JP2.23 CLIMATE VARIABILITY AND THE TEXAS FIRE WEATHER SEASON OF 2005-2006: AN HISTORIC PERSPECTIVE OF A STATEWIDE DISASTER

Kurt M. Van Speybroeck* and Andrew R. Patrick
NWS Brownsville Forecast Office
Brownsville, Texas

Monte C. Oaks
NWS Austin/San Antonio Forecast Office
New Braunfels, Texas

1. INTRODUCTION

The state of Texas lies within both the “cool” and “warm” parts of the Temperate Zone in the Northern Hemisphere. The three major climate types are classified as Continental, Mountain, and Modified Marine (Larkin and Bomar, 1983). The statewide climate of Texas can be characterized as periods of precipitation normally distributed around a local mean, interspersed with episodic drought conditions. The periodic drought episode of 2005-2006 was not unusual in the overall climate data for Texas.

The worst of the drought conditions existed across Texas from Autumn 2005 through Spring 2006. Global climate variability signals, such as the El Niño - Southern Oscillation or ENSO (Philander, 1990), suggested that a drought episode was possible during this time. At the height of the drought, synoptic scale weather patterns developed that enhanced wildland fire danger over much of the state.

The combination of climatic conditions, local weather elements, and a variety of human activity produced record wildland fire response across Texas from December 2005 through April 2006. Several large, complex fires burned millions of acres. Large fires burned across the entire state with the exception of East Texas and the Upper Texas Coast. National Weather Service (NWS) Forecast Offices (WFOs) issued numerous Fire Weather Watches (FWF) and Red Flag Warnings (RFW). Additional NWS efforts included Incident Meteorologists (IMET) being deployed to Incident Command Posts (ICPs) at several locations around in Texas.

Section 2 will discuss the climate regime of Texas. Section 3 will examine the historic relationship between ENSO phases and Texas droughts. Section 4 will discuss basic fire weather meteorology. Section 5 will review the impacts and emergency response actions during the height of the drought and fire activities. Conclusions will be offered in relation to the continuing expansion of the urban/wildland fire interface and periodic droughts.

2. TEXAS CLIMATE DATA

The Climate Atlas of Texas (Larkin and Bomar, 1983) describes most of the state as a Modified Marine climate (Figure 1). This subtropical climate is further divided into four subheadings, subtropical-humid, sub-humid, semi-arid, and arid. These climate regimes do not have fixed boundaries since the onshore flow from the adjacent Gulf of Mexico is continually modified from the coast to the inland areas.

Texas encompasses three major climate types. The Continental Steppe climate best describes the Texas High Plains and Panhandle region. Continental Steppe is characterized by large variations of daily temperature extremes, low relative humidity, and irregularly spaced rainfall of moderate amounts.

The Mountain climate classification best describes the area in Far West Texas and the Trans-Pecos region. Naturally, this encompasses the Guadalupe, Davis, and Chisos Mountain ranges. Interestingly, this particular mountain climate is contrasted by Subtropical Arid climate

---

* Corresponding author address: Kurt M. Van Speybroeck, NWSFO Brownsville, Brownsville, TX 78521; e-mail: kurt.vanspeybroeck@noaa.gov

of the surrounding lowlands (Larkin and Bomar, 1983).

