respect to ENSO phases and then correlated to fire-weather situations, specifically the amount of acreage burned. The dewpoint temperature dataset was then stratified into ENSO phases (El Niño, La Niña, or Neutral). As was stated earlier, dewpoint rather than relative
humidity was chosen for this research because it is a measure of the actual amount of moisture in the air. Dewpoint temperatures are useful for seasonal fire weather outlooks as the seasonal forecast would allow the forecaster to provide sufficient lead time for the relevant local, state, and federal agencies to plan and prepare for wildfire potential months in advance.

Therefore, the yearly averaged dewpoints were plotted with respect to time and simple linear regression analysis was performed. All the cities in the study region all showed an upward trend in the dewpoint temperatures. An F-Test analyses was performed on the Columbia, MO, St. Louis, MO, Kansas City, MO, Littlerock, AR & Springfield, MO dewpoint linear regression chart. According to the F-Test analyses, all areas showed a significant increase in dewpoint temperatures. For example, in Columbia, MO, there is a significant increase in dewpoint temperatures with a 95% confidence level. The rise in dewpoint temperatures is a value that is meaningful as it is consistent with the linear regression charts.

Berger et. al (2002) described that climatic fluctuations due to natural variability inherent in the earth-atmosphere system have been examined extensively (e.g., Wallace and Gutzler, 1981; Blackmon et al., 1984). The importance of these studies, according to Berger et.al (2002), is that interannual variability in climates within the United States Midwest have been linked to coupled ocean-atmosphere phenomena such as the El Niño and Southern Oscillation (ENSO). These phenomena have been shown to influence the mean structure of midlatitude atmospheric circulations on time scales from season to a few years to decades (Berger et al, 2002). To further enhance these findings,
Heilman’s (1998) summation of ENSO effects on fire weather greatly explains that weather events that produce conditions favorable for fire weather are strongly linked to relatively short-term weather. Therefore, Heilman (1998) explains any large-scale circulation changes in the atmosphere brought about by global climatic forcing factors have the potential for altering circulation patterns in the United States and modifying the normal frequency of weather events conducive to severe wildfires i.e, ENSO.

Next two cases were examined, La Nina year 1988, March-April 1989 and El Nino year 1991, March-April 1992 for dewpoint temperatures, flow regimes, precipitation amounts, temperature, Palmer Index and relative greenness to determine the effects of these atmospheric conditions to the amount of acreage burned in the MoArk region.

In the Missouri-Arkansas region, fire weather events are favored when the weather is dry, and vegetation is brown and dry. This makes the late fall through the early spring the time of the year when wildfire potential is greatest, regionally. For example, during the months of March-April, 1989 of La Niña year 1988, average dewpoint temperature for Columbia, MO was 36°F, an average temperature of 60°F and an average precipitation of 1.84 inches there were 3,617 acres burned in the Missouri area. Seasonally, average based on 58 years, for Columbia, MO the spring was a La Niña year with an average dewpoint of 40.7°F. By further examining the atmospheric conditions discussed in chapter 4, there was a slight tropospheric ridge over the United States but the ridge was extremely settle leading to more a zonal flow than your typical ridge/trough scenario. Combined with this zonal flow pattern over the United States, the average wind
speeds were 21m/s, limited precipitation further evidenced by a soil moisture of 450-550mm aided to the fire occurrences over the southern part of Missouri.

The El Niño spring (March-April 1992), average dewpoint temperature for Columbia, MO was 41.5°F, with an average temperature of 66.8°F and an average precipitation of 6.84 inches there were no reported acres burned in the Missouri area. Along with higher average temperature and precipitation, this particular event showed a more pronounced middle tropospheric ridge over the western half of the United States with an accompanying trough over the eastern United States that resulted in a positive vorticity movement where the winds along with moisture moved from south to north bringing the moisture out of the Gulf of Mexico that accompanied this El Niño event. Additionally, combined with an average wind speed of 18m/s and a soil moisture of 400mm, the soil did not have the opportunity to “dry out” and maintained the moisture needed to prevent fire occurrences to occur in the southern part of Missouri as was seen in the La Niña event. Although the comparison is small, a difference of 50mm between the El Niño and La Niña event, the addition of the extra precipitation in the El Niño was enough to prevent any fire occurrences from March-April 1992.

Heilman et al., (1998) also identified through research of Trenberth et al., (1988) that tropical Pacific sea-surface temperature changes associated with the 1988 La Niña episode as the primary factor responsible for the atmospheric circulations over North America that caused the severe drought in the Great Plains region of the United States.

The weather is one of the most changeable aspects of any incident and can not be taken lightly as forecasters must monitor these ever changing
conditions to ensure the safety of operations and how to allow responders to plan operations.
References


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