The 2011 Texas Drought

A Briefing Packet for the Texas Legislature
October 31, 2011

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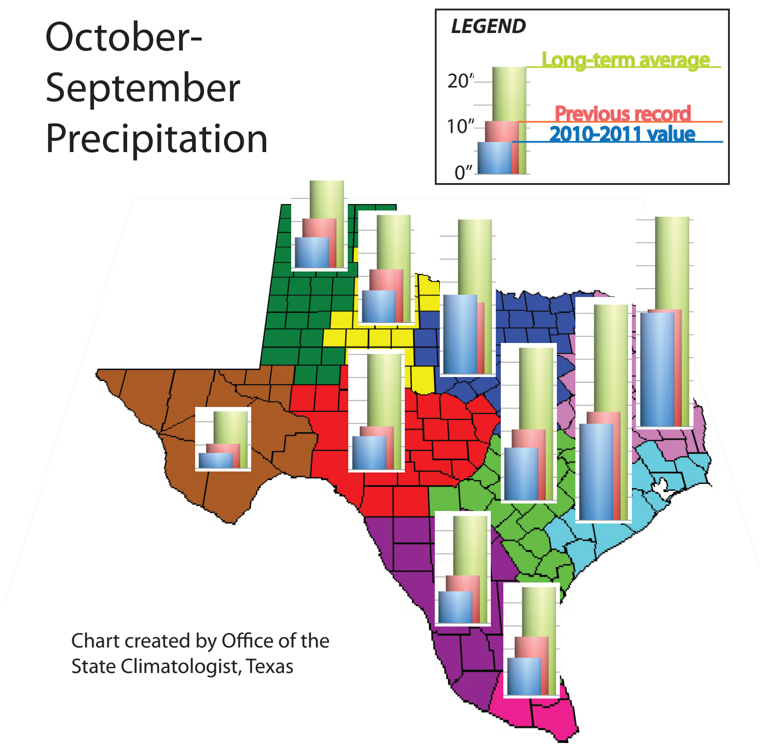

The Office of the State Climatologist is housed in the College of Geosciences, Texas A&M University, College Station, Texas

Executive Summary

The 2011 drought in Texas has been unprecedented in its intensity. The year 2010 had been relatively wet across most of the state, except for extreme eastern Texas. Beginning in October 2010, most of Texas experienced a relatively dry fall and winter, but the record dry March 2011 brought widespread extreme drought conditions to the state. A record dry March through May was followed by a record dry June through August, and the 12-month rainfall total for October 2010 through September 2011 was far below the previous record set in 1956. Average temperatures for June through August were over 2 °F above the previous Texas record and were close to the warmest statewide summer temperatures ever recorded in the United States.

As the drought intensified, the previous year's relatively lush growth dried out, setting the stage for spring wildfires. Conditions were so dry during the spring planting season across much of the state that many crops never emerged from the ground. Continued dry weather through the summer led to increasing hardship for ranchers, who generally saw very little warm-season grass growth while stock tanks dried up. The record warm weather during the summer in Texas was primarily a consequence of the lack of rainfall, but the heat and resulting evaporation further depleted streamflow and reservoir levels. By early fall, trees in central and eastern Texas were showing widespread mortality and dry and windy conditions allowed forest fires to burn intensely and spread rapidly in Bastrop and elsewhere.

Twelve-month rainfall was driest on record across much of western, central, and southern Texas, and many stations received less than 25% of their normal 12-month precipitation. The area near, north, and east of Dallas was comparatively well off compared to the rest of the state, but still endured serious drought conditions and record heat.

This drought has been the most intense one-year drought in Texas since at least 1895 when statewide weather records begin, and though it is difficult to compare droughts of different durations, it probably already ranks among the five worst droughts overall. The statewide drought index value has surpassed all previous values, and it has been at least forty years since anything close to the severity of the present drought has been experienced across Texas.

Because of the return of La Niña conditions in the tropical Pacific, a second year of drought in Texas is likely, which will result in continued drawdown of water supplies. Whether the drought will end after two years or last three years or beyond is impossible to predict with any certainty, but what is known is that Texas is in a period of enhanced drought susceptibility due to global ocean temperature patterns and has been since at least the year 2000. The good news is that these global patterns tend to reverse themselves over time, probably leading to an extended period of wetter weather for Texas, though this may not happen for another three to fifteen years. Looking into the distant future, the safest bet is that global temperatures will continue to increase, causing Texas droughts to be warmer and more strongly affected by evaporation.

About the Texas State Climatologist

The Office of the State Climatologist, Texas, is housed in the Department of Atmospheric Sciences, College of Geosciences, Texas A&M University. The OSC has been designated an AASC-Recognized State Climate Office (ARSCO) by the American Association of State Climatologists. The mission of the OSC is to enable the State of Texas and its citizens make best possible use of climate data and outlooks, to monitor and document climate events and conditions across the state, to conduct climate research with direct benefit to Texans, and to serve as a local point person for NOAA and other federal agencies with regards to Texas climate. The OSC posts reports and real-time climate monitoring information on its web site (http://atmo.tamu.edu/osc, soon to be upgraded to http://climatexas.tamu.edu) and houses an archive of Texas climate-related publications.

The Texas State Climatologist is nominated by the President of Texas A&M University and appointed by the Governor of Texas. John Nielsen-Gammon has served as the Texas State Climatologist since the year 2000. He received his Ph.D. in Meteorology from the Massachusetts Institute of Technology in 1990 and joined the faculty of Texas A&M University in 1991. Nielsen-Gammon is a Fellow of the American Meteorological Society and Past President of the International Commission for Dynamical Meteorology. His climate-related research focuses on regional drought causes and regional drought and climate monitoring, and he has also played a key role in understanding the meteorological conditions contributing to high concentrations of ozone in the Houston area. The Houston Chronicle hosts his blog on weather and climate issues called Climate Abyss.

The Texas State Climatologist is a designated member of the Texas Drought Preparedness Council.

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1) Introduction

Drought is a condition of hardship due to lack of water caused by unusual meteorological conditions. Drought affects both society and the natural environment. Society attempts to use water to maximum benefit, and hardship results when insufficient water is available for the normal types and amounts of water uses. Natural ecosystems have adapted to the occasional occurrence of drought, though human interactions with the environment have sometimes reduced natural resilience.

The severity of a drought depends on its intensity and duration. Differences in drought duration make it difficult to compare various droughts. A short-term drought, one lasting less than six months or so, will have a large impact on the agricultural industry but cause relatively few water supply problems. In contrast, a long-lasting drought of low intensity may have relatively little agricultural impact but may cause major problems for water suppliers due to steadily declining reservoir and aquifer levels.

As shown in this report, the 2011 drought in Texas has been unprecedented in its intensity. While the current period of below-normal rainfall has only lasted slightly more than a year, the lack of rainfall has been so profound that many water supplies throughout the state have been seriously affected. With the drought very likely to continue for at least several more months, wintertime replenishment of water supplies will generally be below normal and additional worsening of water supply conditions is likely in 2012.

This report considers the Texas portion of the 2011 drought. As of this writing, drought conditions extend almost continuously across the southern United States from Arizona to North Carolina and from parts of the Northern Plains into central Mexico (source: North American Drought Monitor). However, the exceptional drought conditions have disproportionally affected Texas and Oklahoma along with neighboring parts of New Mexico, Colorado, Kansas, Arkansas, Louisiana, and the country of Mexico.

For designing policy to mitigate the impacts of this or future droughts, it is essential to understand the present drought in a historical context. A drought so rare as to be unlikely to recur in the next thousand years might require a one-time intervention, while a drought likely to repeat itself within our lifetimes may require a greater emphasis on permanent mitigation or adaptation measures.

A second area of policy concern is the potential continuation of the present drought beyond the immediate future. While most water systems are designed for the drought of record, most have never actually had their infrastructure and water plans tested by the drought of record. It is not too late to consider the possibility that this drought may turn out to be worse than the drought of record and to take steps to prepare for that possibility.

This report focuses on the meteorological aspects of the 2011 Texas drought. The second section of this report describes the conditions leading up to the onset of the 2011 Texas drought. Section three illustrates how dry conditions developed across the state during fall of 2010 and winter, spring, summer, and early fall of 2011. The fourth section considers the 2011 drought's place in the meteorological record books on a statewide, climate division, and local scale. Finally, section five considers the outlook for the present and future droughts over the next year, the next decade, and beyond.

2) Setting the Stage: Rainfall Patterns through September 2010

During the past fifteen years, Texas has experienced a succession of droughts interspersed by relatively wet years. This period of frequent drought followed the wettest ten to twenty years in the Texas climate record (Nielsen-Gammon, 2011). Note: unless otherwise stated, all weather records quoted in this report are with respect to a period of record extending from 1895 to the present.

The drought of 1995-1996 broke the string of wet years and partly influenced major water planning legislation enacted in many states, including Texas. A brief drought in 1998 was followed by the drought of 1999-2002, which reached its peak in most of Texas with record-setting temperatures in early September 2000 but which lingered in far West Texas two more years. The 2005-2006 drought was widespread across most of Texas but never really achieved historical proportions. The 2007-2009 drought, on the other hand, was relatively localized when it reached its peak intensity in 2009, but for some locations in south-central and south Texas it may well have been the worst drought on record up to that point (Nielsen-Gammon and McRoberts, 2009).

This section and the next will evaluate rainfall shortages using a drought index called the Standardized Precipitation Index, or SPI. The SPI has become one of the most popular drought indices, in part because of its simplicity and flexibility. The SPI takes a particular value of accumulated precipitation (such as precipitation over the past six months) at a given location and rescales it based on the historical record of precipitation variability at that location. The result is an index value that is negative when present conditions fall into the drier half of expectations based on historical values and positive when present conditions fall into the wetter half of expectations. The more negative the SPI value, the more unusually dry the weather conditions. The following table shows some sample values of SPI and their interpretation. Note that assessments of actual drought severity should not be based exclusively on a single measure.

SPI range	*Expected frequency*	*Designation*
0.5 to -0.5	About 40% of the time	Near Normal
-0.5 to -0.7	About 10% of the time	Abnormally dry
-0.8 to -1.2	About 10% of the time	Moderate drought
-1.3 to -1.5	About 5% of the time	Severe drought
-1.6 to -1.9	About 3% of the time	Extreme drought
-2.0 to -2.5	About 1.5% of the time	Exceptional drought
Below -2.5	About 0.5% of the time	Exceptional drought

Table 1: Interpretation of various ranges of values of the Standardized Precipitation Index (SPI). Source: modified after http://droughtmonitor.unl.edu/classify.htm (accessed October 30, 2011).

SPI values below -2.5 are unlikely to have occurred previously on a given date in the historical record. SPI values below -3.0 have an expected return period for a given date of once every 1000 years in an unchanging climate, though the historical record is too brief to allow such low probabilities to be calculated with much accuracy.

This report presents SPI maps from the online archives of the Office of the State Climatologist, Texas (OSC). The maps are accessible through http://atmo.tamu.edu/osc/drought and the method of map generation is described in McRoberts and Nielsen-Gammon (2011b). The input data is the 4 km daily precipitation analysis produced by the National Weather Service's River Forecast Centers, calibrated using long-record stations in the Cooperative Observer Network. These maps provide an excellent guide to the distribution of drought conditions across Texas in space and time, but the quality of the maps is occasionally hampered by uncorrected errors in the radar estimation of precipitation. The color gray designates areas with insufficient radar coverage for accurate precipitation estimation.

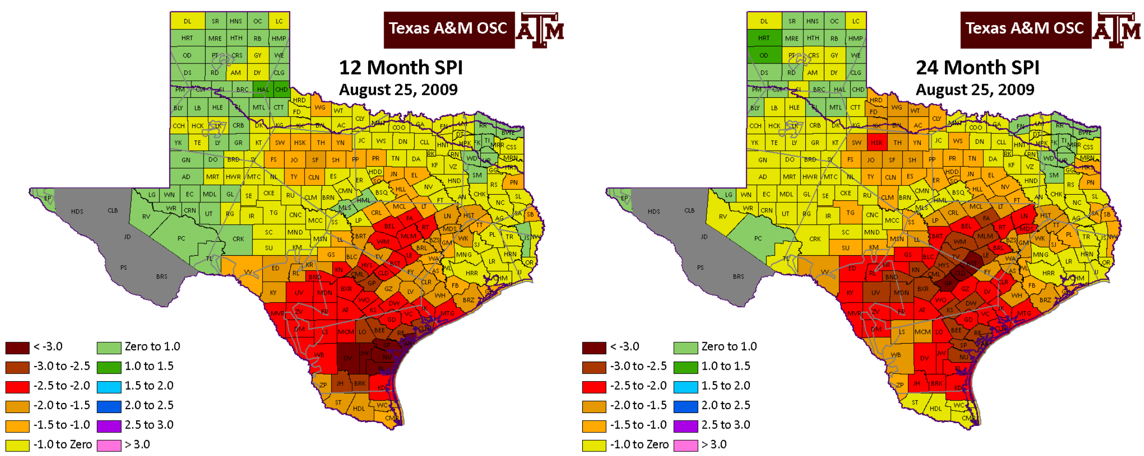


Figure 1: SPI values for accumulated precipitation over 12 months (left) and 24 months (right), at the height of severity of the 2007-2009 drought.

The 2007-2009 drought was most severe in south-central and south Texas (Fig. 1). The short-term dryness was most acute in the Coastal Bend area, where at least one county experienced a total failure of its cotton crop, while longer-term drought was most intense along and just southeast of the Balcones Escarpment in central and south-central Texas. Extreme drought conditions in the Lower Valley and east Texas were largely mitigated by the rainfall from hurricanes Dolly and Ike and tropical storm Edouard.

The distribution of drought in August 2009 is shown here for two reasons. First, it indicates which portions of the state were most seriously affected in 2007 and 2009 and which may not have recovered prior to the 2011 drought. Second, it provides a useful point of comparison by which to indicate the much greater severity of the 2011 drought.

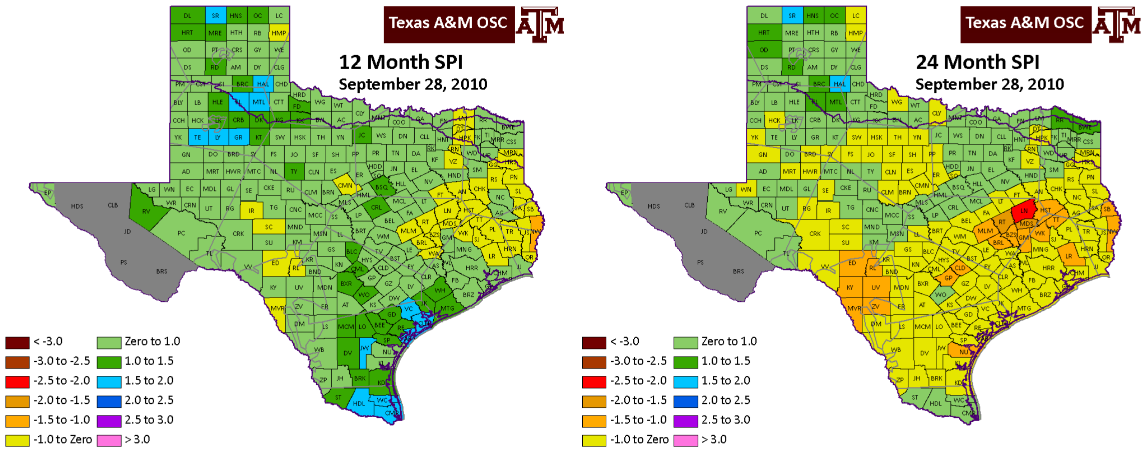


Figure 2: SPI values for accumulated precipitation over 12 months (left) and 24 months (right), just prior to the onset of the 2011 drought.

The date of onset of the 2011 drought can be stated with remarkable precision: September 27, 2011. On that date a storm system bringing widespread rain to Texas left the state. Though it could not be known at the time, twelve of the next thirteen months would bring below-normal precipitation to Texas.

The September 2010 conditions reflected a relatively wet winter, spring and summer, caused in part by an El Niño event in the tropical Pacific. Based on rainfall over the preceding 12 months, most of the state was above or near normal (Fig. 2), with the driest conditions found along the Louisiana border. When 2009 is factored in, the two-year accumulations averaged near-normal across the state, with the lowest two-year totals (compared to normal) found in scattered pockets in the southern and eastern portions of the state.

Parts of eastern Texas would rightfully take exception to the claim that the drought started at the end of September 2010. As Fig. 2 shows, moderate drought conditions already existed at both one-year and two-year time scales in Newton County, and other parts of eastern Texas had just finished a summer with below-normal rainfall and unusually little hay production. However, for the state as a whole, the end of September represents the "high water mark" prior to the onset of widespread drought conditions. In the U.S. Drought Monitor (http://droughtmonitor.unl.edu), only 2.4% of the state was classified as being in drought at the end of September.