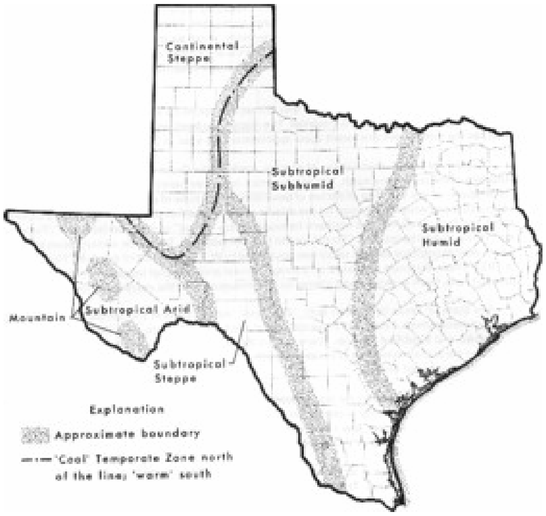


Fig. 1. Climate classifications of Texas

2.1 *Average Annual Precipitation*

Climate records from the State of Texas and the National Climatic Data Center (NCDC) indicate the average annual precipitation varies greatly across Texas. Annual precipitation ranges from nearly 1219 mm (48 in) along the upper Texas coast to roughly 762 mm (30 in) along the middle and lower Texas coast to less than 250 mm (10 in) across Far West Texas (Figure 2). Annual temperature ranges are characteristic of a region that straddles the warm and cool Temperate Zone in the Northern Hemisphere.

2.2 *Maximum/Minimum Temperatures*

July and August have the highest average daily maximum temperature, with average maximum temperature values ranging between 32.8° C (91° F) and 35° C (95° F) statewide.

Typically, the warm season extends from April through October in Deep South, South central, southwest and Far West Texas. The average warm season is considerably shorter in the northern portions of the state (i.e. Panhandle, North Central and northwest Texas).

Average minimum temperature data is similar in character to the maximum temperatures with warm season minima peaking in July and August. These average monthly minima range from 18.3° C (65° F) to 23.9° C (75 ° F) with the cooler temperatures recorded across the northern portions of the state. Warmer average minimum temperatures are noted in South and Deep South Texas along the lower Texas Coast.

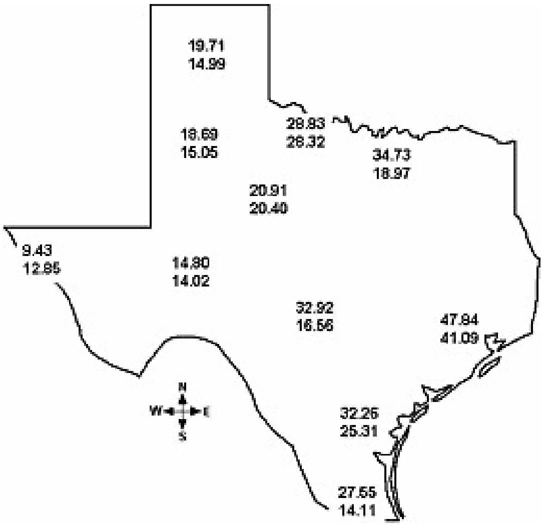


Fig. 2. Regional average annual precipitation (inches). Amounts from 2005 listed beneath regional annual averages.

3. DROUGHT AND CLIMATE VARIABILITY

The physical geography and size of Texas contributes to climatologic events of periodic severe drought. Given such a large area, simultaneous severe statewide drought episodes are rare, although drought episodes can occur on a sub regional scale with varying regularity. In the most extreme drought episodes, nearly all climate classifications and sub regional areas will experience drought conditions.

The worst Texas drought occurred from 1950-1957 (Nielsen-Gammon, 2004). The next most severe drought to impact Texas is the Dust Bowl years of 1932-1939. Less memorable droughts include 1909-1918, which includes Texas' driest year on record (1917). Finally the early 1890s also were noted as dry years, with records indicating Texas received generally less than half its normal annual rainfall.

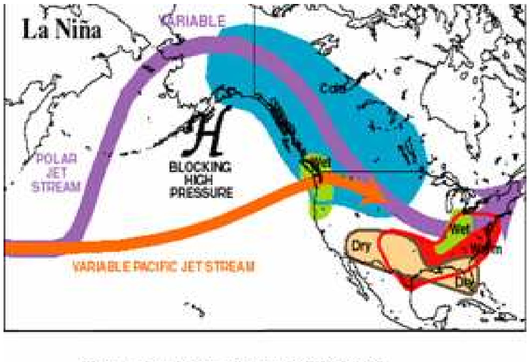
These droughts occurred roughly at 20 year intervals, but were disrupted in the 1970s. However, drought returned to a large part of Texas in the late 1990s and again during 2005.

