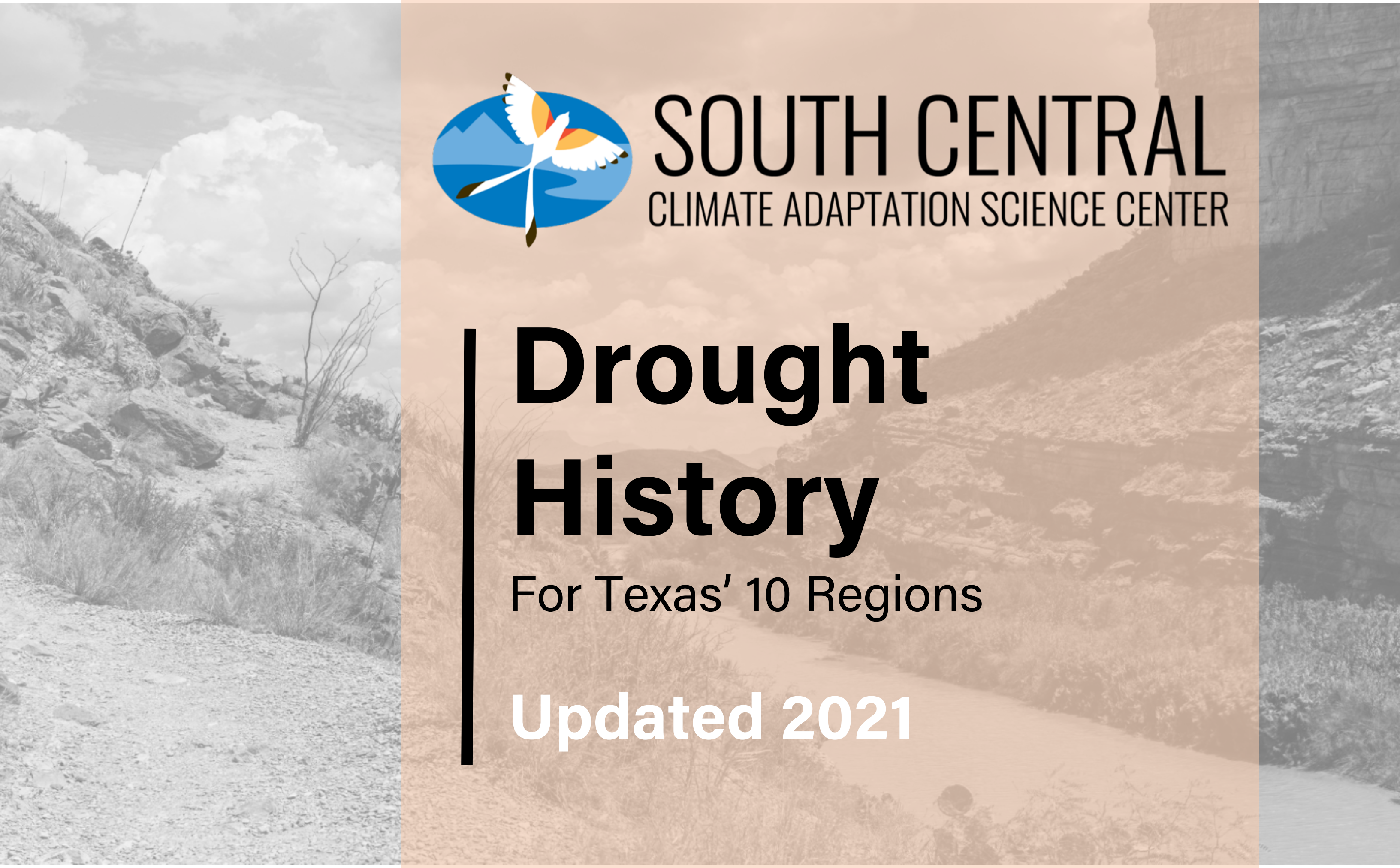

South Central Climate Adaptation Science Center

Drought History

For Texas' 10 Regions

Updated 2021

southcentralclimate.org

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What is drought?