3) Drier and Drier: Development of the 2011 Texas Drought

This section tells the story of the evolution of the 2011 Texas Drought to date using four separate SPI indices. The two-month SPI characterizes precipitation shortages (and excesses) for the two-month period ending on the date specified. This index is most useful for monitoring the month-to-month variations in rainfall and for characterizing short-term drought stress during the warmer parts of the year. The six-month SPI characterizes the rainfall amounts during the preceding half-year, and is most useful for characterizing shallow soil moisture available to agricultural crops and forage grasses. The twelve-month and 24-month SPI maps are most useful for characterizing precipitation on time scales relevant to the recharge of reservoirs and some aquifers, as well as deep soil moisture available to trees.

October 2010

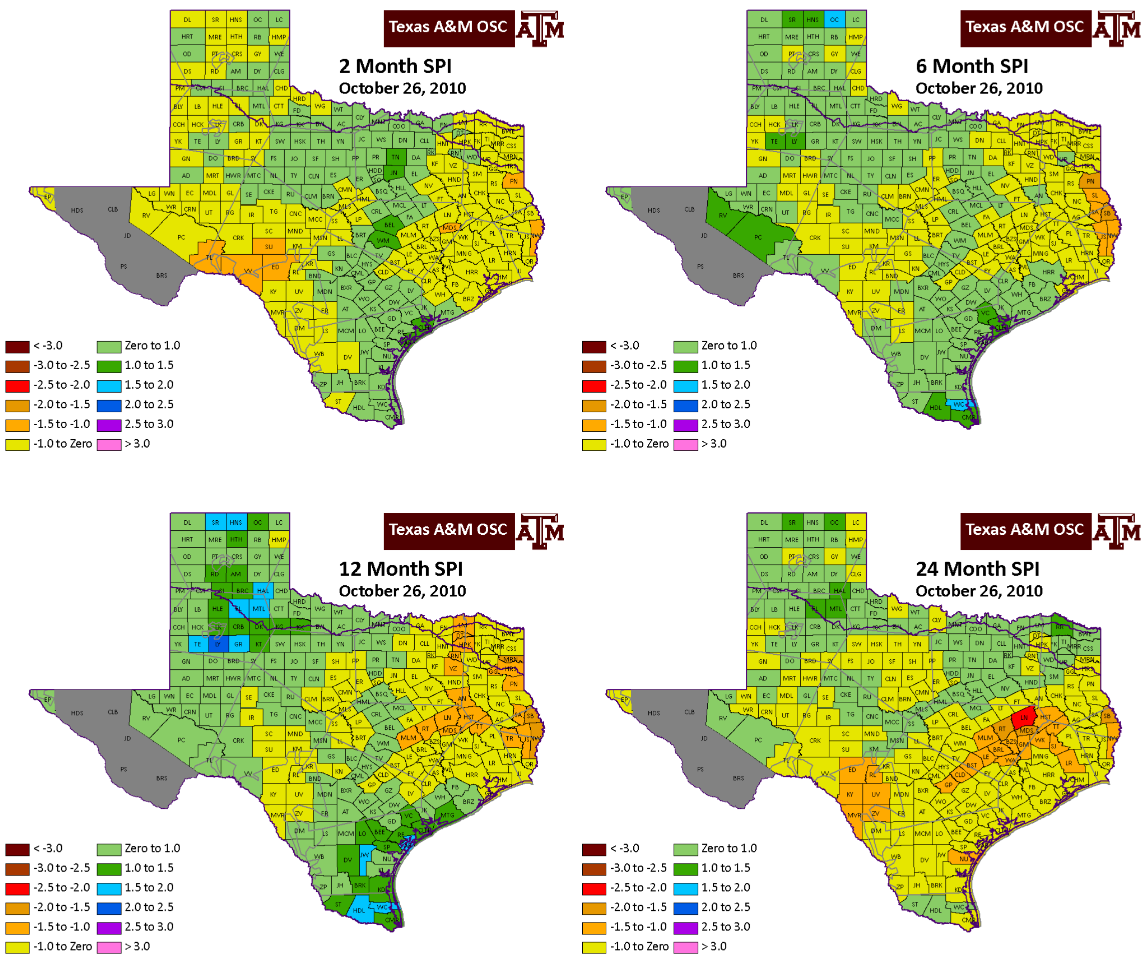


Figure 3: SPI drought index values as of October 26, 2010. The more negative values indicate more severe drought conditions.

Already by the end of October, the dry conditions in eastern Texas were becoming increasingly clear, as some rainfall events prior to the summer no longer contributed to the current SPI values. The two-month SPI reflected a combination of a wet September, with multiple tropical disturbances bringing rain to south Texas and the I-35 corridor, and an October that was eighth-driest on record for the state as a whole.

November 2010

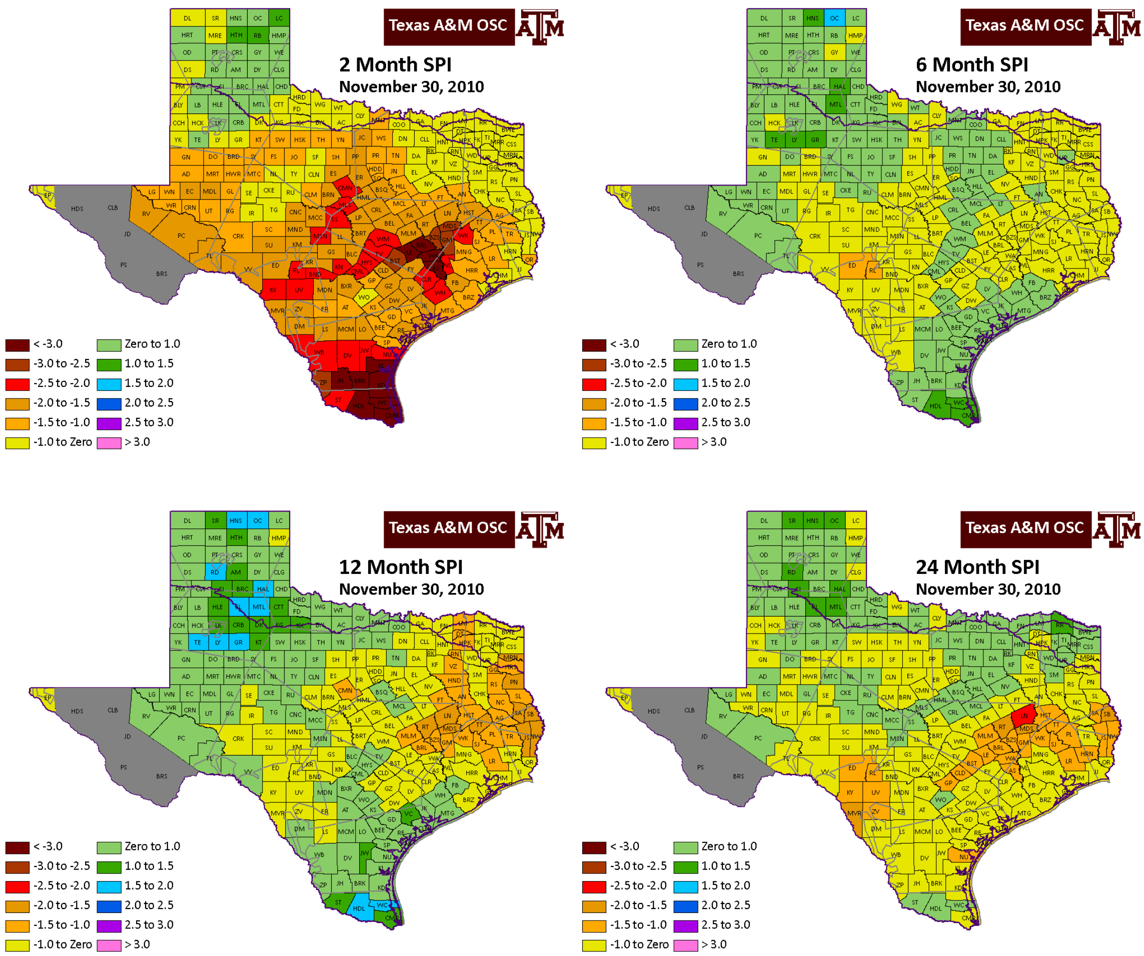


Figure 4: SPI drought index values as of November 30, 2010. The more negative values indicate more severe drought conditions.

At the end of November, the two-month SPI is based on two consecutive dry months, and Figure 4 shows that the fall dryness was exceptional in parts of central and south Texas. The Panhandle had actually received above-normal precipitation for the two-month period, due almost entirely to rain from a single storm system on the 11th and 12th of November.

December 2010

December was the third consecutive drier-than-normal month for Texas. The November 11-12 Panhandle rain event was all that kept the entire state from receiving below-normal precipitation for the November-December period. The three months of dry weather had thrown most of eastern Texas into drought conditions according to the six-month and 12-month SPI maps (Fig. 5). The year 2009 had been the 11th wettest on record for the East Texas climate division (#4), but the year 2010 was the 8th driest. The 12-month and 24-

month SPI maps in Fig. 5 indicates that 2010 was driest toward the Louisiana border, while 2009 was apparently wettest near the Oklahoma border. This left the southern half of the Louisiana border in drought conditions for all at all depicted time scales, based on the SPI.

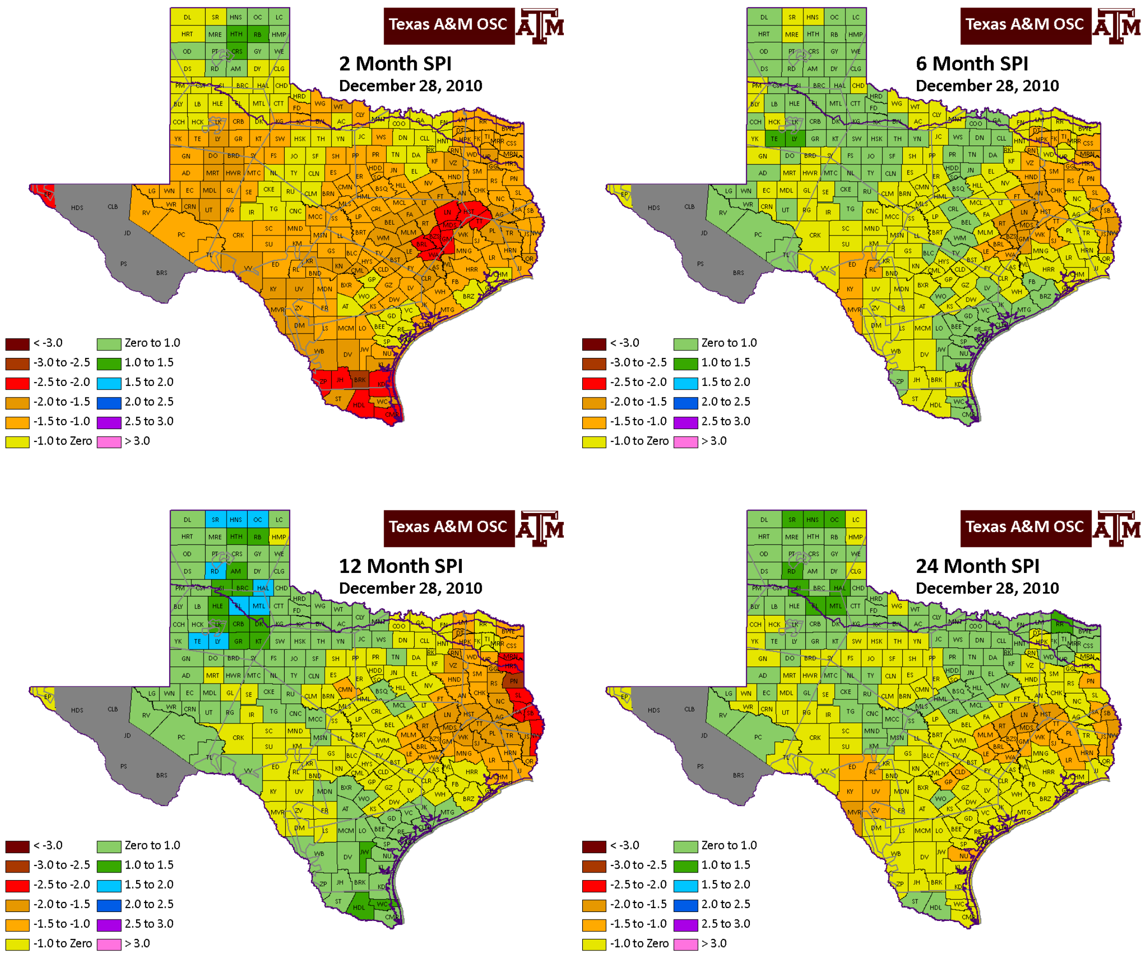


Figure 5: SPI drought index values as of December 28, 2010. The more negative values indicate more severe drought conditions.

Both short-term and long-term drought were also already present in east-central Texas, in an area centered on Bryan/College Station, and in the western Winter Garden area of southwestern Texas east of Del Rio. In the rest of the state, the wet summer was still substantially reducing the potential impact of the dry fall. However, the combination of a wet summer and dry fall provided substantial fuel for wild fires. Potential wildfire danger is indicated by those areas in which the two-month SPI is much drier than the six-month SPI.

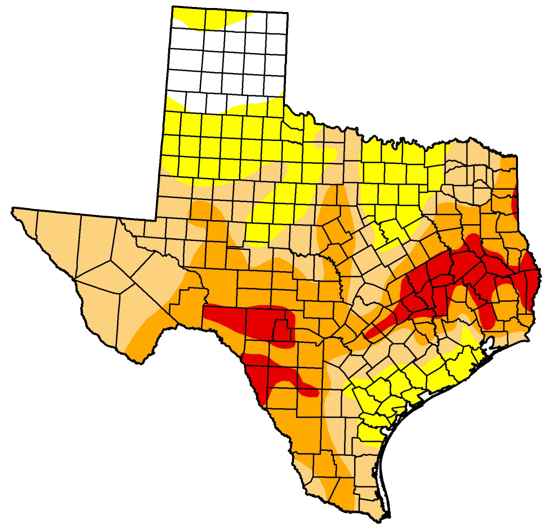
U.S. Drought Monitor

December 28, 2010
Valid 7 a.m. EST

Texas

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	7.89	92.11	69.43	37.46	9.59	0.00
Last Week (12/21/2010 map)	13.61	86.39	73.68	38.41	9.66	0.00
3 Months Ago (09/28/2010 map)	75.57	24.43	2.43	0.99	0.00	0.00
Start of Calendar Year (12/29/2009 map)	72.90	27.10	6.98	2.32	0.00	0.00
Start of Water Year (09/28/2010 map)	75.57	24.43	2.43	0.99	0.00	0.00
One Year Ago (12/22/2009 map)	72.27	27.73	8.14	2.32	0.00	0.00



Intensity:

- *D0 Abnormally Dry*
- *D1 Drought - Moderate*
- *D2 Drought - Severe*
- *D3 Drought - Extreme*
- *D4 Drought - Exceptional*

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, December 30, 2010
D. Miskus, CPC/NOAA

Figure 6: U.S. Drought Monitor for Texas for December 28, 2010. Available online at http://droughtmonitor.unl.edu.

Three months into what would become the 2011 drought, the U.S. Drought Monitor was indicating short-term drought across most of Texas (Figure 6). Already, 69.4% of the state was classified as being in at least moderate drought. However, exceptional drought had not yet made an appearance, and only 9.6% of the state was in extreme drought.