Realizing the drought builds upon itself through the depletion of surface and subsurface moisture, some relationship exists between drought and noteworthy temperatures records. For example, the hottest summer in Texas was recorded in 1936, during the Dust Bowl drought. By understanding climate variability and its effects on weather a relationship between climate and severe drought events in Texas might be inferred.

3.1 Climate Variability

Increased understanding and monitoring the impacts of global climate systems has led to several long-range forecast model systems. Identification of the ENSO index, and the observable weather trends across Texas have been used to develop climatological forecasts regarding specific weather trends.

Composite weather maps developed by the Climate Prediction Center (CPC, 2006), show the general weather trends in various regions of North America (Figure 3). These composite weather trends exhibit a significant relationship with various climate variations such the El Niño (warm phase) and La Niña (cold phase) of the ENSO (Figures 4).



Climate Prediction Center/NCEP/NWS

Fig 3. Climate trends associated with El Niño/La Niña. Dry and warmer over Texas.

Data from NCDC in Asheville, NC shows a significant lack of annual precipitation that relates well to the climatological pattern of drought across Texas.

Table 1 shows six of the ten driest years in Texas occurred in one of the three major drought decades on record (1910s, 1930, or 1950s). The three years that did not occur within the drought decades (1963, 1948, 1988), were coincident with La Niña phase of the ENSO.

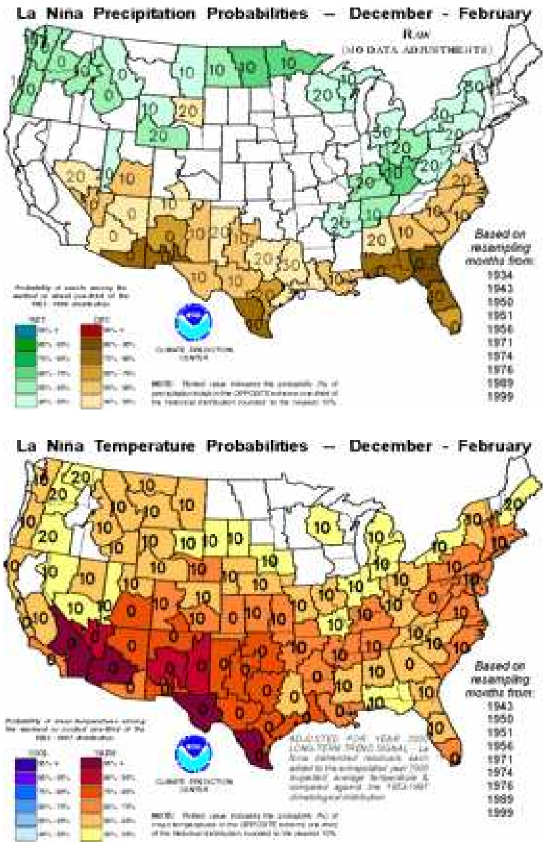


Fig 4. Average Temp/Precipitation Anomalies during El Niño/La Niña cycles (CPC, 2006).

Assumptions could be made regarding the overall climate, precipitation correlation, and temporal proximity to drought decades and ENSO cool phases. With such a strong relationship between drought and precipitation combined with the relationship between precipitation deficits and La Niña, identifiable patterns regarding drought and fire weather are beginning to emerge.

The data shows less correlation to annual average temperatures. However, when seasonal temperature data is examined (Dec-Feb), a stronger relationship becomes evident between drought and average temperature. Observation records of the ENSO variance are displayed in Figure 5. The close relationship among drought years, record dry years, and ENSO cold phase (La Niña, blue) are of particular interest.

Climate variability will likely continue and climate indicators can suggest the onset of severe to exceptional drought. With these signals dangerous fire weather patterns could be anticipated with increasing confidence.