Defining drought can be difficult because the impacts associated with drought are often far-reaching and devastating. A *meteorological drought* is a prolonged period when precipitation is below "normal" for the location (Heim 2002). An *agricultural drought* occurs when soils are too dry to grow healthy vegetation, particularly crops or forests. As water becomes scarce in rivers, lakes, and other water bodies, a *hydrological drought* develops. If, at any time, the water demands of society (e.g., water for drinking, maintaining lawns and gardens, washing clothes) exceed the availability of good-quality water, then a *socioeconomic drought* has occurred. A socioeconomic drought may arise even during times of normal precipitation because of increased water demand from a growing population, increased temperatures and wind speeds, new businesses, or other societal changes.

Why be prepared for drought?

Since 1980, the National Oceanic and Atmospheric Administration has identified 29 droughts nationwide as weather disasters based on both damages and costs in the amount of $269.6 billion dollars; 17 of which directly affected Texas. The 2012 drought, which at its height affected over 80% of the contiguous U.S., resulted in estimated damages and costs of over $50 billion from both direct and indirect impacts.

Drought can result in crop, pasture, and forest damage; increased livestock and wildlife mortality; increased Fire hazard; threats to aquatic and wildlife habitats; increased water demand; and reduced water supplies.

Proper management of water resources is necessary to protect supplies for drinking water, sanitation, and Fire protection as well as to maintain economic activity and environmental sustainability. ***Because disasters affect families, neighbors, and businesses locally, community-level planning is necessary to reduce the vulnerability to drought in Texas***.

"Droughts-of-Record" in Texas

For purpose of planning, we consider the "drought-of-record" to be the drought with the worst environmental conditions rather than the drought with the worst recorded impacts. Hence, a shorter and less severe drought with high monetary losses in our recent past (e.g., during 2011) will not outweigh a long and severe drought in our early history, when fewer people lived in the region. We choose to prepare for the worst.

How to prepare for drought?

Local officials and other key stakeholders in Texas will be better prepared for drought when they complete the following: (1) have assessed their vulnerability to drought, (2) understand past droughts and the local climate, (3) monitor drought, (4) prepare a thorough set of actions to be taken before, during, and after a drought, and (5) educate citizens on this plan.

Having a plan in place will enable these individuals to understand key factors to monitor so they may respond proactively to drought conditions early. Following this plan helps reduce the risk such that, when drought conditions occur, water resources do not run out. This report will help governmental officials and resource managers in Texas by overviewing the climate and drought history since record-keeping began in the late 19th century.

How is drought measured?

To quantify drought severity, the scientific community has developed several methods to assess drought, including departure from normal precipitation, the Palmer Drought Severity Index, and the Standardized Precipitation Index. All three use weather observations to diagnose drought conditions. The simplest of these is the annual departure from normal precipitation, which is the actual precipitation total for the year subtracted from the annual normal. Large negative values indicate a precipitation deficit for that year.

The Palmer Drought Severity Index uses observations or estimates of precipitation, temperature, and soil water content. Values typically range from +4 representing extremely wet conditions to –4 representing extremely dry conditions. Values less than –1 indicate some level of drought, and the values become more negative with less rainfall and hotter temperatures.

The Palmer Drought Severity Index helps to diagnose agricultural drought because it is sensitive to soil moisture conditions and works well at relatively long-time scales. The index does not account for reservoir levels and streamflow, so it has drawbacks for diagnosing hydrological drought.

The Standardized Precipitation Index is based solely on precipitation but has the advantage of multiple time scales (e.g., 3 months, 6 months, 1 year) to better highlight short-term versus long-term droughts. Values typically range from +2 as extremely wet to –2 as extremely dry, with values less than –1 representing drought.

A more recent method to measure drought intensity is the U.S. Drought Monitor (Figure 1). This product depicts weekly drought conditions for the United States on a drought intensity scale of D0 to D4, with D0 representing areas that are abnormally dry and D4 representing areas of exceptional drought. Although the levels are subjectively determined, they are established through expert review of weather and water data, including local observations, as well as reports of drought impacts from local, tribal, state, and federal officials as well as the public and media. Figure 1 displays the weekly percentage of area in each of Texas' regions by D0 through D4 drought since 2000[1].

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[1] Data provided by the National Drought Mitigation Center.