January 2011

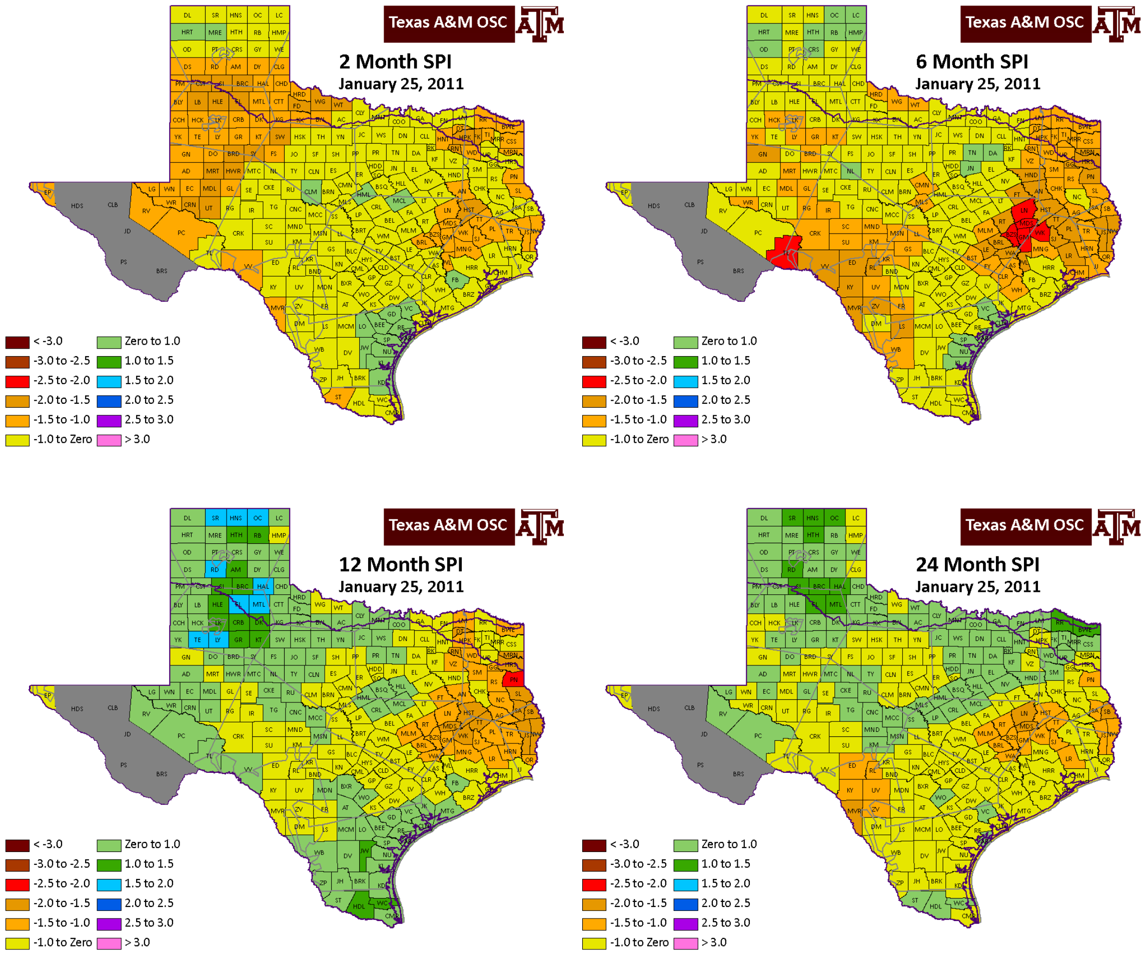


Figure 7: SPI drought index values as of January 25, 2011. The more negative values indicate more severe drought conditions.

January was the only month within the period in which statewide average rainfall (barely) exceeded its long-term average. The precipitation was sufficient to bring the two-month and six-month totals to above normal in the Coastal Bend area (Fig. 7); this rain was extremely beneficial for establishing suitable conditions for crop planting and seed germination. Most of the rest of the state also benefited temporarily from the rainfall (or, in northern Texas, snowfall). However, less than a tenth of an inch of precipitation was record in most of western Texas, and the lack of mid-season precipitation and snow cover would have serious implications for much of the winter wheat crop.

By the end of January, the area around Bryan/College Station had crossed into the exceptional drought threshold at the six-month accumulation period. However, environmental and societal water demands are minimal in that region during the wintertime, so the impacts of the drought were still far short of exceptional. Terrell County in southwest Texas had also crept into exceptional drought on the basis of six-month precipitation.

February 2011

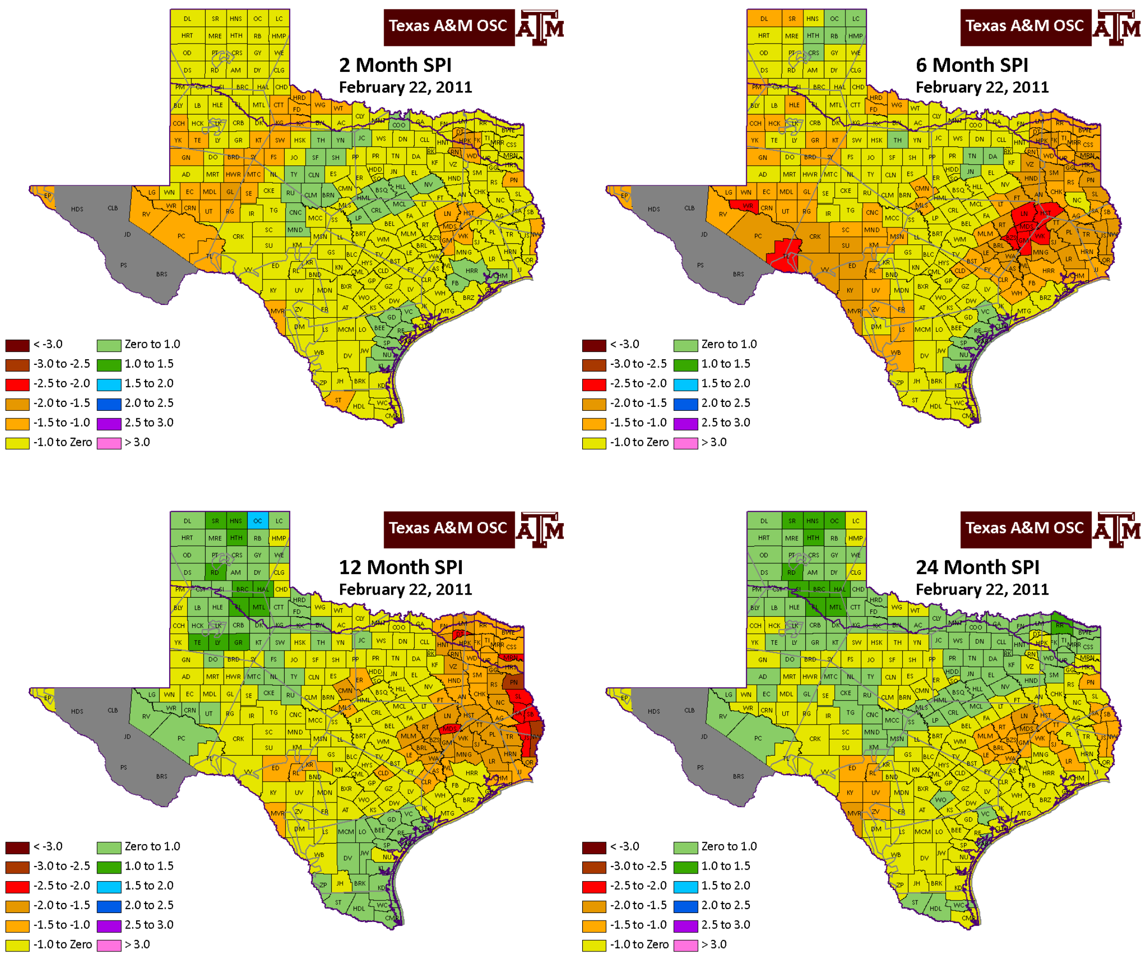


Figure 8: SPI drought index values as of February 22, 2011. The more negative values indicate more severe drought conditions.

February was again a dry month, but not exceptionally so. The SPI index maps (Fig. 8) showed little change from the end of January. At this point, six months into the drought, true drought conditions were present throughout east Texas, extending westward almost as far as Dallas, Austin, and Houston. Drought conditions also prevailed across southwestern Texas and parts of western and northern Texas as well. According to the U.S. Drought Monitor (not shown), the fraction of the state suffering under drought was about the same size as at the end of December.

March 2011

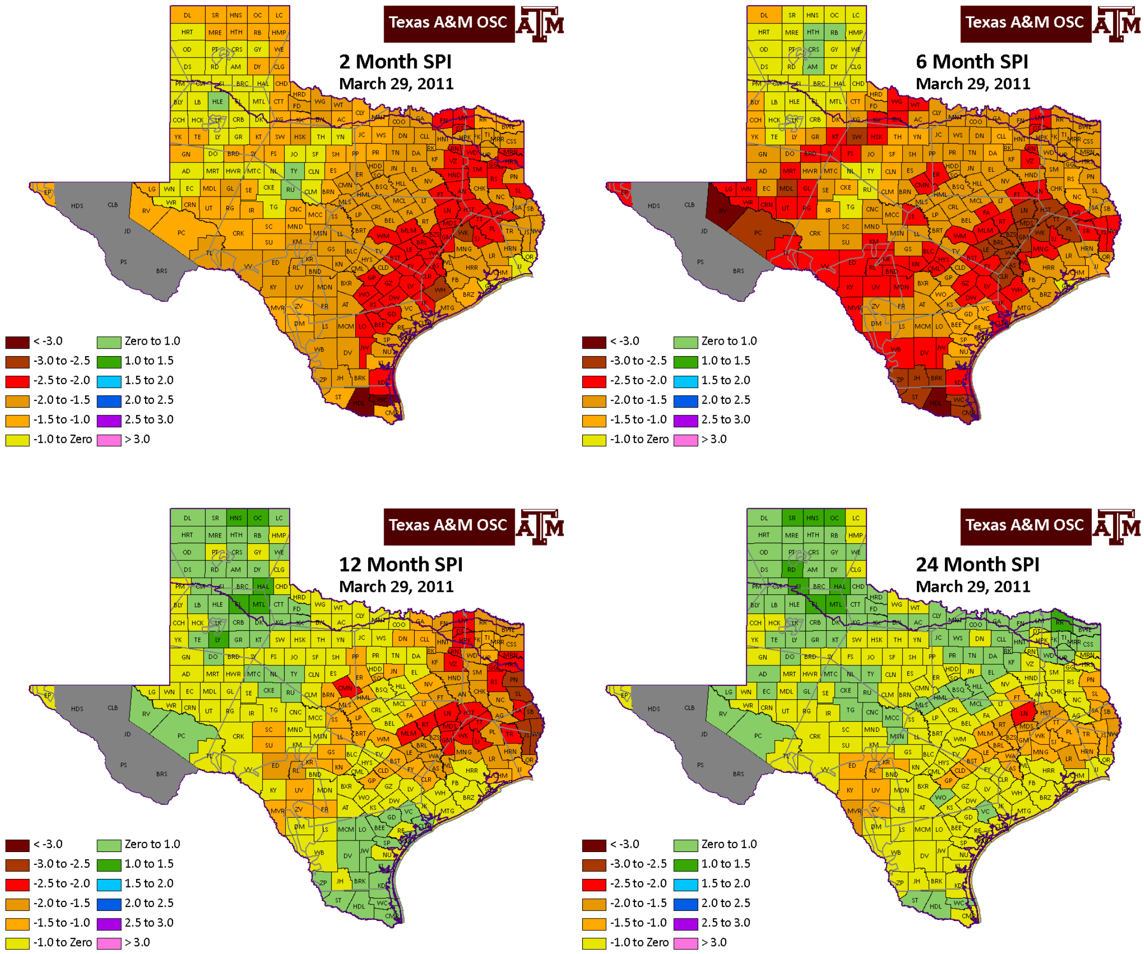


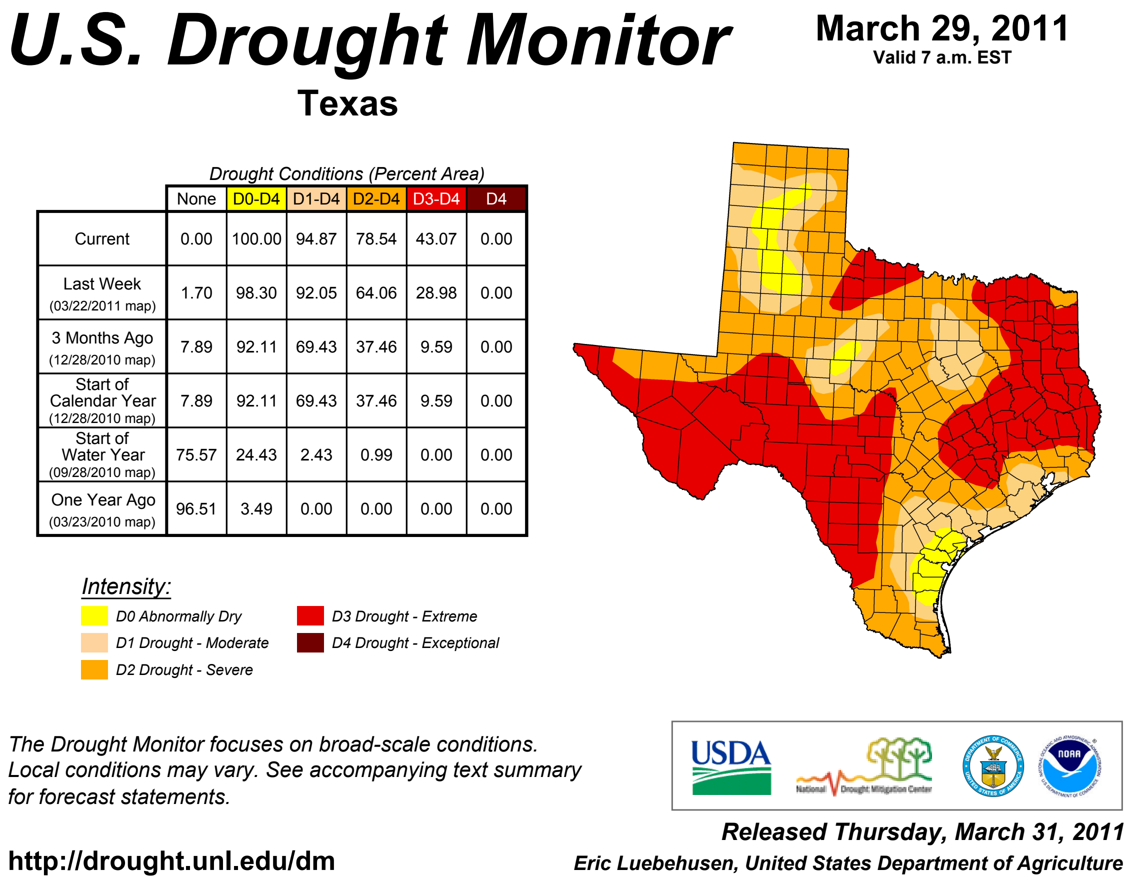
Figure 9: SPI drought index values as of March 29, 2011. The more negative values indicate more severe drought conditions.

While Texas was already in serious drought at the end of February 2011, the upcoming months were disastrous for farmers and ranchers. With ample rain beginning in March, the most serious drought impacts might have been limited to the winter wheat crop and excess winter feeding costs for ranchers.

Instead, the opposite happened. March 2011 was the driest March on record for the state of Texas as a whole. Below-normal precipitation for the February-March period occurred everywhere except parts of western Texas, where rainfall in February and March is normally light (Fig. 9).

The record dry March combined with the removal of September from the six-month precipitation accumulation period combined to allow the six-month SPI to depict terrible drought conditions across the state. Many counties in east-central, south, and west Texas had SPI values below -2.5, implying a lack of cool-season rainfall that was probably unprecedented in the historical record. The only portion of the state with positive SPI values at the six-month time scale were in the Panhandle, due to the storm back in November.

Aside from the Panhandle, the remarkable lack of rainfall combined with springtime warmth to dry out the previous year's growth of grasses. Because the previous growth season had been relatively wet, there was ample dry grass available to serve as fuel for wildfire, especially in central and western Texas where absolute precipitation amounts were smallest and winds tended to be stronger. By early April, wildfires were burning in many parts of western and west-central Texas.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	94.87	78.54	43.07	0.00
Last Week (03/22/2011 map)	1.70	98.30	92.05	64.06	28.98	0.00
3 Months Ago (12/28/2010 map)	7.89	92.11	69.43	37.46	9.59	0.00
Start of Calendar Year (12/28/2010 map)	7.89	92.11	69.43	37.46	9.59	0.00
Start of Water Year (09/28/2010 map)	75.57	24.43	2.43	0.99	0.00	0.00
One Year Ago (03/23/2010 map)	96.51	3.49	0.00	0.00	0.00	0.00

Figure 10: U.S. Drought Monitor for Texas for March 29, 2011. Available online at http://droughtmonitor.unl.edu.

The U.S. Drought Monitor indicated dry conditions throughout Texas at the end of March 2011 (Fig. 10). More significantly, over 43% of the state was classified as D3, extreme drought, the second most severe drought category. The Drought Monitor began 2000, and in its existence only two weeks during August 2006 had a greater portion of Texas in extreme or exceptional drought. That record would be broken during the first week of April 2011. The record for the greatest percentage of Texas in severe or worse drought would be broken during the third week of April, as would the record for the greatest percentage of Texas in at least moderate drought when the entire state was so designated. The record for the greatest percentage of Texas in exceptional drought would be broken during the fourth week of April.

So according to the U.S. Drought Monitor, the 2011 Texas drought was already in April the most severe Texas drought in recent memory.