Annual Precipitation - TX Driest Years (1895 - 2005)	
Year	Amount (mm) - Rank
1917	380.7
1956	394.2
1954	457.4
1910	498.1
1963	501.7
1901	515.6
1948	525.8
1951	526.8
1988	539.8
1909	548.9

Table 1. 10 driest years on record for Texas.

4. FIRE WEATHER PATTERNS

Three primary elements can affect extreme wildfire behavior. This is often referred to as the "triangle" of topography, fuels, and weather. Several basic weather criteria are necessary for critical or extreme wildland fires. Hot, dry, and windy conditions are generally ideal for the rapid growth and spread of wildfires. These conditions often persist over a large area of Texas in association with the ENSO cold phase (Figure 5).

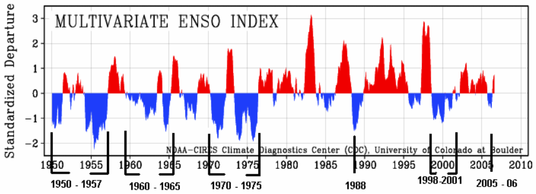


Fig 5. El Niño/La Niña events since 1950.

As the synoptic weather pattern changes within the climatic conditions, periods of critical fire weather and fire behavior can develop. Typically in Texas, the driest months of the year occur in the late fall and winter (Bomar, 2001). When the ENSO cold phase is established, this anomalous dry and warm pattern can be significantly amplified, as it was from late November 2005 through February 2006. Several significant weather features are common across Texas during winter and early spring. Texas lies in the lee of the Rocky Mountains and borders the Gulf of Mexico to the southeast. This location can often be the focus of extreme weather conditions, amplifying fire behavior. The presence of the Low Level Jet, lee side cyclogenesis, dry line intrusions, and adiabatic warming from the Mexican Plateau can generate the hot, dry, and windy environment needed for extreme fire behavior.

Observational indices have been developed and are used by fire and forestry agencies to assess drought and potentially extreme fire danger. The Keetch-Byram Drought Index (KBDI) is a primary indicator of persistent drought (Keetch and Byram, 1968). This index was designed as a drought index specifically for fire potential assessment, representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper soil layers.

The Palmer Drought Index (Palmer, 1965) was developed to use temperature and rainfall information in an empirical formula to assess dryness. It has become the semi-official drought index across the United States. Several additional fire weather and drought indicators are used in wildfire threat assessment, such as the National Fire Danger Rating System (NFDRS), fire potential index, and the Live Fuel Moisture index.

The general weather conditions and several of these indices were suggesting the onset of exceptional drought with associated extreme fire weather conditions by late 2005.

4.1 *Conditions Nov. 2005 – Feb. 2006*

According to the ENSO climate signal, the La Niña cool phase was underway by November 2005 and lasted through Spring 2006. This favored a change in the large scale sensible weather pattern. This migration from climatological normal, to a dry and warmer pattern during the driest months of the year, led to severe drought conditions being reported across much of Texas. Severe to exceptional drought classifications were reported across the eastern half of Texas from early November 2005 through May of 2006. The moderate to severe drought extended across west Texas and through much of the panhandle at the same time. KBDI and Palmer data from NCDC showed a pronounced drought episode was developing in November 2005. By December 2005 the eastern two thirds of Texas recorded KBDI values of 600 to 800, revealing maximum dryness. Palmer index readings showed moderate to extreme drought over most of the state. The drought conditions continued to worsen through April 2006 with Texas recording KBDI above 700 and a Palmer index of severe to extreme drought.

Several vigorous weather systems brought strong winds and sharp wind shifts, but little precipitation. With the antecedent drought conditions existing for an extended period, these weather features set the stage for wildfires on an unprecedented scale. The only remedy for this dangerous situation was for a large scale weather pattern change, or for the spring “green up” of vegetation, which is tied to the climatological increase of rainfall in the Spring.