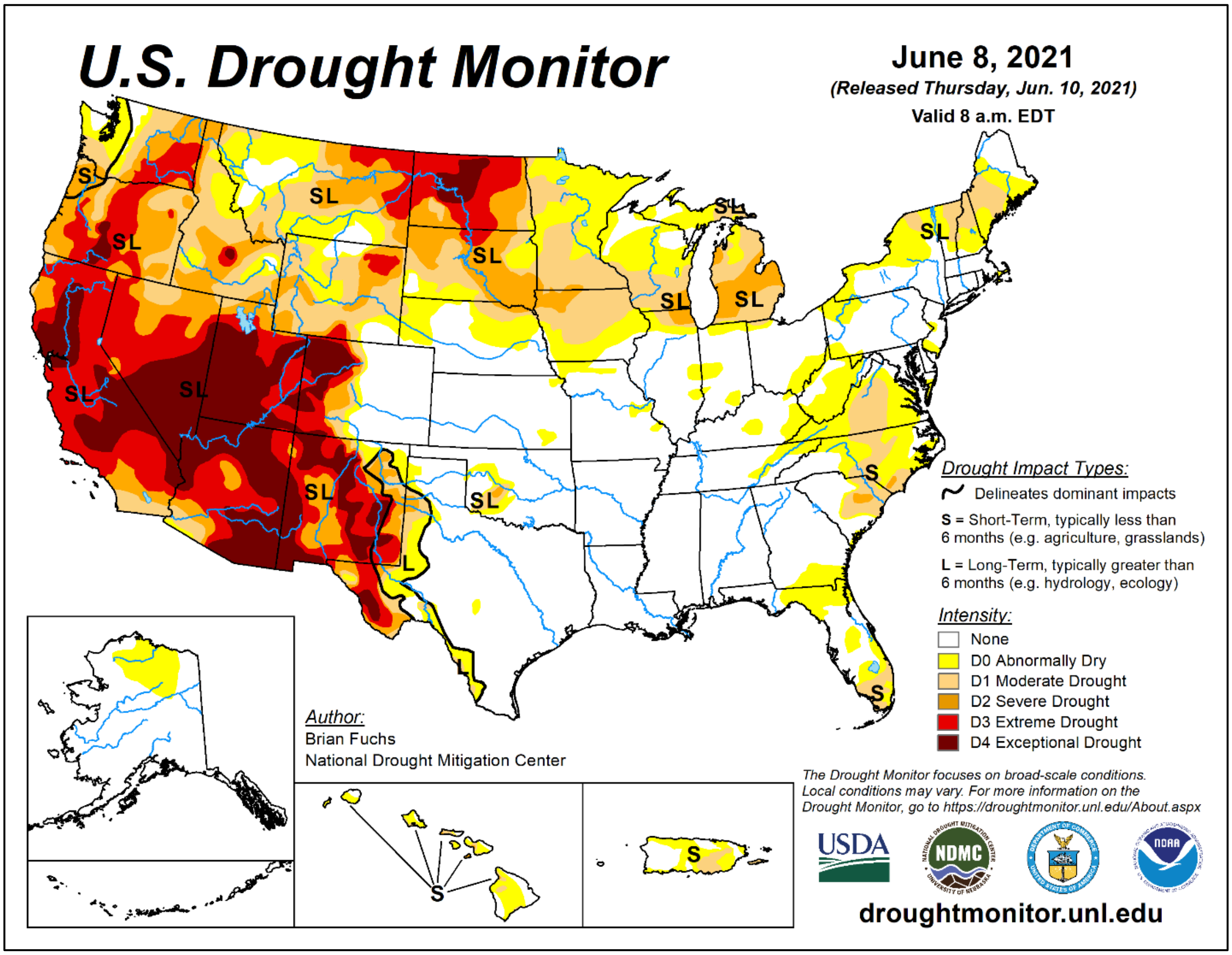


***Figure 1**. Example map of the U.S. Drought Monitor from the drought assessment issued for the week preceding June 10, 2021. The color scale (yellow to dark red) displays the level of drought from D0 (abnormally dry) to D4 (exceptional drought). Significant regional impacts on agriculture are designated with an "**S**" and regional impacts on water supply are designated with an "**L**". The maps are released each Thursday at 8:30 a.m. Eastern Time. Courtesy of the National Drought Mitigation Center.*

Has Texas experienced drought?