April 2011

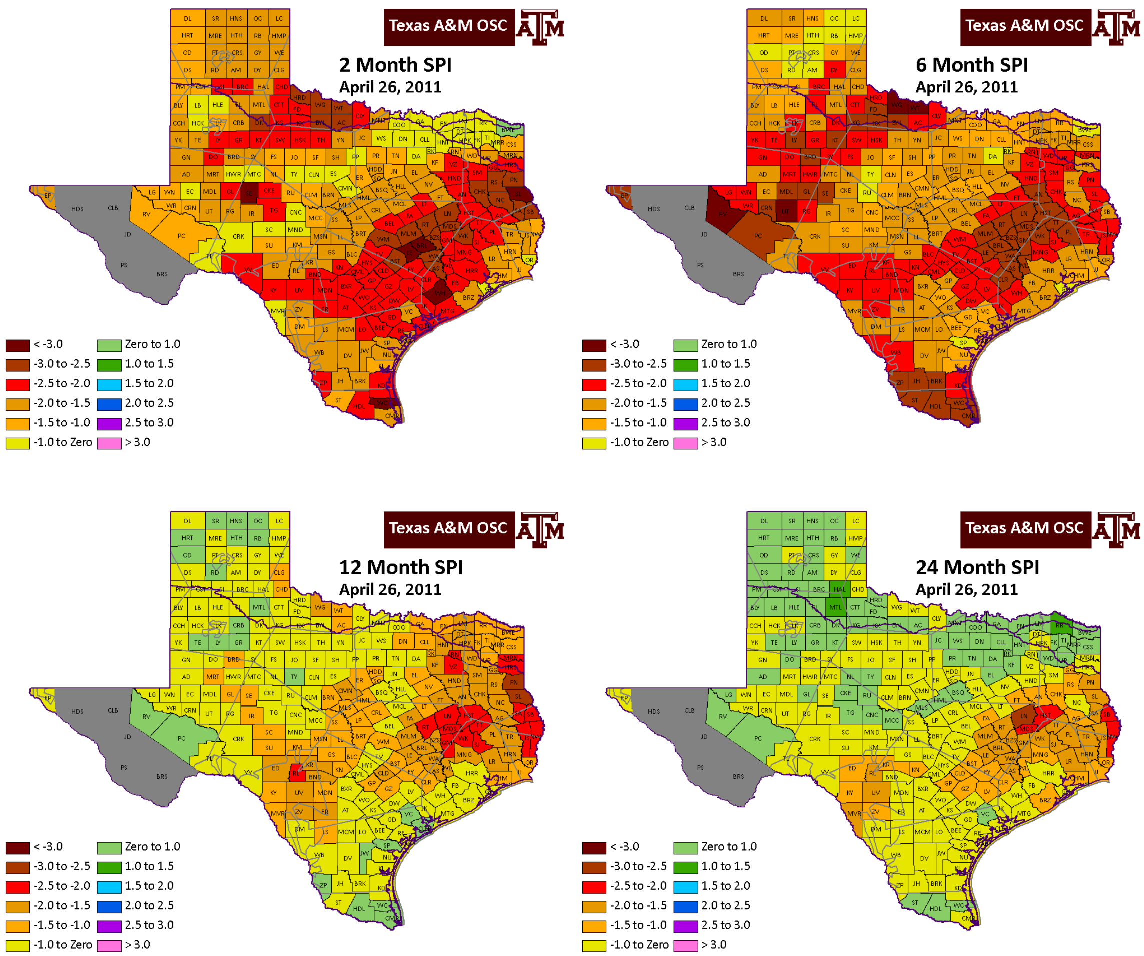


Figure 11: SPI drought index values as of April 26, 2011. The more negative values indicate more severe drought conditions.

The dry weather continued in April, and the SPI index values tracked with the U.S. Drought Monitor in showing worsening conditions (Fig. 11). The two-month SPI shows that only the very northeastern top of Texas received more precipitation than the historical norm. Elsewhere, precipitation was well-below normal, providing insufficient moisture for development of warm-season dryland crops and initiation of warm-season forage growth.

Besides east-central, south, and west Texas, a new area of especially dry conditions emerged in west-central Texas, extending from the Midland-Lubbock area to the Red River between Childress and Wichita Falls. In all but a handful of counties, the wet weather at the beginning of the preceding twelve-month period was overshadowed by the more recent dry weather.

May 2011

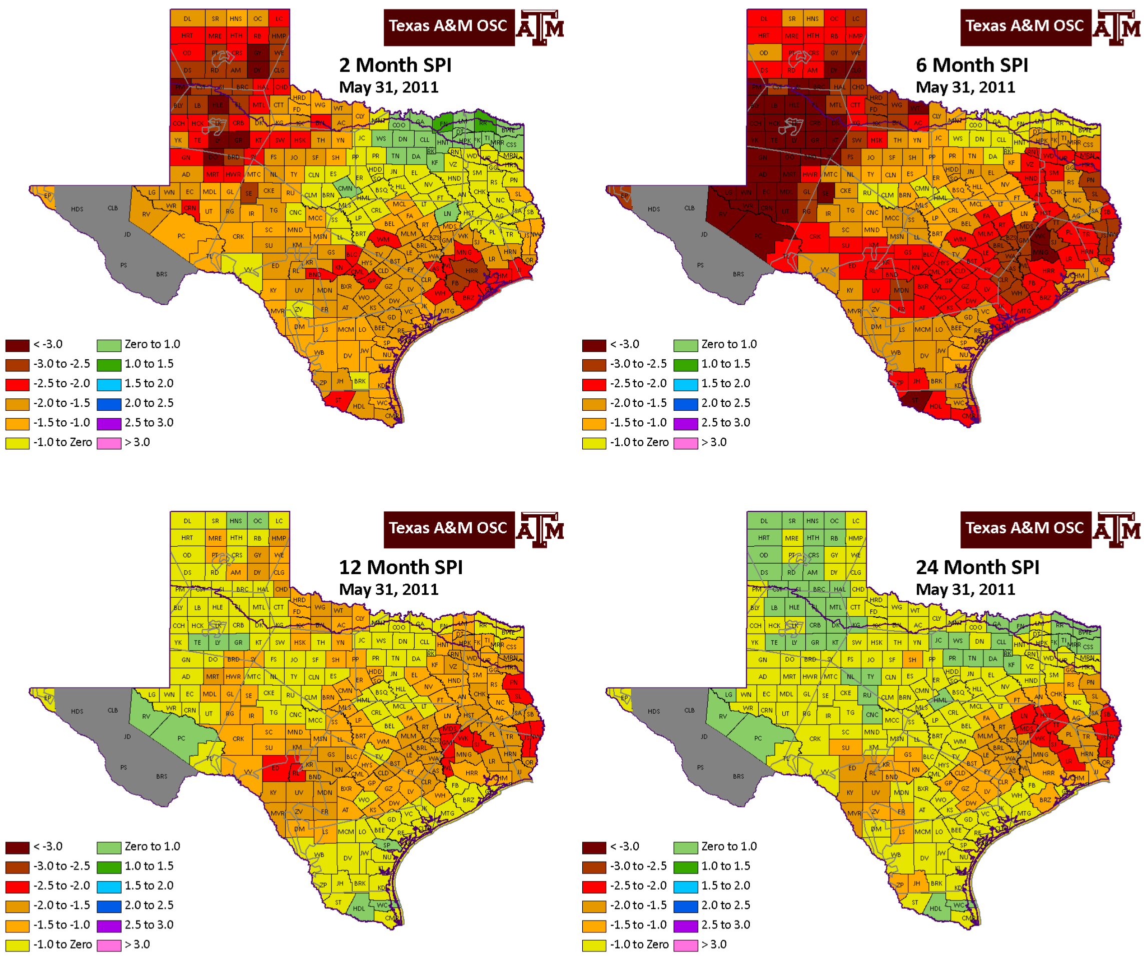


Figure 12: SPI drought index values as of May 31, 2011. The more negative values indicate more severe drought conditions.

Statewide, May averages more precipitation than any other month. May 2011 turned out to be the ninth-driest May on record, and the three-month period from March through May was the driest March-May on record. For all of the state except parts of north-central and northeast Texas, the dry March-May, on the heels of an already dry winter, guaranteed very low to nonexistent dryland crop yields for the 2011 growing season, irrespective of potential future rainfall. In the drier areas, warm-season forage had yet to emerge.

The wetter conditions in northeast Texas were on the edge of a region of flood-producing rainfall extending from eastern Oklahoma and Arkansas northeastward into the Ohio River Valley. In general, if one region of the country is unusually dry, another region will be unusually wet, so the floods can be thought of as being caused by the same set of circumstances that produced the 2011 Texas drought as of the end of April.

With the November Panhandle storm no longer part of the six-month accumulation period, the six-month SPI (Fig. 12) showed a remarkably broad area of -3.0 or worse drought across much of western Texas. This part of Texas is normally dry during the wintertime, but the rains become more plentiful during May as squall lines and severe thunderstorms typically form along the dryline. In 2010-2011, many areas had received less than 10% of even their meager normal rainfall and a large swath of the state west of Midland had not received any measurable precipitation whatsoever during December through May.

June 2011

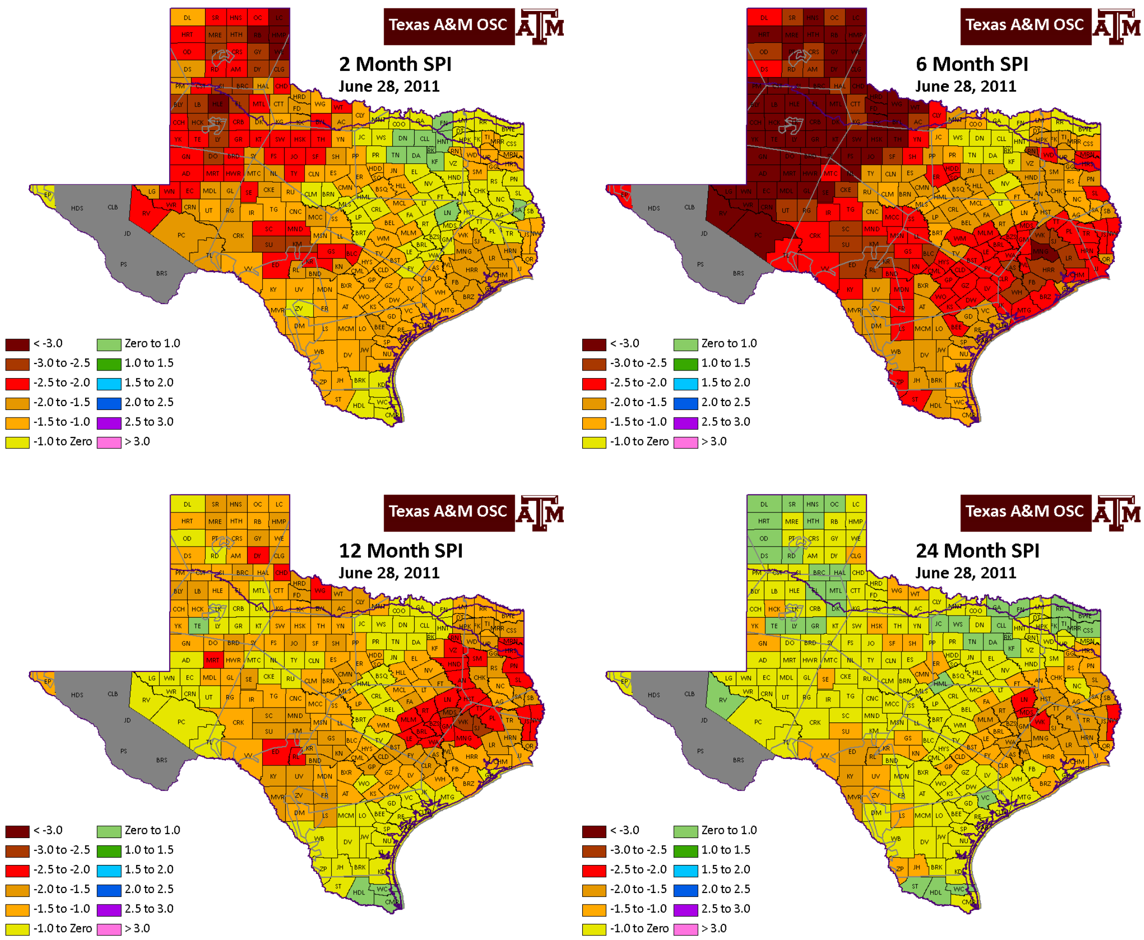


Figure 13: SPI drought index values as of June 28, 2011. The more negative values indicate more severe drought conditions.

The near-total absence of dryline thunderstorm activity continued through June (Fig. 13). Thus the Panhandle, which had benefited from a November storm that missed the rest of the state, now suffered through spring weather not merely much drier than normal, but much drier than any previous record. In the High Plains climate division (#1), May-June precipitation averaged 0.57", roughly 8% of the long-term average for those two months and less than half of the previous record set in 1999, and the 1.63" average for the first six months of the year was likewise less than half the previous record set in 1954. Most counties west of a San Angelo-Wichita Falls line had six-month SPI values below -3.0, indicating an agricultural drought far worse than anything previously experienced in the area.

Despite the particular severity of the drought there, West Texas received little attention because the drought was extremely bad elsewhere too. Most of the area within 75 miles of Interstate 10, from the western border to the eastern border, had six-month SPI values below -2.0, and the timing seemed designed to produce maximum impact on ranchers. In most of the state, warm-season grasses were still very slow to develop, and stock tanks and stream flows were rapidly declining because of the lack of precipitation combined with the excessive heat.

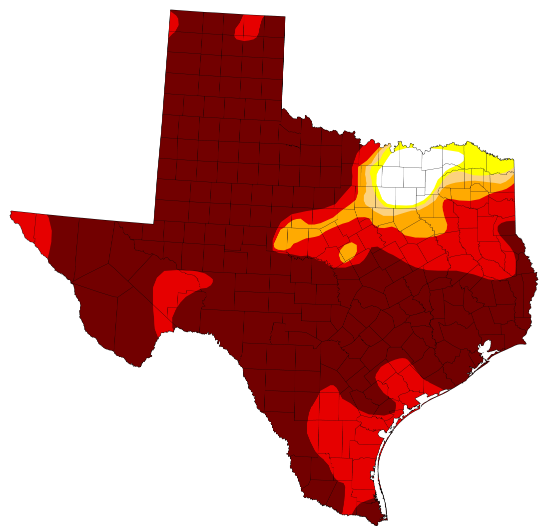
U.S. Drought Monitor

Texas

June 28, 2011
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	2.68	97.32	95.71	94.52	90.62	72.32
Last Week (06/21/2011 map)	3.33	96.67	95.71	94.52	91.31	70.61
3 Months Ago (03/29/2011 map)	0.00	100.00	94.87	78.54	43.07	0.00
Start of Calendar Year (12/28/2010 map)	7.89	92.11	69.43	37.46	9.59	0.00
Start of Water Year (09/28/2010 map)	75.57	24.43	2.43	0.99	0.00	0.00
One Year Ago (06/22/2010 map)	51.78	48.22	13.00	0.00	0.00	0.00



Intensity:
- *D0 Abnormally Dry*
- *D1 Drought - Moderate*
- *D2 Drought - Severe*
- *D3 Drought - Extreme*
- *D4 Drought - Exceptional*

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, June 30, 2011
Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

Figure 14: U.S. Drought Monitor for Texas for June 28, 2011. Available online at http://droughtmonitor.unl.edu.

Because the more recent lack of rainfall had occurred at precisely the time of year when rain was most needed, the U.S. Drought Monitor showed that drought conditions had rapidly worsened during the three months ending June 2011 (Fig. 14). Three months before, 43% of the state had been in extreme drought; by the end of June, 72% of the state was depicted as being in exceptional drought. The only portion of the state not shown as abnormally dry was the region near and north of Dallas, where several counties had received adequate rain during May and June.

Amplifying the severity of the drought was the excessive heat that had developed across the state. June was the warmest June on record and the fourth warmest month on record up to that point. Unusually warm weather is common during summertime droughts in Texas, because the lack of available soil moisture causes almost all of the energy in the Sun's rays to go into heating up the ground and the adjoining air. The high temperatures in turn produce greater drought stress in most plants and accelerate evaporation from streams, reservoirs, and stock tanks.