5. The 2005-2006 Texas Fire Season

The acreage consumed by wildland fires in Texas from December 2005 through April 2006 exceeded 1.3 million acres. This surpassed all previous amounts in recent history (personal communication, Texas Forest Service). This event has been called the worst fire season since the 1950s. Wildfires claimed 19 lives and generated 500 million dollar in property damage. Firefighters from over 45 states were mobilized to respond to the various fire outbreaks (Hannemann, 2006).

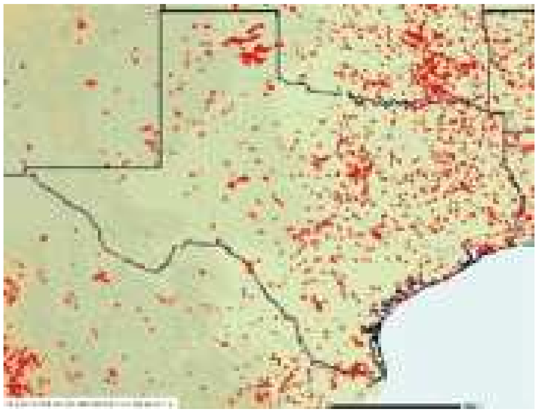


Fig 6. NASA MODIS detected fires Dec 2005 – Apr 2006

An increasing number of smaller fires are undocumented by state or federal response agencies. This is largely due to the increasing number of responses by volunteer fire departments. The TFS suggested that the number of volunteer fire departments has doubled from 1975 through 2005 (Galloway, 2002). A graphical comparison of reported fires, to satellite detected fires can be seen in Figures 6 and 7.

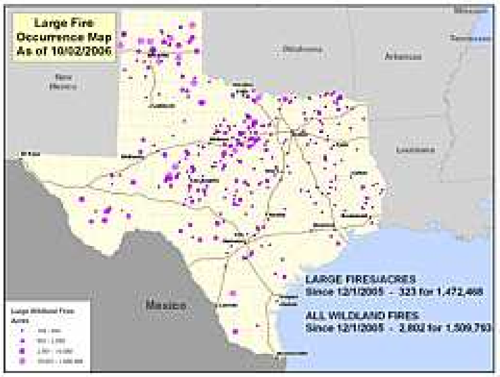


Fig 7. Large fires reported by state/federal agencies.

The NWS delivered critical weather support during the extended fire danger. Field offices, IMET services, and NWS regional support were key to protecting lives and property. Texas NWS offices issued several thousand Red Flag Warnings and Fire Weather Watches during the disaster. State and local officials used these forecasts to justify county statewide burn bans, fireworks restrictions, and emergency disaster declarations. At the peak of drought, a majority of counties in Texas were under some form of burn ban or disaster declaration.

NWS IMETs delivered 310 days of specialized meteorological services to the ICP decision teams. IMETs also delivered point specific forecasts, incident specific briefings, and planning services to state and federal emergency officials.

Resources mobilized through the Texas Interagency Coordination Center (TICC) included 3,994 personnel, 181 fire engines, 186 dozers, and 120 aircraft. These resources were deployed across the state, expanding the need for critical operational meteorological services.

Figures 8, shows the recent trend of amounts of acreage burned per fire during the cool season as compared to fires during the warm season.

This type of climate variability and fire behavior may be related to La Niña episodes and amplified drought impacts. Meteorological effects and patterns characterized by frontal passages, with cool season climate periods of strong winds, dramatic wind shifts, and drier continental air masses would increase the likelihood of extreme fire behavior.

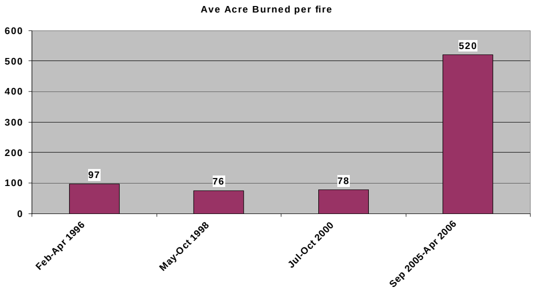


Fig 8. Average acres burned per fire during active periods since 1996.