Drought is a recurring condition in Texas and is part of our climate. Our climate history can provide us insight into what we may see in the future. Being "drought ready" means, in part, that we recognize how our climate has changed over time. This report examines Texas' drought history.

The Climate of Texas

Temperature and precipitation are the two main elements of our climate. Because Texas is located in the middle latitudes, and northwest of the Gulf of Mexico, its citizens experience a wide range of weather conditions. Hence, our climate is highly variable, from year to year, season to season, and month to month.

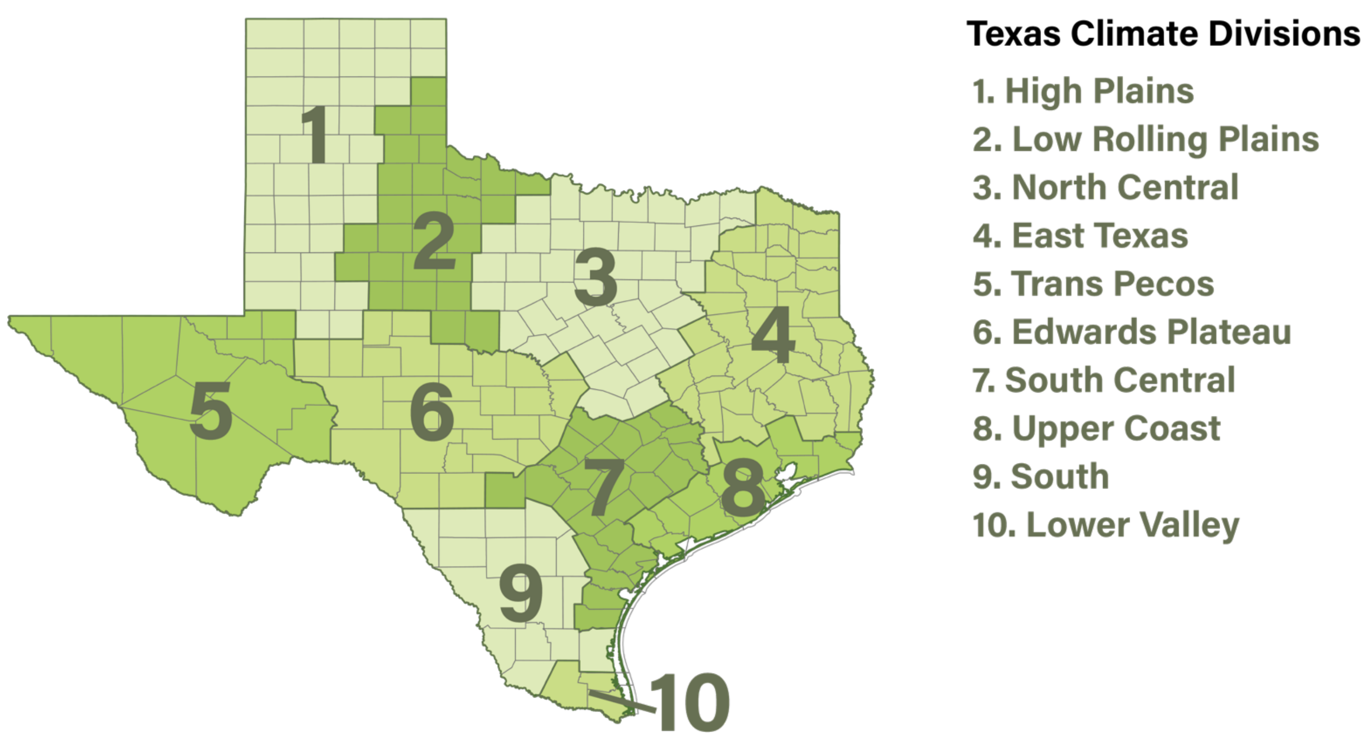


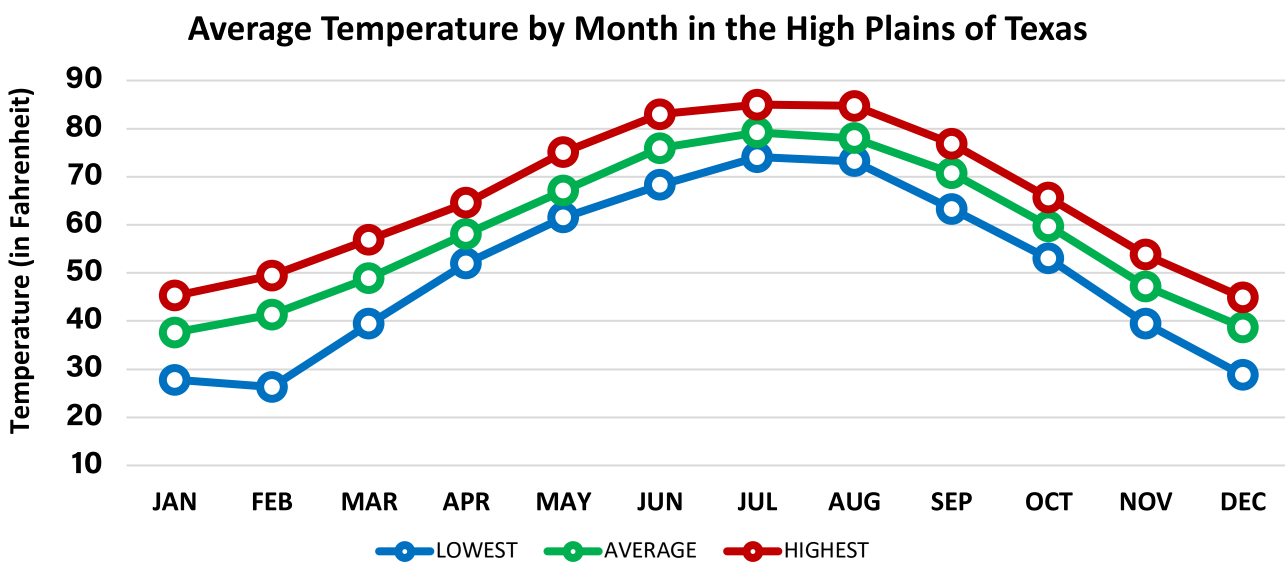
Figure 2. Climate Divisions of Texas

Climate Division 1: High Plains

Texas' High Plains region has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 3 shows the annual temperature (top) and annual precipitation (bottom) in the High Plains of Texas since 1895. The annual temperature for the High Plains of Texas averages 58.57 degrees Fahrenheit, while precipitation averages 18.58 inches. Warmer-than-average periods have spanned the 1930s, the 1950s, and the late 1990s through the early 2010s. Significant periods of drier-than-average conditions include the early 1910s, the 1930s, the 1950s, the 1960s, and the early 2010s.

***Figure 3**. The average annual temperature (top graph) and total annual precipitation (bottom graph) in the High Plains of Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the High Plains, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 4. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 4).