July 2011

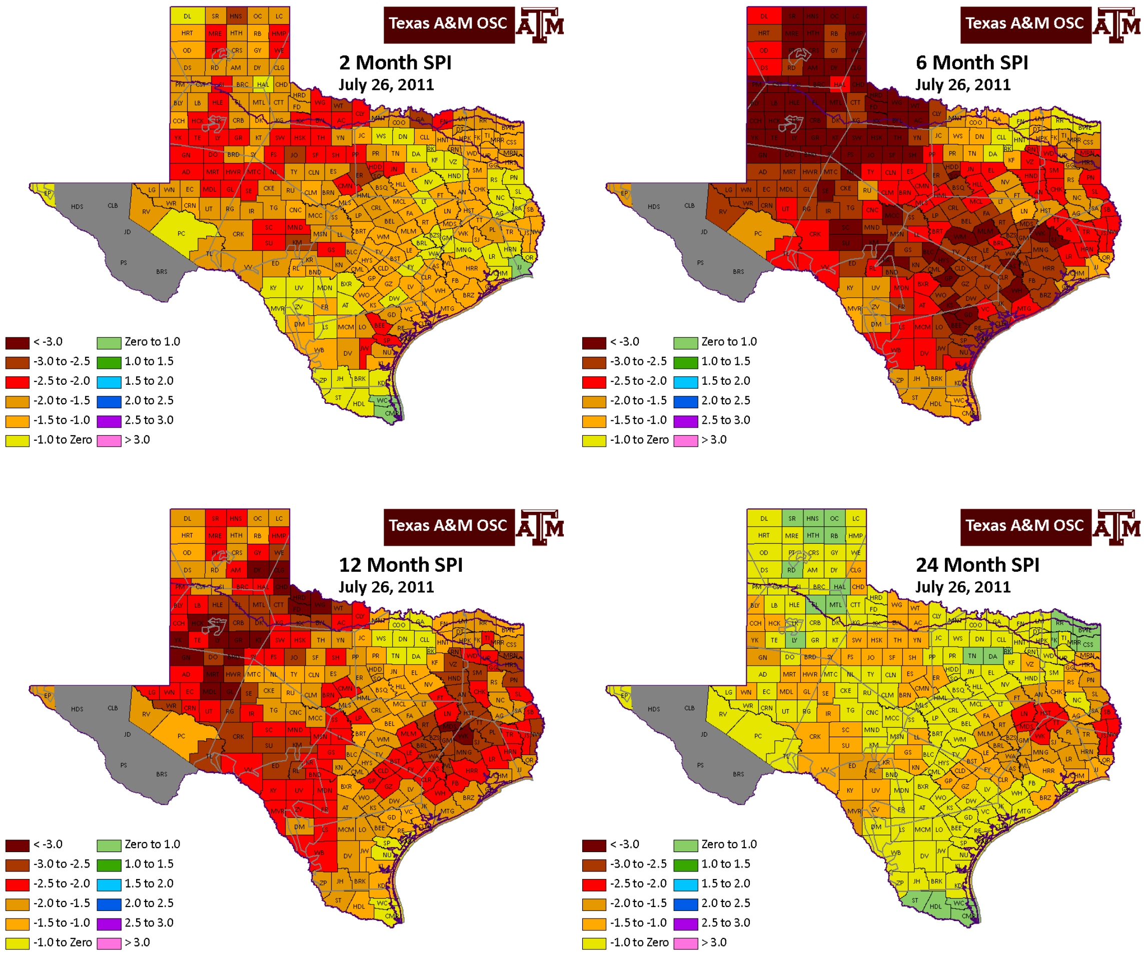


Figure 15: SPI drought index values as of July 26, 2011. The more negative values indicate more severe drought conditions.

The dry weather continued into July, which was the third driest July on record despite the occurrence of a landfalling tropical depression (Don). The six-month SPI (Fig. 15) showed that extremely severe drought conditions (SPI < -2.5) had spread from west Texas across the Edwards Plateau into central and south-central Texas. With rains during June and July 2010 now a distant memory, the twelve-month SPI had plummeted, with SPI values below -2.5 in many parts of the state.

At the same time, temperatures continued to set records. July was not just the warmest July on record for Texas but the warmest month ever in the state. Records for days with triple-digit temperatures began to be threatened.

The prolonged dry and hot weather had also begun to have a serious impact on trees. Normally, trees are able to tolerate short-term drought because their root systems penetrate deeper into the soil. By the end of July, twelve months of remarkably dry and hot weather across central and eastern Texas had caused even deep soil moisture to become seriously depleted.

August 2011

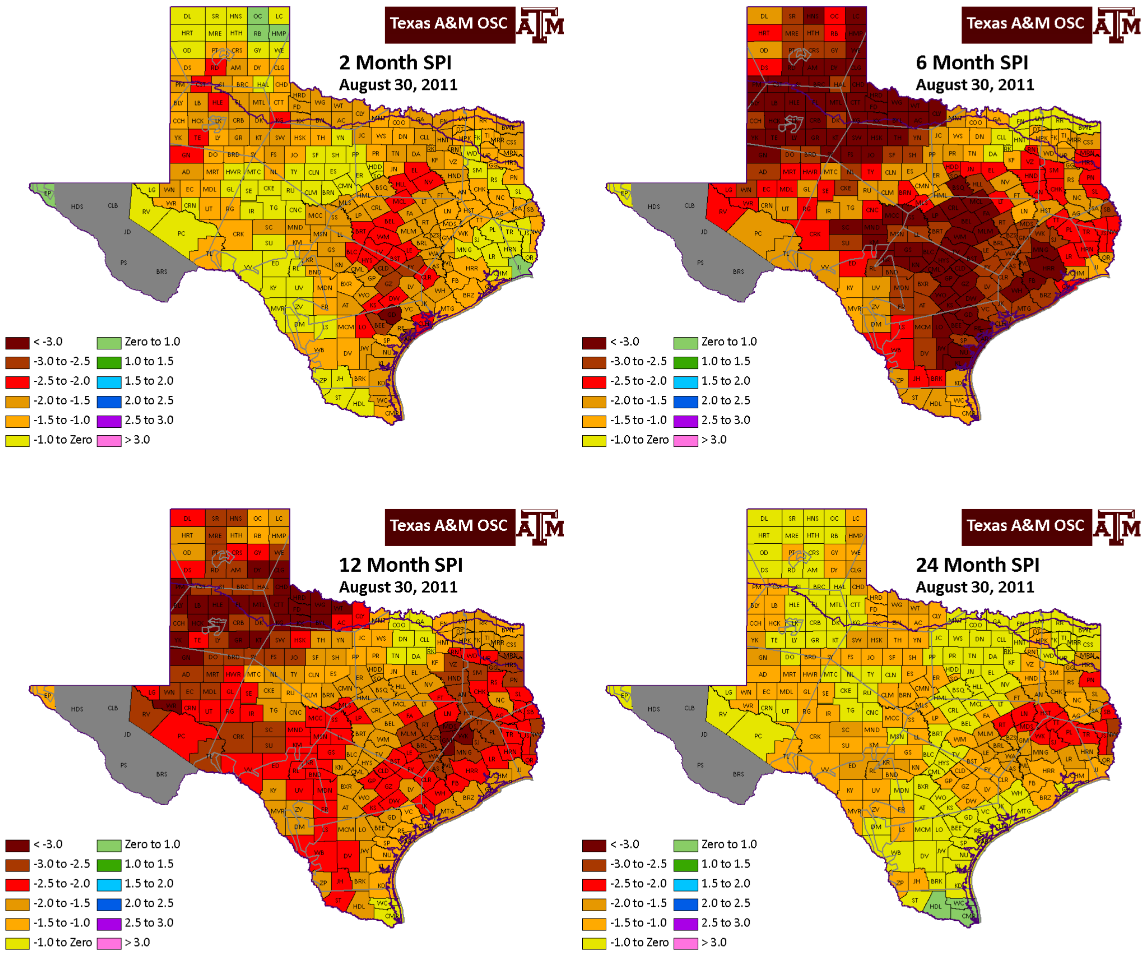


Figure 16: SPI drought index values as of August 30, 2011. The more negative values indicate more severe drought conditions.

In August, scattered rains in parts of west Texas had reduced the severity of drought conditions in some areas, but elsewhere conditions worsened (Fig. 16). The two-month SPI indicated that July and August had been especially dry almost precisely where the previous summer's rainfall had been most beneficial: along a line from Corpus Christi through Austin and nearly to Dallas. Over the six months from March through August, rainfall in that area was so small that the six-month SPI was below -3.0, and similar conditions were found near Houston, in much of the Hill Country, and almost the entire region north and west of Abilene.

The record for warmest month in Texas, set during July, was surpassed by more than one degree Fahrenheit in August. The combined June-August temperatures were in a statistical dead heat with those of Oklahoma, but both states shattered the previous record for warmest June-August, set by Oklahoma in 1934.

September 2011

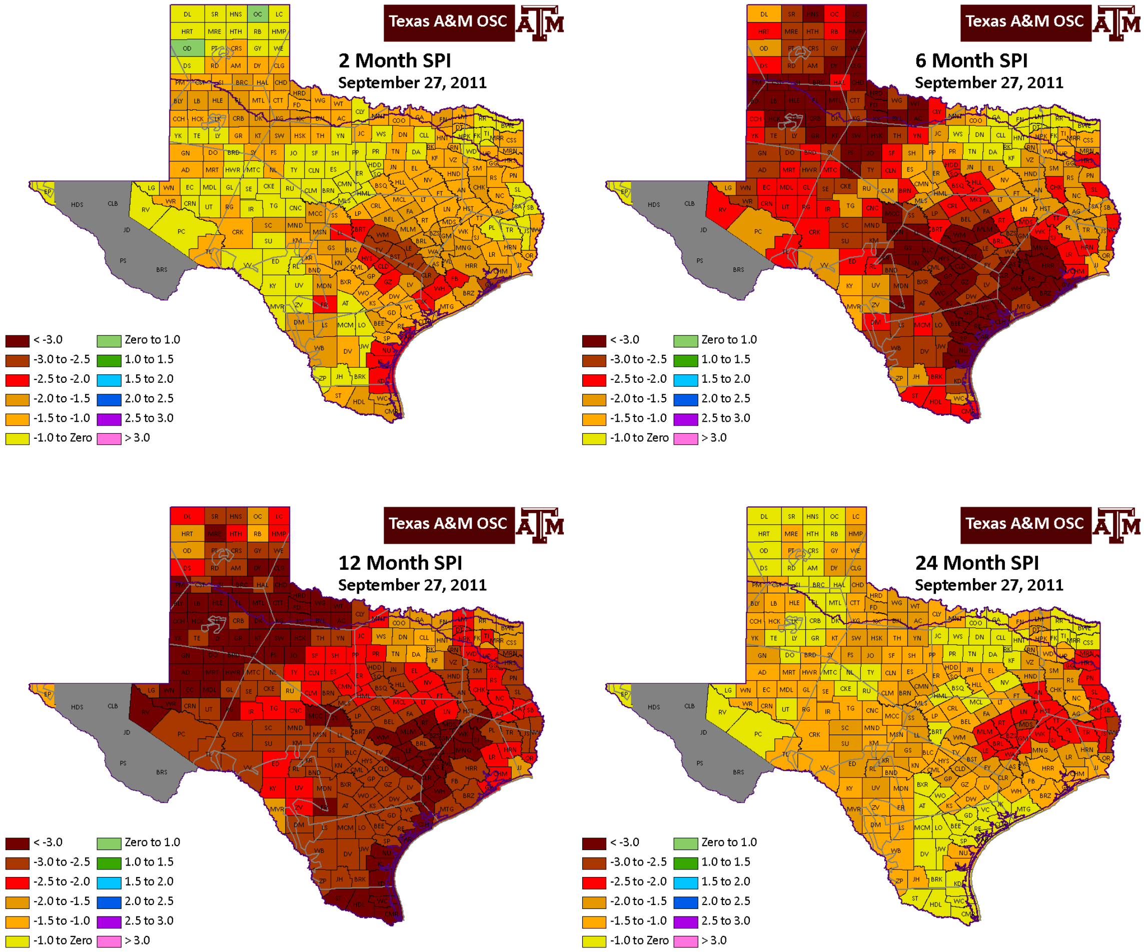
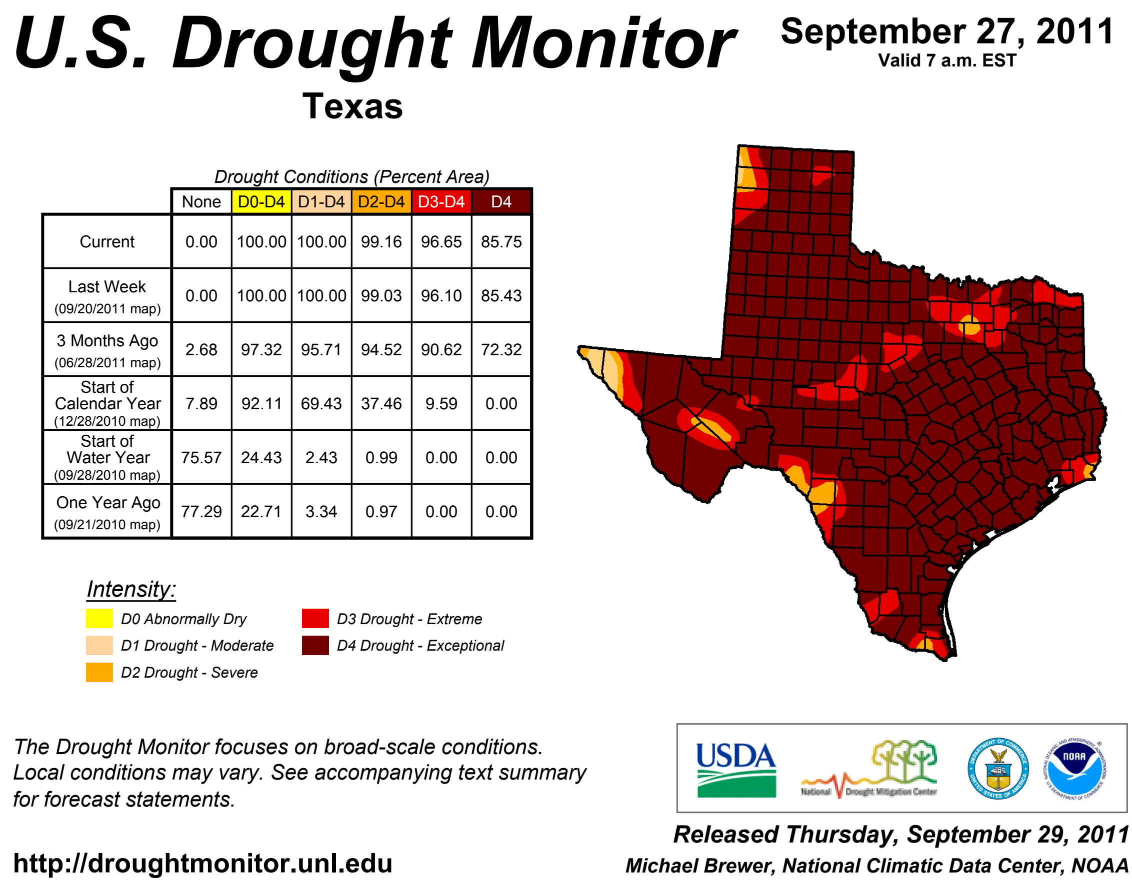


Figure 17: SPI drought index values as of September 27, 2011. The more negative values indicate more severe drought conditions.

The continued record warm and dry weather had caused most Texas forests to become extremely dry, and the near approach of Tropical Storm Lee, making landfall in Louisiana, provided the high winds necessary to produce a widespread outbreak of rapidly-growing forest fires. The most well-known of this group was the Bastrop Fire Complex, but other fires burned large areas of timber and some homes in northeast Texas and northwest of Houston.

By the end of September, the drought was one year old, and the twelve consecutive months of precipitation from October 2010 through September 2011 were the driest twelve consecutive months on record for the state. Texas averaged slightly more than 11” for the twelve months, much less than the 27” average value and roughly 2.5” less than the previous 12-month record set during the 1950s drought. The dry statewide conditions are reflected in the twelve-month SPI map (Fig. 17), which depicts most of the state at -2.5 or below and only a few corners of the state with SPI values better than -1.5.



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	99.16	96.65	85.75
Last Week (09/20/2011 map)	0.00	100.00	100.00	99.03	96.10	85.43
3 Months Ago (06/28/2011 map)	2.68	97.32	95.71	94.52	90.62	72.32
Start of Calendar Year (12/28/2010 map)	7.89	92.11	69.43	37.46	9.59	0.00
Start of Water Year (09/28/2010 map)	75.57	24.43	2.43	0.99	0.00	0.00
One Year Ago (09/21/2010 map)	77.29	22.71	3.34	0.97	0.00	0.00

Figure 18: U.S. Drought Monitor for Texas for September 27, 2011. Available online at http://droughtmonitor.unl.edu.

The U.S. Drought Monitor map for October 4, 2011 (Fig. 18) depicts the most severe drought conditions yet experienced in Texas as of this writing. Only 3% of the state was not classified in at least extreme drought, and almost 88% of Texas was classified as exceptional drought. If the U.S. Drought Monitor depicted conditions corresponding to D5 or D6, they would probably be widespread across Texas.