The increasing dangers and property loss associated with wildfires has led to changes in emergency fire response.

5.1 *Evolution of Wildand Fire Response*

Wildfire response has evolved dramatically over the past few decades, due largely to advancements in technology, and increasingly sophisticated political agreements. A few decades ago, major fire outbreaks were handled almost exclusively by local firefighters with some minor assistance from either the Texas Forest Service (TFS) or United States Forest Service (USFS) (personal communication with T. Spencer at TFS 2006).

Major wildfire responses today often involve support structures that bridge local, state, federal, and even international borders. Improvements in transportation capabilities have allowed for almost unlimited firefighting resource potential. While the added resources have undoubtedly resulted in improved fire response efficiency, complex organizational structures have resulted in a culture change with respect to incident management. Developed in the 1970s following a series of catastrophic fires in California, the Incident Command System (ICS) was developed for the purpose of standardizing and improving communication through all levels of emergency responders working an incident. An incident is an occurrence or event, natural or human-caused that requires emergency response to protect life or property. (FEMA Course IS-100, 2005).

Active wildfire seasons in recent years have resulted in a large number of ICP trained professionals, including 69 NWS certified IMETs. Texas land management agencies have seen increased demand for non-wildfire support for incidents such as the Columbia Shuttle Recovery in 2003 and the aftermath of Hurricanes Katrina and Rita in 2005. Improved efficiency in fire response logistics may be counterbalanced by the increased demand for non local wildfires and non wildfire response missions.

5.2 *Population*

Texas is among the fastest growing states within the United States of America in terms of population. Census data shows Texas growing from 9.5 million people in 1960 to nearly 21 million in 2000 (U.S. Census Bureau, 2000) and is projected to reach 24.6 million by 2010 (U. S. Census Bureau, 2005).

Since 1970, the Texas population growth rate has been roughly double that of the national average (Murdock, 2002). Population growth has had a particular impact in the Texas Hill Country, along the Interstate 35 Corridor, in the areas surrounding the three largest metropolitan areas of Dallas/Fort Worth, Houston, and San Antonio, and in the Lower Rio Grande Valley. Figure 9 illustrates the large areas of land representing the strongest growth and infers the location of

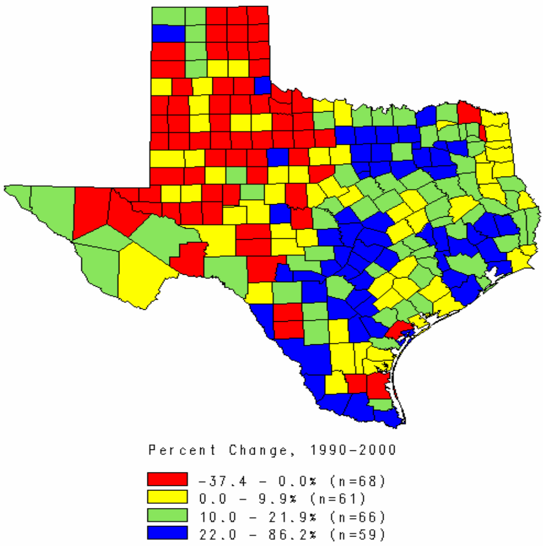


Fig 9. Percent change of population by county from 1990-2000.

Texas' expanding urban/wildland fire interface. Compounding the effect of the population increase is the change in character of the average homestead. The USDA indicated that farms smaller than 50 acres have nearly tripled in number compared to 1974 (USDA, 2002). Cattle ranching remained steady during this period, suggesting decreased acreage managed through livestock production. It is speculated that this reduction in cattle grazing is a leading cause of the dramatic increase of the volatile juniper fuels over Central Texas. The juniper acreage has increased from 3 million acres in the late 1980s to near 21 million acres today (Galloway, 1997). The coupling of rapid urbanization with changing land management practices could make the Texas Hill Country and Interstate 35 corridor a high risk area for devastating wildfires during any future climatological dry cycle.