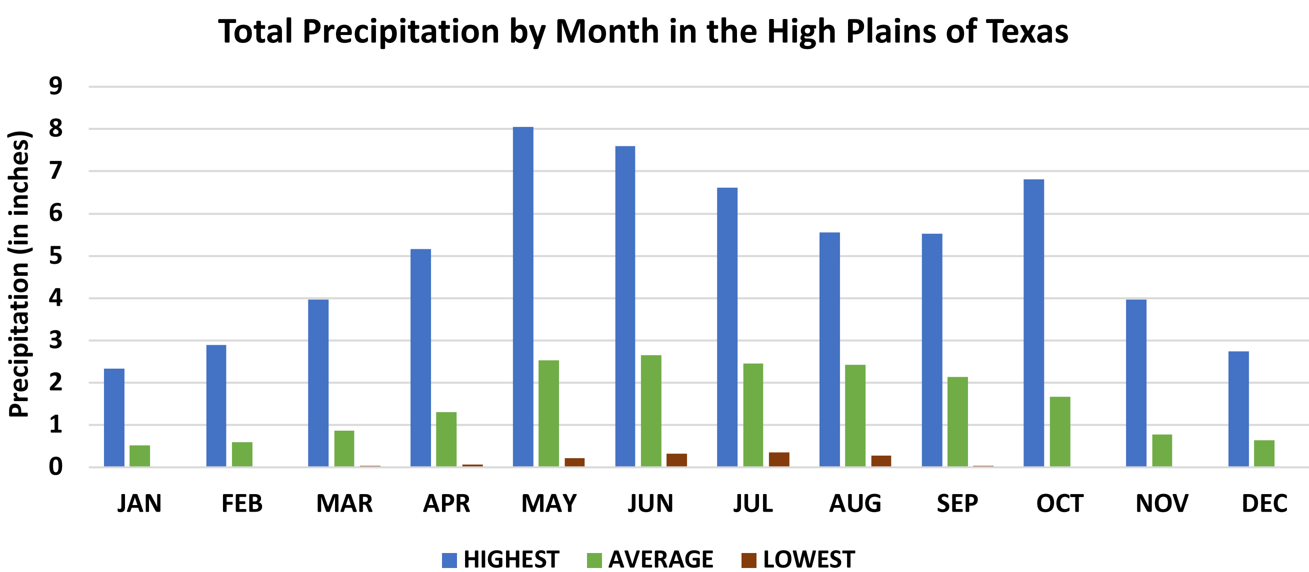


Figure 4. *Top graph: The monthly average temperature (in degrees Fahrenheit) across the High Plains using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. Bottom graph: The average total precipitation by month across the High Plains using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

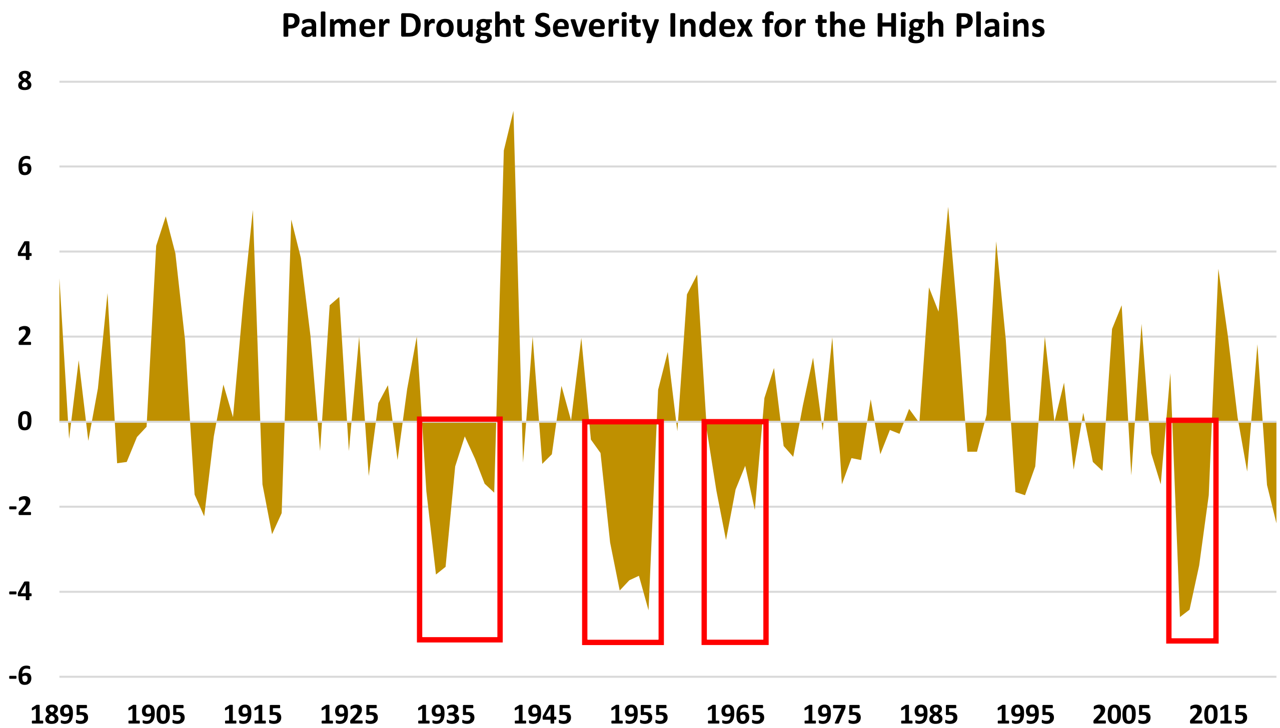


Figure 5. *Above is the Palmer Drought Severity Index for the High Plains Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 2: Low Rolling Plains