October 2011

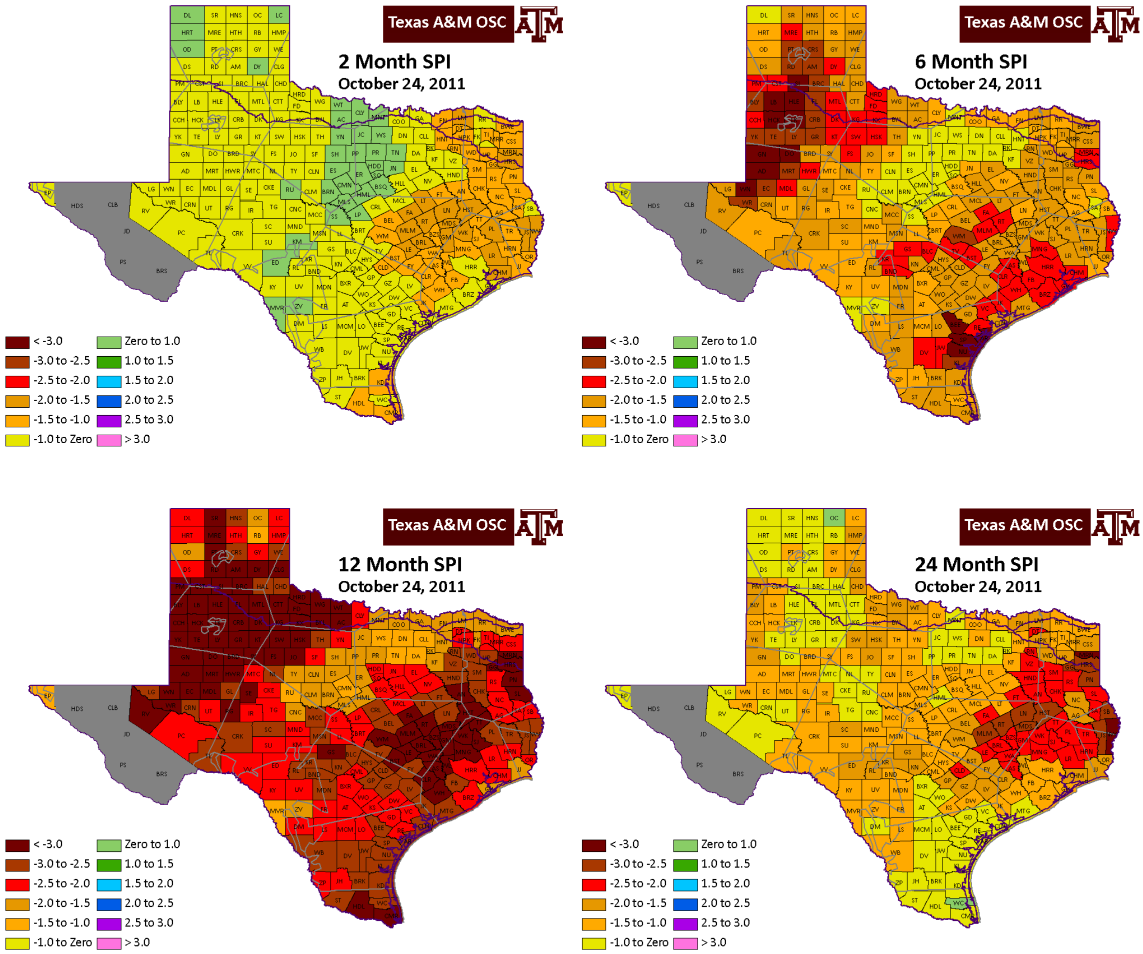


Figure 19: SPI drought index values as of September , 2011. The more negative values indicate more severe drought conditions.

It appears that October will yet again be another month with below-normal precipitation for Texas, despite an early October rain event that brought over 6” of rainfall to parts of the state. The rain alleviated much of the shorter-term dry conditions in central Texas, but twelve-month rainfall deficits continued to be daunting.

As the drought continues, longer-term rainfall shortages begin to emerge. Twelve counties in eastern Texas are below -2.5 on the 24-month SPI map (Fig. 19), including one county along the Louisiana border below -3.0. This implies long-term issues for streamflow and reservoir levels in eastern Texas. In west and central Texas where other reservoirs are at or near historic lows, the magnitude of the lack of rainfall during the past year is extreme, but two-year rainfall totals there generally fall within the -1.0 to -1.5 range, much less unusual than in eastern Texas where almost no values are between -1.0 to -1.5.

4) Historical Perspective

Temperatures

The June-August average temperature across Texas was roughly 2.5 °F warmer than any previous Texas summer and over 5 °F above the long-term average. The public's attention was captured by the unusually high number of days reaching or exceeding 100 °F.

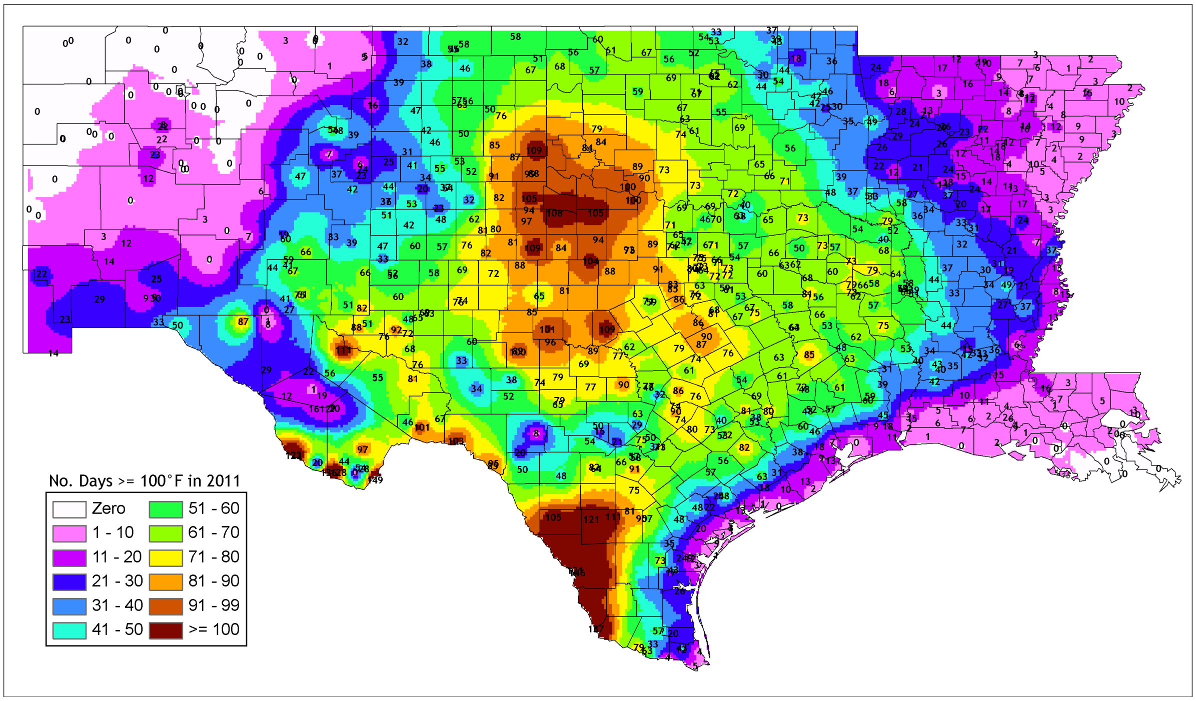


Figure 20: Number of days with maximum temperatures equaling or exceeding 100 °F in calendar year 2011 (through October 17, 2011). Graphic created by Brent McRoberts, Office of the State Climatologist, from Applied Climate Information System data.

Assuming no further 100 F days, the final tally for stations in the south-central United States is shown in Fig. 20. Note that the interpolation does not take into account topographic features, so the analysis will misrepresent the actual pattern in regions of large topographic relief such as far west Texas.

Many parts of the state achieved the "double-triple": at least 100 days of at least 100 degrees. Such areas include a large portion of south Texas surrounding Laredo, parts of north Texas near and west of Wichita Falls, and stations along the Rio Grande upstream at least as far as Big Bend. Much easier to count are the four stations that did not have a single day reach 100 F: two of them are along the Gulf Coast, while the other two are in far west Texas at altitudes exceeding 5000' above sea level.

According to my preliminary analysis, most of the excess summer heat was a direct consequence of the lack of rainfall prior to and during the summer. When there is little water available for evaporation, most of the energy from sunlight goes into heating the ground and the overlying atmosphere. Based on a statistical analysis of past summers, each inch of rainfall below normal in Texas is associated with summertime temperatures at least half a degree warmer.

Gauge-Based Precipitation

The SPI analysis in the preceding section is based on National Weather Service precipitation analyses that use radar estimates of precipitation as a starting point and a statistical analysis of regional precipitation records. A much more direct assessment of drought severity may be made by directly analyzing the long-term climate records from the United States Historical Climatology Network, Version 2 (USHCNv2).

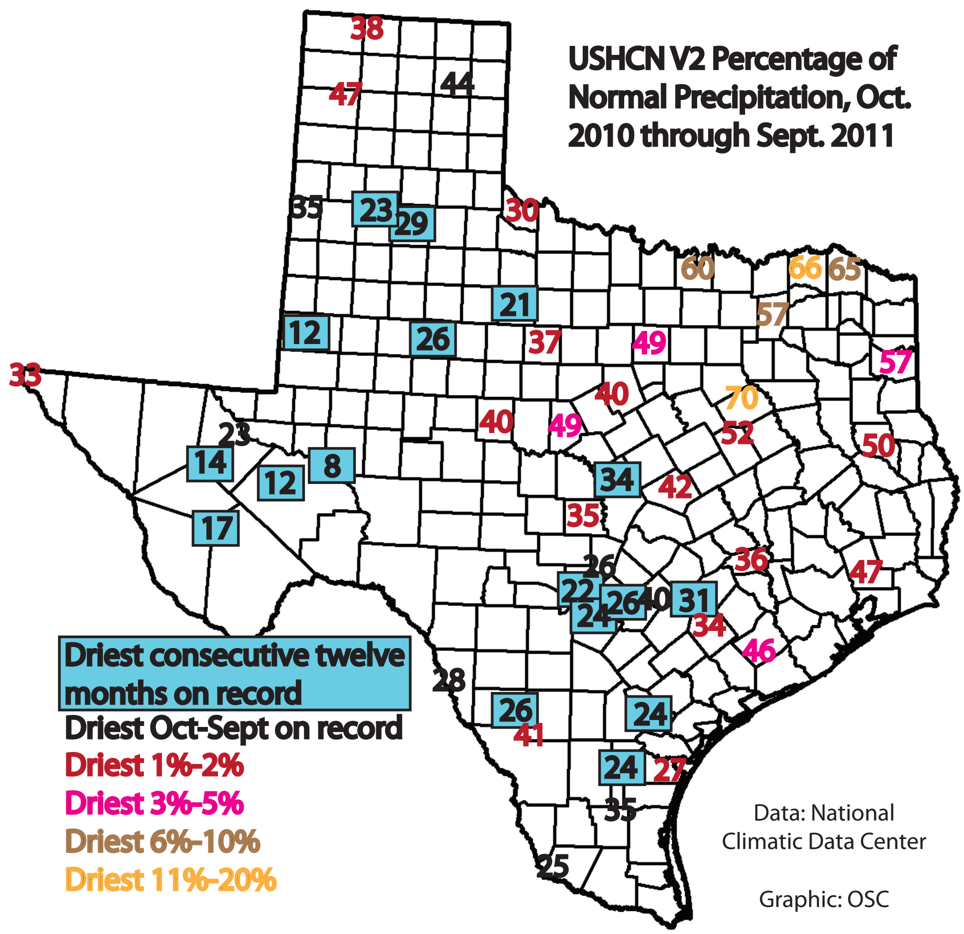


Figure 21: Percentage of normal precipitation for the 12-month period October 2010 through September 2011, as observed by the USHCNv2 station network. An additional station (Nacogdoches) has been added to fill a gap in the distribution of stations in eastern Texas. The colors indicate the ranking of the observed precipitation relative to previous October-September periods or, for exceptionally dry stations, all previous twelve consecutive month periods regardless of starting month.

Figure 21 shows that, across much of western and south-central Texas, the twelve-month period ending in September 2011 was the driest twelve consecutive months on record. About one-third of all Texas USHCNv2 stations set their all-time twelve-month record, and over half of the stations experienced their driest October-September on record. The lowest measurement was a remarkable 8% of normal at the McCamey USHCNv2 station. It was as though McCamey received one month of rainfall instead of one year of rainfall.

The twelve months were among the driest five percent throughout the state except for parts of Texas near, north, and east of Dallas. Though the lack of precipitation near Dallas was not as extreme as in the rest of the state, Dallas was forced to suffer through the exceptionally high temperatures caused by the dryness across the rest of the state, exacerbating evaporative stresses on plants and water supplies.

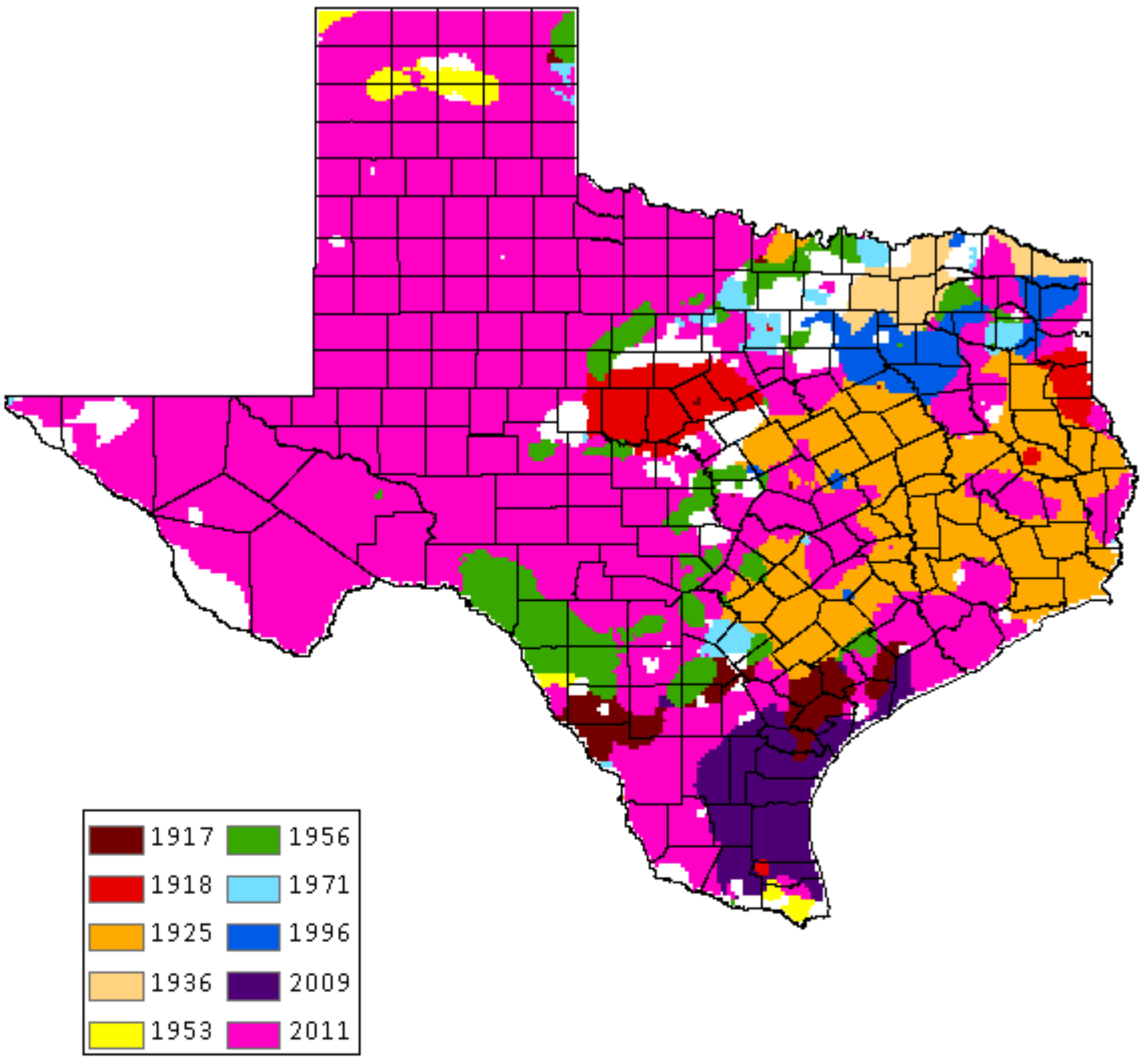


Figure 22: Year experiencing the lowest percentage of normal precipitation for the period prior to and during the growing season, defined here as the nine-month period ending June, July, or August, based on spatial analysis of Cooperative Observer Network data. Only the ten years having the greatest coverage are indicated. Only the 100 years since 1911 are analyzed.

Figure 22 provides another perspective on the drought in an historical context, by showing which year out of the past 100 experienced the smallest percentage of normal precipitation prior to and during the growing season. For most of the state, 2011 had the driest growing season conditions, as indicated by the pink shading. The year 2011 was worst for almost every location in the western half of Texas, as well as for many locations in central, south, southeast, and northeast Texas. In many parts of central and east Texas, the 1925 drought surpassed the 2011 drought in short-term intensity. Elsewhere, record-setting years were 2009 in the Coastal Bend area, 1917 in parts of south Texas, 1956 in many parts of central Texas, and 1918 in parts of central and eastern Texas. Various other years establish the driest observed conditions in north-central and northeast Texas, where the current 2011 drought is not as severe as elsewhere.

Except for the Coastal Bend and parts of north-central and northeast Texas, most of the state has not experienced an agricultural drought as severe as this one for fifty-five years, and more than half of the state has never experienced a growing season drought so severe.