6. SUMMARY

Periodic drought episodes across the state of Texas can be expected based on past climatological data. Climate variability and indicators such as ENSO cycle and long term drought monitoring suggest the periodic severe drought events might be anticipated by several months. With the onset of a drought event in Texas, a corresponding signal with respect to wildland fire dangers appears to be developing. Drought events during the cold season may favor increasing fire activity and severity, when compared to droughts that extend into the warm season.

Multi-agency ICP response has increased the efficiency of wildfire attack and protection efforts. Increasing population, the expansion of the urban/wildland interface, and the ever changing land use issues will likely contribute to large scale firefighting responses in the future.

Weather patterns that favor extreme fire behavior (i.e. strong and shifting winds, dry conditions, instability) will remain a threat to life and property across Texas. Increasing observational skill and experience at recognizing dangerous fire weather scenarios based on climatic changes may offer significant lead time to anticipate future disasters. This knowledge, experience, and lead time might be used for fire prevention efforts, resource and logistics planning, and heightened awareness of the population in general to the link between climate and local weather trends.

7. ACKNOWLEDGEMENTS

The authors would like to thank Tom Spencer and the staff of the Texas Forest Service for their cooperation and help in collecting data and statistics related to the fires and emergency response. We also extend sincere thanks to Bernard Meisner of NWS Southern Region Science and Training Services Branch and Jon Zeitler, Science and Operations Officer, NWSFO Austin/San Antonio for their review of the manuscript and consultation. Thank you to Dorris A. Hood Techniques Development Unit Meteorologist, NASA Spaceflight Meteorology Group, Johnson Space Center and Jesus A. Haro Warning Coordination Meteorologist, NWSFO Brownsville for converting and generating the needed graphics.

8. REFERENCES

Bomar, George, 2001: The Handbook of Texas Online Weather Section. Texas State Historical Association.

Federal Emergency Management Agency (FEMA) Course ISC-100, 2005. pp. 5.

Galloway, D., 2002: Texas Forest Service Internal Survey. A Comparison from 1975 to 2002. TFS, College Station, TX.

Galloway, D., 1997: Texas Agriculture Experiment Station Juniper Symposium. San Angelo, TX.

Hannemann, P., 2006: Cover Letter attached to Certificates of Appreciation from Lone Star State Incident Management Team.

Keetch, John J; Byram, George. 1968: A drought index for forest fire control. Res. Paper SE-38. Asheville, NC: U.S. Dept. of Agriculture, Forest Service, Southeastern Forest Experiment Station. pp. 32 (Revised 1988).

Larkin, Thomas J; Bomar, George. 1983: Climatic Atlas of Texas. Texas Department of Water Resources.

Murdock, Steven H., White, S., Hoque, N., Pecotte, B., You, X., Balkan, J. 2002: A Summary of the Texas Challenge in the Twenty First Century: Implications of Population Change for the Future of Texas. Dept. of Rural Sociology, Texas A & M University, pp. 109

Nielsen-Gammon, John; Mosier, Matt. 2005: Texas Climate Bulletin. Vol. 18 Number 12.1, Office of the State Climatologist, Dept. of Atmospheric Sciences, Texas A & M University.

Nielsen-Gammon, John; Johnson, H. 2004: Texas and Oklahoma's Greatest Hits: The most significant weather events to strike Texas and Oklahoma. OSC Report 04-1. p. 3

Palmer, W. 1965: Meteorological drought. *Research Paper No. 45*. U.S. Weather Bureau. NOAA Library and Information Services Division, Washington, D.C.

Philander, S.G.H., 1990: El Niño, La Niña and the Southern Oscillation. Academic Press, San Diego, CA, pp. 289

United States Census Bureau, 2005: Population Pyramids and Demographic Summary and Demographic Summary Indicators for States.

United States Census Bureau, 2000: United States Summary: Population and Housing Unit Counts.

United States Dept. of Agriculture, 2002: 2002 Census of Agriculture – State Data. USDA, National Agriculture Statistics Service.