The Low Rolling Plains region of Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 6 shows the annual temperature (top) and annual precipitation (bottom) in the Low Rolling Plains of Texas since 1895. The annual temperature for the Low Rolling Plains of Texas averages 62.58 degrees Fahrenheit, while precipitation averages 23.03 inches. Warmer-than-average periods have spanned the 1920s, the 1930s, the 1950s, and the late 1990s through the 2000s. Significant periods of drier-than-average conditions include the 1910s, the mid-1920s through the early 1940s, the 1950s, the mid-1960s, and the early 2010s.

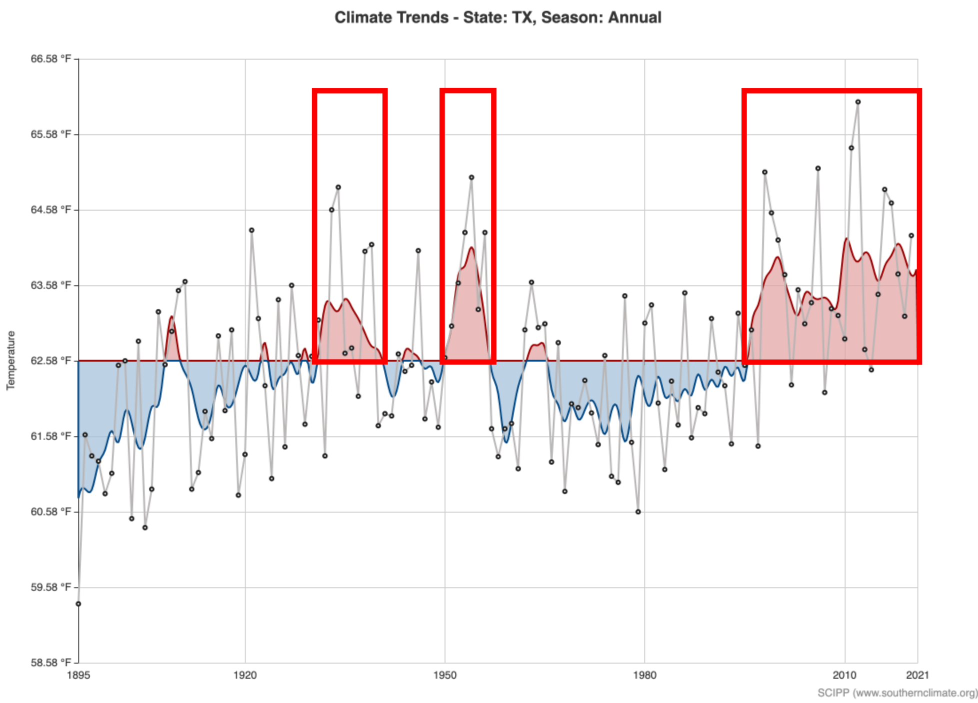
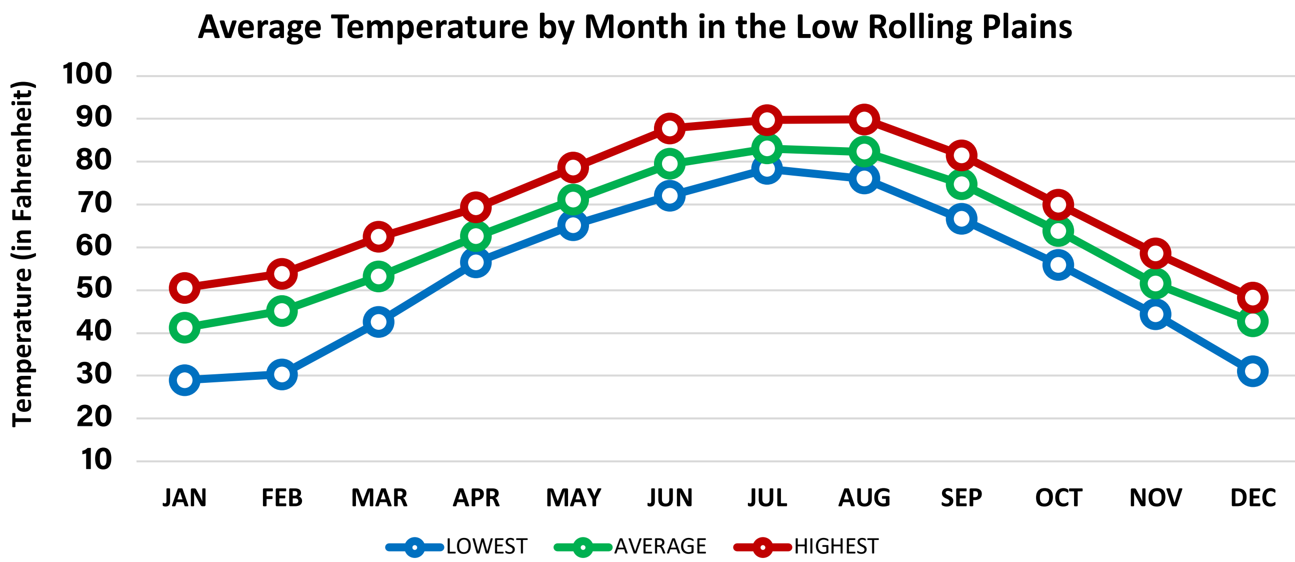