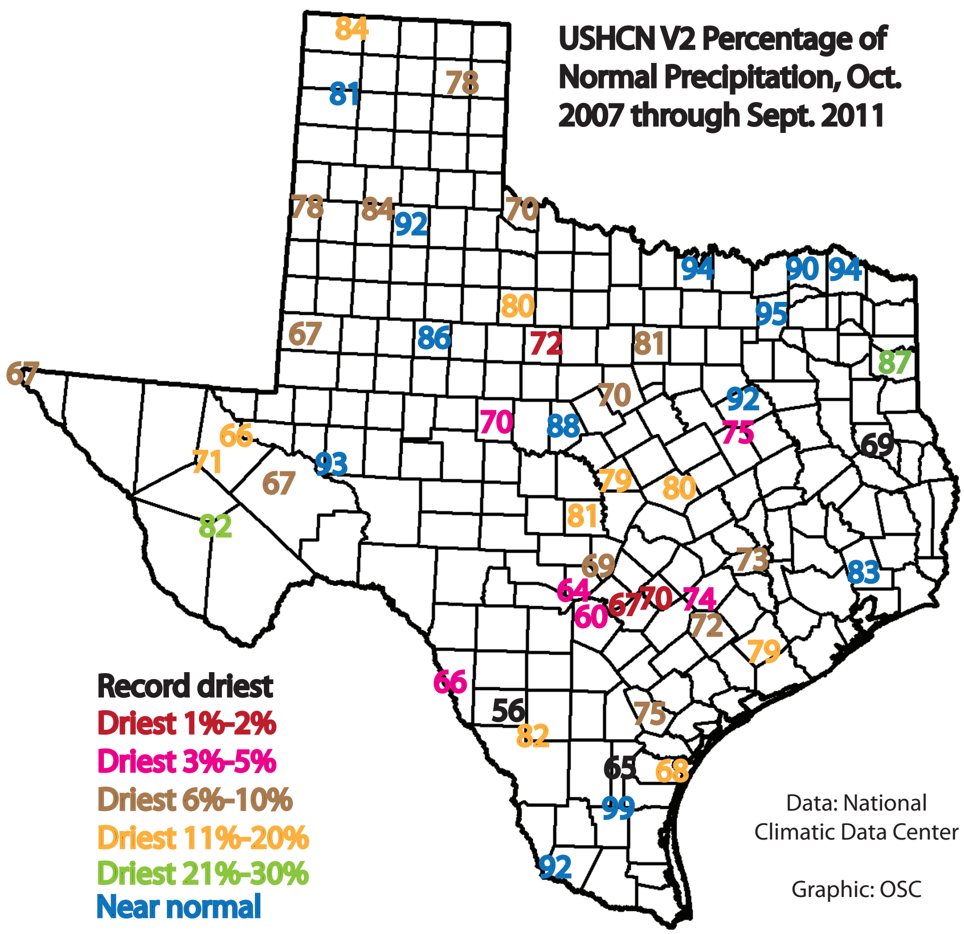


Figure 23: Percentage of normal precipitation for the 4-year period October 2007 through September 2011, as observed by the USHCNv2 station network. An additional station (Nacogdoches) has been added to fill a gap in the distribution of stations in eastern Texas. The colors indicate the ranking of the observed precipitation relative to previous October-September periods.

Though the drought has been most intense at time scales of one year or less, the lack of precipitation has been so extreme that the multi-year precipitation totals are also unusually dry. The four years since October 2007 includes a two-year drought (2008-2009) and a relatively wet year (2010) in addition to the current 2011 drought.

Figure 23 shows the four-year accumulated precipitation as a percentage of normal, color-coded as in Fig. 21. At a few stations in south and east Texas, the past four years has already been drier than any previous corresponding four-year period, including any such period during the drought of the 1950s. The current drought may well be considered to be worse than the 1950s drought in these areas.

Elsewhere, the long-term drought is least severe in northeast Texas, extreme south Texas, and parts of western Texas. In these locations, the lack of rain by itself doesn't imply a long-term water shortage, though the warm temperatures will have enhanced evaporation and made water available worse than the numbers in Fig. 23 would indicate.

Statewide Records

Because the drought was widespread throughout the state of Texas, its overall evolution and intensity is well represented by statewide average conditions. Table 2 shows the historical ranks of monthly statewide precipitation since the beginning of the drought. The statewide precipitation values represent area-weighted averages of values within each of the ten Texas climate divisions. Precipitation data are obtained from the National Climatic Data Center and are adjusted to correct for changes in network configuration (McRoberts and Nielsen-Gammon 2011a). The rankings indicate that a dry fall and winter was followed by an exceptionally dry spring and summer. October values are not yet in but will probably place the precipitation among the 40th to 50th driest Octobers. Note that precipitation values for August and September are preliminary and subject to change.

Month	*Ranking*
October 2010	8th driest
November 2010	29th driest
December 2010	14th driest
January 2011	47th wettest
February 2011	19th driest
March 2011	Record driest
April 2011	5th driest
May 2011	9th driest
June 2011	6th driest
July 2011	3rd driest
August 2011	6th driest
September 2011	7th driest

Table 2: Ranking of monthly precipitation among historical values, based on Texas statewide average precipitation.

When unusually dry months occur one after the other, multimonth precipitation records are likely to be broken. Tables 3-5 show records established for three-month, six-month, and nine-month periods.

Months	*Precipitation Amount (in.)*	*Ranking*
February-April 2011	1.80	Record driest
March-May 2011	2.66	Record driest
April-June 2011	3.39	2nd driest
May-July 2011	3.35	2nd driest
June-August 2011	2.48	Record driest
July-September 2011	2.54	2nd driest

Table 3: Ranking of three-month precipitation among historical values, based on Texas statewide average precipitation.

Months	*Precipitation Amount (in.)*	*Ranking*
November 2010-April 2011	5.20	2nd driest
February-July 2011	5.15	Record driest
March-August 2011	5.14	Record driest
April-September 2011	5.93	Record driest

Table 4: Ranking of six-month precipitation among historical values, based on Texas statewide average precipitation.

Months	*Precipitation Amount (in.)*	*Rank*
December 2010-August 2011	8.25	#1
November 2010-July 2011	8.55	#2
January-September 2011	8.59	#3
October 2010-June 2011	8.64	#4
June 1917-February 1918	9.36	#5

Table 5: All-time rankings of nine-month accumulated precipitation, based on Texas statewide average precipitation.

The records tend to become more extreme as the durations become longer. Note, in Table 3, that the driest March through May on record was immediately followed by the driest June through August on record. The nine-month precipitation totals in Table 5 are much lower than any other nine-month precipitation totals for any time of year.

Table 6 shows the overall ranking of non-overlapping 12-month precipitation totals. (Non-overlapping means that a particular month is not allowed to be part of more than one 12-month period.) The record driest 12-month period was the 12-month period from October 2010 to September 2011. While the recent numbers are still preliminary and subject to slight changes, the previous record (set in 1956) was broken by a comfortable 2.5 inches.

Months	*Precipitation Amount*	*Rank*
October 2010-September 2011	11.18	#1
October 1955-September 1956	13.69	#2
February 1917-January 1918	14.27	#3
July 1924-June 1925	15.50	#4
February 1910-January 1911	17.62	#5
January 1956-December 1956	17.85	#6
March 1901-February 1902	17.91	#7
October 1908-September 1909	18.24	#8
June 1970-May 1971	18.50	#9
November 1951-October 1952	18.69	#10
October 1950-September 1951	18.88	#11
May 1977-April 1978	19.35	#12
November 1962-October 1963	19.40	#13
September 2005-August 2006	19.66	#14

Table 6: All-time rankings of twelve-month accumulated precipitation, based on Texas statewide average precipitation. Periods are constrained to be non-overlapping.

Two other aspects of Table 6 deserve comment. First, the driest four periods are substantially drier than the remaining periods. For statewide one-year precipitation deficits, 2010-2011, 1955-1956, 1917-1918, and 1924-1925 are by far the most extreme events since records began in 1895. Second, it was necessary to continue the list to period number 14 to ensure that the list included another drought from the past 30 years. This means that while there have been several severe one-year droughts in the past, none of the recent Texas droughts measure up except for the current one. Though it would have been difficult to prepare for a drought of this magnitude, it had been many decades since Texas had experienced a one-year drought anywhere close to the present one in severity.

Palmer Drought Severity Index

The information presented so far has focused on the lack of rainfall, with some additional discussion of unusually high temperatures. The most common measure of drought intensity in the United States is the Palmer Drought Severity Index, or PDSI. The PDSI attempts to assess the relative amount of water available in the soil, based upon precipitation, an estimate of evaporation based on temperature, and information regarding soil type. Because it combines temperature and precipitation information, it is a more comprehensive measure of drought intensity than the SPI. Unlike the SPI, the PDSI has its own intrinsic time scale, so a single numerical value characterizes the overall drought intensity.

Drought is considered to be present when the PDSI value is below -2, and extreme drought is present when the PDSI value is below -4. The National Climatic Data Center calculates PDSI values for each climate division as well as a statewide PDSI value.

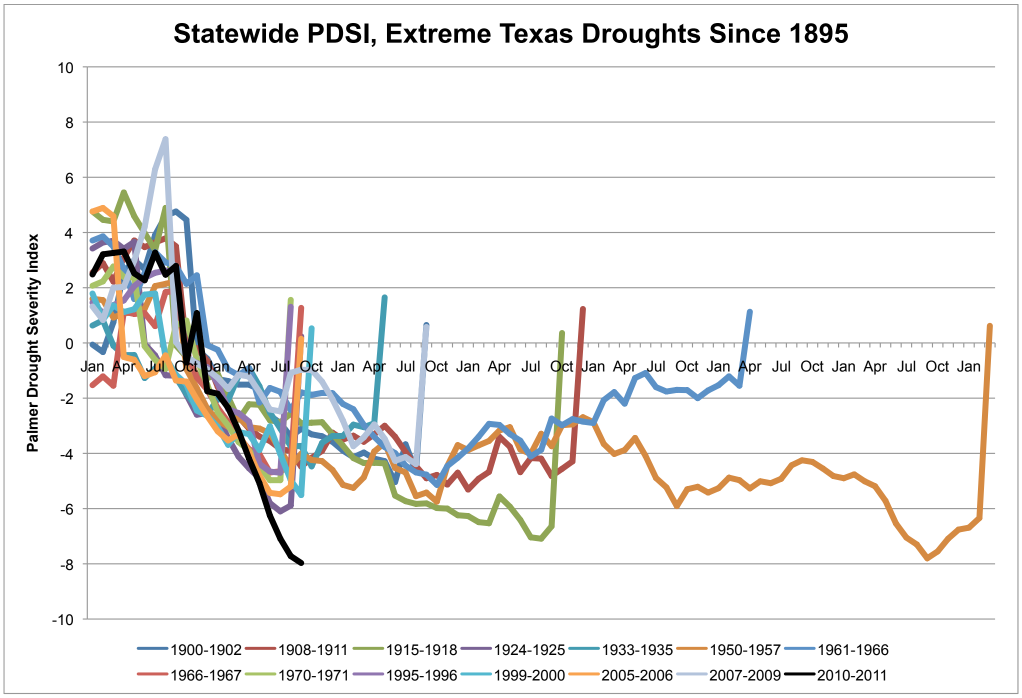


Figure 24: Texas statewide Palmer Drought Severity Index values for all previous droughts attaining a PDSI value of -4 or lower. Droughts are plotted on a common time scale, beginning in January of the year in which the run of negative PDSI values first appeared and ending when the PDSI value again became positive. Drought endings appear abrupt because the PDSI jumps suddenly from a characterization of dry conditions to a characterization of wet conditions. Thus the PDSI is ill-suited for monitoring recovery from drought.

In Fig. 24, the evolution of statewide PDSI values for all fourteen previous extreme droughts are plotted on a common time scale. As Fig. 24 shows, the most recent PDSI value for the 2011 drought (shown in black) is a record low value for statewide PDSI, surpassing the previous record set in 1956 (orange). However, the 1950-1957 drought is generally regarded as a much worse drought overall because it lasted for so many years. The most intense year of that drought, in 1956, immediately followed five other consecutive drought years.

The 1915-1918 drought might also arguably be worse than the 2010-2011 drought overall. The 1915-1918 drought was third most intense, according to the PDSI, but it maintained values below -5 from June 1917 through September 1918. In contrast, the 2010-2011 drought has only had five or six months below -5.

Ultimately, all droughts are different, and it is not possible to say at what point a particular drought surpasses another in overall severity. At this point, the 2010-2011 drought is easily the most severe one-year drought on record and is clearly among the top five overall. Whether it lasts long enough and remains intense enough to surpass the 1908-1911, 1961-1966, 1915-1918, and 1950-1957 droughts (or whether it already has surpassed some of them) will depend on both future weather and the means by which one drought is compared against another.

Climate Division Perspective

The previous sections discussed the overall statewide intensity of the drought as well as the severity of the drought recorded at specific rain gauges. In this section, the historical ranking of the 2011 drought within the various climate division of Texas is considered.

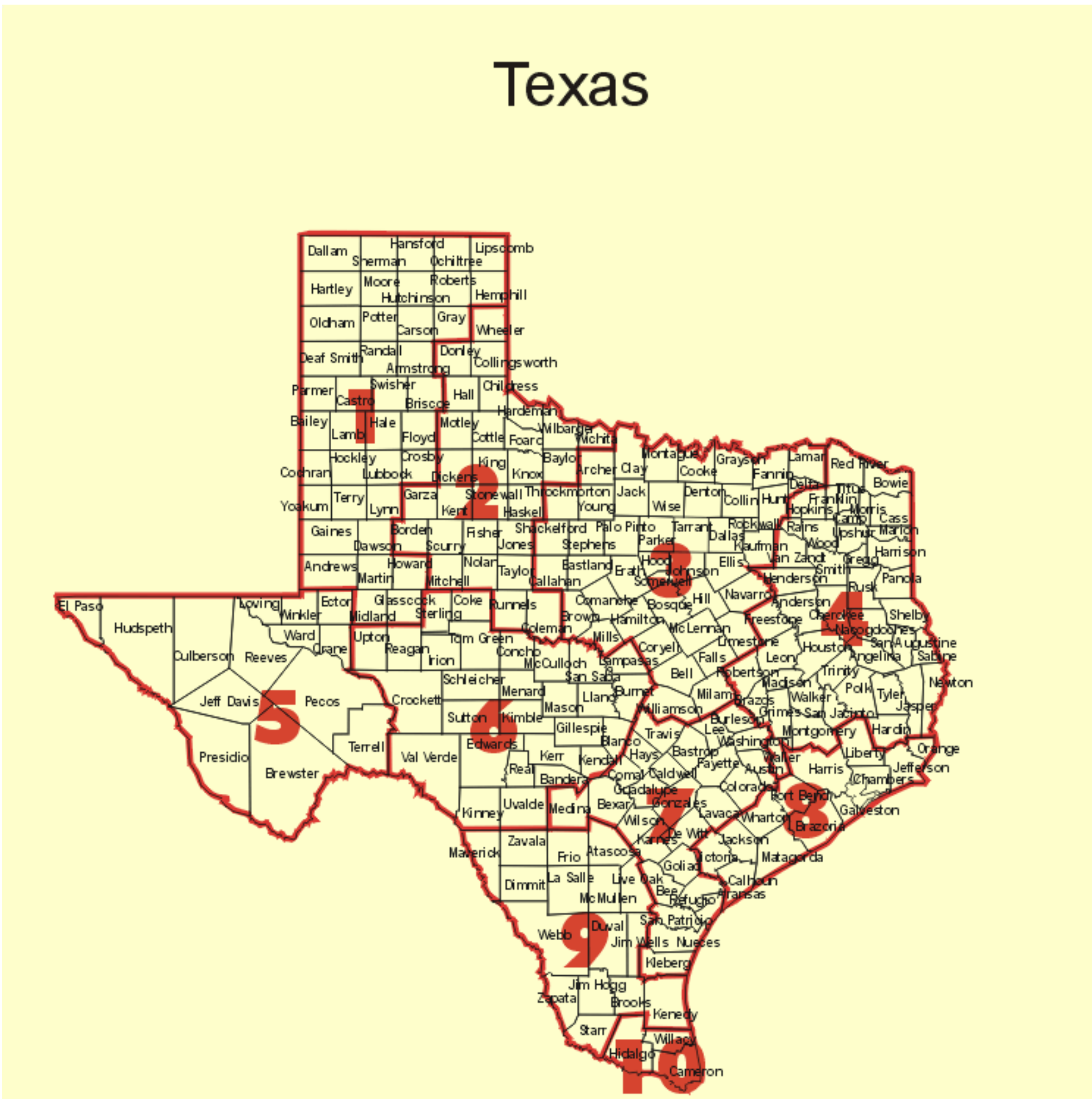


Figure 25: Boundaries of Texas climate divisions. Figure from NOAA's Climate Prediction Center.

Texas is divided into ten climate divisions (Fig. 25). Nine are approximately equally-sized, while climate division #10 separately reflects conditions within the farming region of the Lower Valley.

Table 7 shows the PDSI values and drought durations within each of the ten climate divisions during the major Texas droughts of the past and present. The table allows one to compare the intensity and duration of the present drought to past droughts in the same portion of the state.

	High Plains	Low Rolling Plains	North Central Texas	East Texas	Trans-Pecos	Edwards Plateau	South Central Texas	Upper Coast	South Texas	Lower Valley
	1	2	3	4	5	6	7	8	9	10
1908-1911	-5.31 11 26	-5.66 14 40	-4.29 1 30	13	-4.49 4 24	-4.23 3 33	-4.91 4 34	12	34	18
1915-1918	-4.04 1 19	-5.61 16 22	-6.03 15 27	-5.99 **10** 27	-4.33 4 20	-5.25 15 28	-6.16 20 33	**-5.72** **14** 34	-4.43 8 30	25
1924-1925	11	-4.81 4 13	-5.61 5 10	-5.99 7 13	9	-4.90 3 10	-5.19 3 10	-5.38 6 12	6	3
1933-1935	-5.01 10 32	-4.03 1 13	4	4	-5.23 9 29	-4.57 2 17	3		1	
1950-1957	-5.86 **24** **58**	-6.33 **25** **71**	**-6.92** **22** **71**	-4.54 8 **40**	-5.10 **16** **74**	**-6.08** **29** **66**	**-6.67** **36** **67**	-5.45 12 **55**	**-5.73** **20** **77**	**-4.89** **5** **79**
1961-1966	-4.19 1 24	11	-4.00 1 14	27	28	-4.54 4 25	-5.04 7 32	-4.14 2 34	35	; 0
1966-1967	8	8	-4.56 3 8	7	3	-4.33 3 8	-4.63 2 7	5	4	1
1970-1971	10	-4.67 2 9	-4.18 1 5	8	5	7	-4.84 2 7	6	5	5
1995-1996	5	4	-4.07 1 6	5	-4.06 1 23	-4.12 1 6	-4.31 1 6	2	10	7
1999-2002	5	7	9	10	-5.12 7 56	-5.06 6 13	-4.09 1 10	-4.69 6 13	8	-4.23 2 31
2005-2006	-4.38 2 7	-4.78 3 8	-4.47 3 14	-4.11 5 16	4	-4.04 1 11	-4.95 8 14	6	-4.42 3 11	-4.42 3 16
2007-2009		9	3		1	16	-6.51 3 16	8	-4.77 3 12	4
2010-2011	**-6.73** 4 6	**-7.08** 5 7	-5.37 3 7	**-6.47** 7 14	**-6.22** 5 10	-6.05 5 8	-5.79 4 7	-5.32 3 6	-4.98 1 6	-4.45 1 6

Table 7: Droughts surpassing -4 PDSI in three or more climate divisions. Shown are the minimum PDSI value, the number of months at or below -4 PDSI, and the number of months at or below -2 PDSI.

Only two droughts have reached extreme (PDSI below -4) status in all ten climate divisions: the 1950-1957 drought and the current drought. The PDSI attains its lowest value in the current drought within four climate divisions: 1, 2, 4, and 5. From a historical perspective, the current drought is worst in East Texas (climate division #4). The current drought far exceeds the 1950-1957 drought in intensity (though not in duration), has already surpassed the 1924-1925 drought by all measures, and is most strongly rivaled by the 1915-1918 drought. Based on the combination of precipitation and temperature incorporated into the PDSI, the present drought is already at least the third-worst drought on record in East Texas.

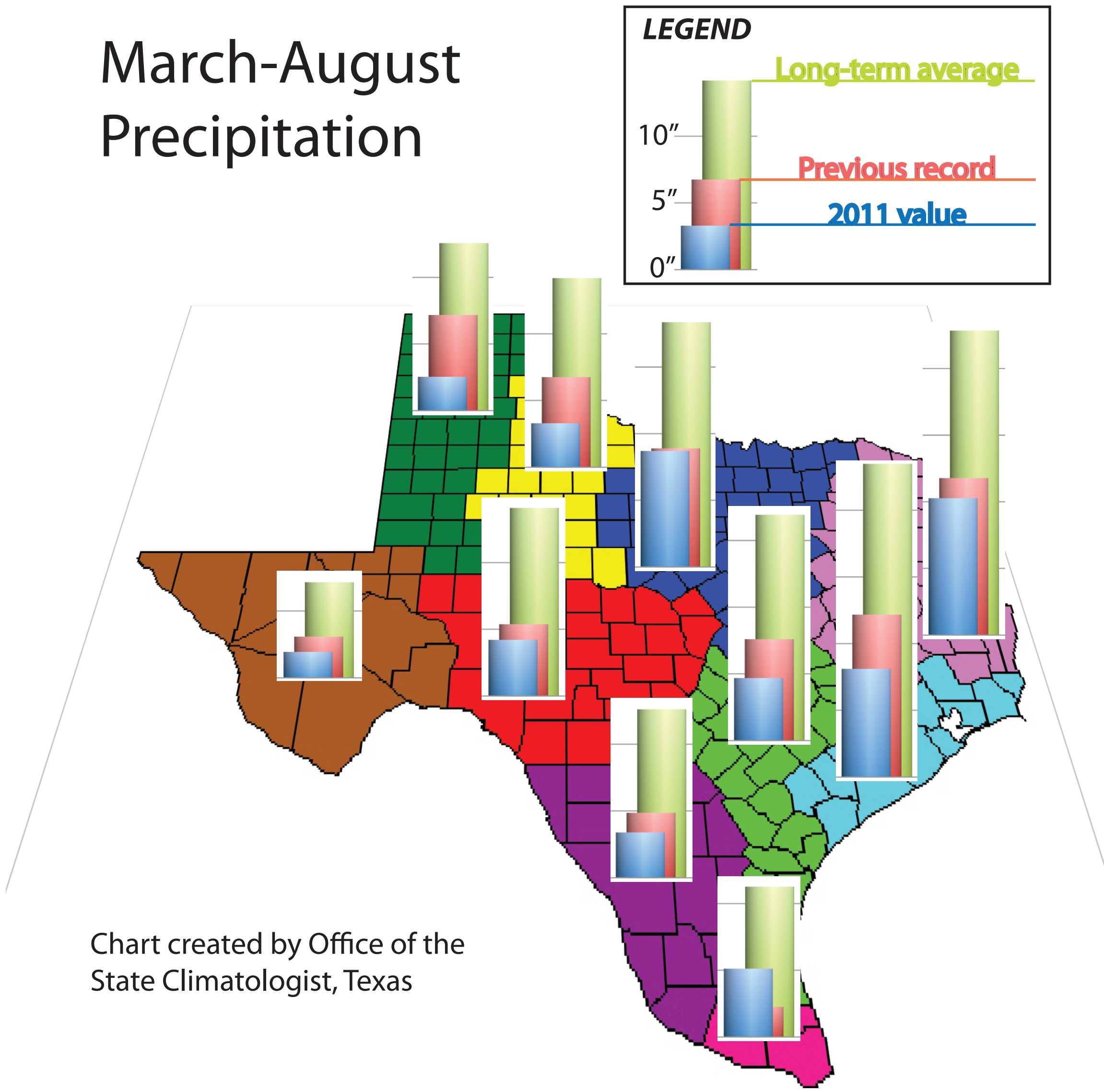


Figure 26: Climate division average precipitation for March-August 2011 (blue), compared to the long-term average for March-August (green) and the previous record for driest March-August (red). See legend for scale.

Figure 26 is a graphical depiction of the driest six-month period of the 2011 drought. The six-month rainfall was below the previous record in all but climate division 10 (see Fig. 25 for climate division identification). In climate divisions 1 and 2, the total rainfall was less than half the previous record and less than a quarter of normal precipitation. Even the "wettest" climate division received less rainfall than normally occurs everywhere but climate division 5.

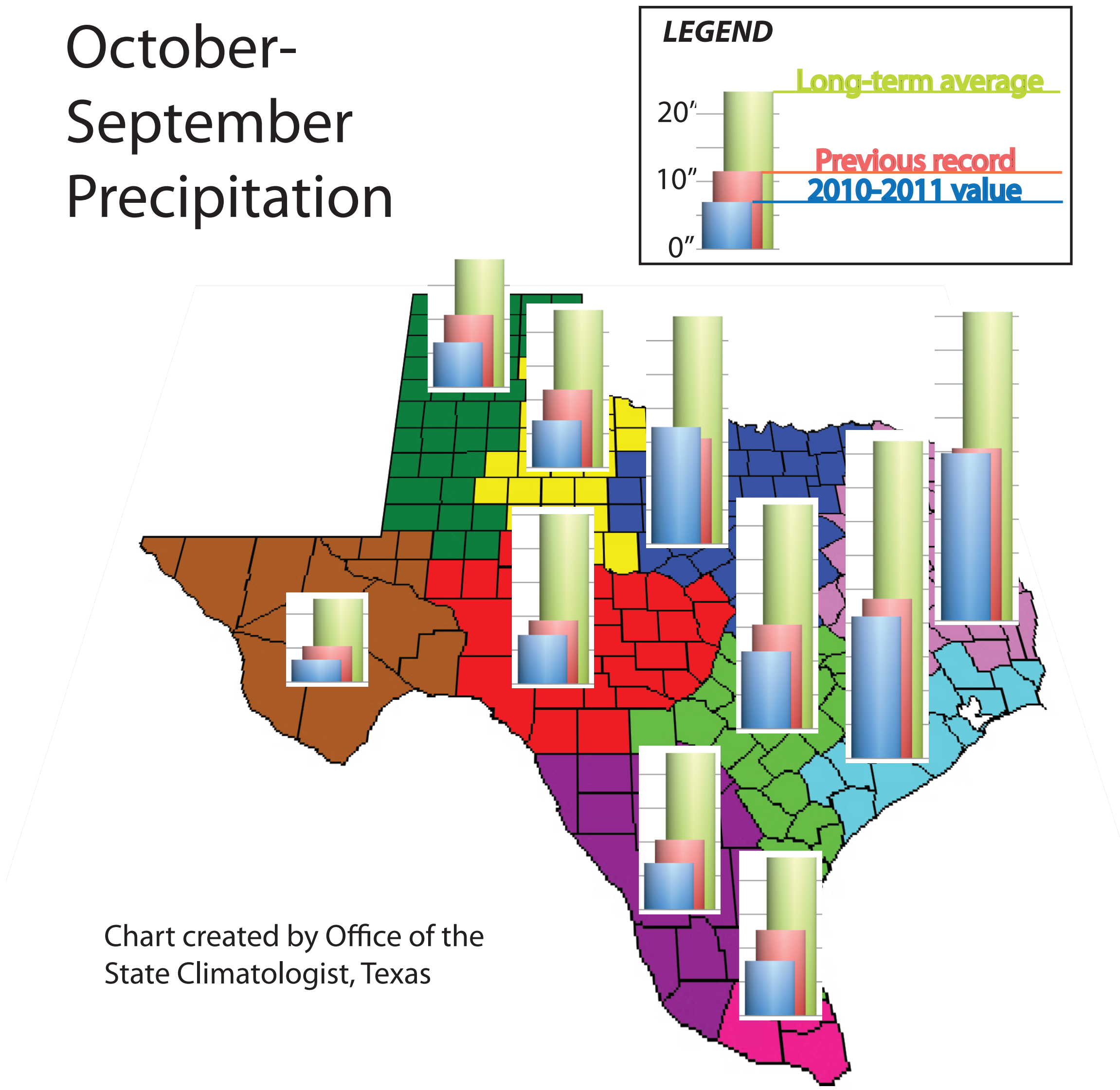


Figure 27: Climate division average precipitation for October 2010-September 2011 (blue), compared to the long-term average for 12 months (green) and the previous record for driest October-September (red). See legend for scale.

The twelve-month totals are no less staggering. East Texas received the normal rainfall of the Low Rolling Plains. South Central Texas received the normal rainfall of the Trans-Pecos. Only North Central Texas managed to receive more precipitation than its previous record. Most climate divisions received much less than half of their normal precipitation.

5) What's Next

The 2010-2011 drought has now lasted for a year in most of Texas, longer in many parts of east Texas. At this point it seems likely to continue for at least another year.

La Niña conditions have become established in the tropical Pacific Ocean, and most La Niña events induce changes in weather patterns that lead to dry late fall to early spring conditions for Texas and surrounding parts of the southern United States. Accordingly, NOAA's Climate Prediction Center is predicting that November through January precipitation in Texas has about a 50-55% chance of being below the normal range, a 33% chance of falling within the normal range, and a 12-17% chance of being above the normal range. The outlook for February through April is only slightly better: a 45% chance of being below the normal range, a 33% chance of falling within the normal range, and a 22% chance of being above the normal range. Thus, substantial improvement of drought conditions between now and the end of April 2012, while possible, is not likely.

Substantial rains are always possible from May through October, so many parts of the state may well get lucky and receive significant drought relief by this time next year. However, there is no reason at this point to expect the summertime precipitation to be above normal, and even near-normal conditions would allow a continuation of the present drought into fall 2012. It therefore seems likely that at least a large portion of Texas will need to endure a second summer of drought.

Though a second year of drought is expected, the lack of rainfall will almost certainly not be as extreme as it was during the first year. This expectation is based on little more than the fact that the 2010-2011 rainfall total was such an outlier that it is highly unlikely to recur in any given year. Also helping slightly is the fact that the 2011-2012 La Niña is not forecasted to be as intense as the 2010-2011 La Niña, though scientists disagree on whether the strength of La Niña is closely related to the strength of its effects on United States weather.

More rainfall in 2011-2012 would be good news for farmers and ranchers. The lack of deep soil moisture would make crops and forage particularly vulnerable to extended periods of dry weather, though, so the rainfall would have to come at the right time. However, a continuation of the drought would be bad for water supplies across the state. The effects of drought tend to be cumulative on surface water storage and aquifers: continued depletion without adequate recharge would lead to more water restrictions and priority calls.

Whether the drought will last beyond a second year is impossible to determine at this point. There have been rare occasions in the past when La Niña conditions were observed for three consecutive years. Conversely, an El Niño event would be likely to bring wetter than normal conditions to Texas. It is also possible that tropical Pacific conditions will return to a neutral state, with little resulting impact on Texas precipitation.

Historical records and atmospheric model simulations indicate that long-term precipitation variations in Texas are primarily controlled by a sea surface temperature pattern called the Pacific Decadal Oscillation, or PDO. Presently the PDO is in a configuration associated with relatively dry weather in Texas, and it has been in that configuration since about 1998. Some observational and model evidence suggests that a slowly-varying temperature pattern in the Atlantic Ocean, called the Atlantic Multidecadal Oscillation or AMO, also affects Texas precipitation, with dry conditions favored when the Northern Hemisphere Atlantic Ocean is relatively warm. Presently, the AMO is in its warm phase, and has been since about 1995. During the past decade or so, with both patterns in an unfavorable state, Texas has experienced multiple droughts, including drought in five of the last seven years.

The only other recent time both patterns were clearly in an unfavorable state was from the mid 1940s to the early 1960s. During that period, Texas experienced its drought of record (1950-1957) and a second prolonged drought (1961-1966). Tree ring evidence indicates that such multi-year droughts have also occurred in Texas prior to weather records.

The same conditions that seemed to enable the drought of the 1950s are in place today. Whether Texas will continue with its recent pattern of drought years interspersed with occasional wet years or whether the present drought will evolve into a prolonged one is impossible to determine at this point.

Also unknown is how long the unfavorable PDO and AMO conditions will last. Some recent research suggests that the AMO may change sign in the next few years and begin favoring rainfall in Texas. Based on past history, the present phase of drought susceptibility could last anywhere from three more years to fifteen more years.

Beyond the next few years, climate change must be taken into account. Projected changes in precipitation are relatively small compared to past natural precipitation variations (Nielsen-Gammon, 2011), so it seems unlikely that anthropogenic climate change will induce a substantial decrease in Texas precipitation by mid-century. Natural variations presently have Texas in a dry phase, so it seems relatively likely that as the PDO and AMO evolve over the next couple of decades Texas will pass into another relatively wet phase, albeit temporary. Scientists also do not know whether La Niña, which exerts such a strong influence on Texas weather from year to year, will become more or less frequent as the climate changes.

Projected temperature changes are much larger than past decade-scale temperature variations in Texas, and the projected warming is robust across models. While it is not known how much warmer temperatures will become, an increase of several degrees Fahrenheit by mid-century in Texas is well within the realm of possibility.

Whether such a large temperature increase comes to pass or not, it seems very likely that temperatures will become at least somewhat warmer than present, so that evaporation will have an increasingly large impact on water supplies throughout Texas. Future droughts will almost certainly be warmer than the Texas droughts of the past, and consequently will tend to be more severe even if precipitation is unchanged. It took rainfall only a third of normal to achieve summertime Texas temperatures five degrees warmer than their 20th century average; perhaps by mid-century a drought with two-thirds of normal precipitation will be sufficient to achieve similarly warm conditions.

In summary, a second year of drought in Texas is likely. Whether the drought will end after two years or last three years or beyond is impossible to predict with certainty, but what is known is that Texas is in a period of enhanced drought susceptibility due to global ocean temperature patterns and has been since at least 2000. The good news is that these global patterns tend to reverse themselves over time, probably leading to an extended period of wetter weather for Texas, though this may not happen for another three to fifteen years. Looking into the distant future, the safest bet is that global temperatures will continue to increase, causing Texas droughts to be warmer and more strongly affected by evaporation.

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