Figure 6. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in the Low Rolling Plains of Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the Low Rolling Plains, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 7. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 7).



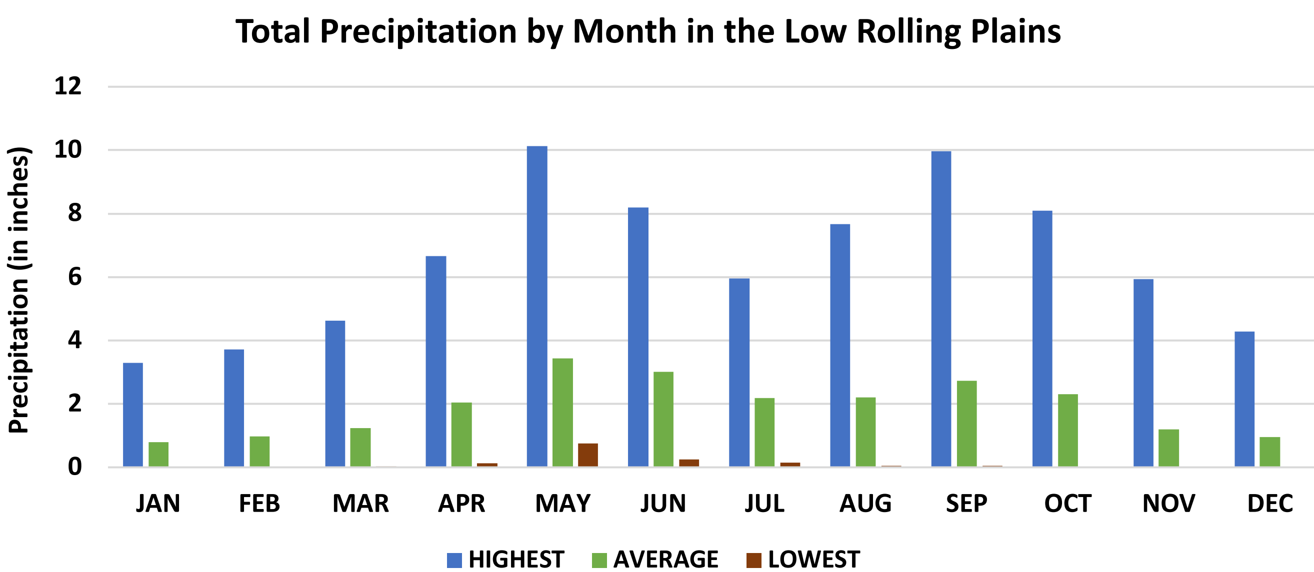


Figure 7. ***<u>Top graph</u>:*** *The monthly average temperature (in degrees Fahrenheit) across the Low Rolling Plains using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across the Low Rolling Plains using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

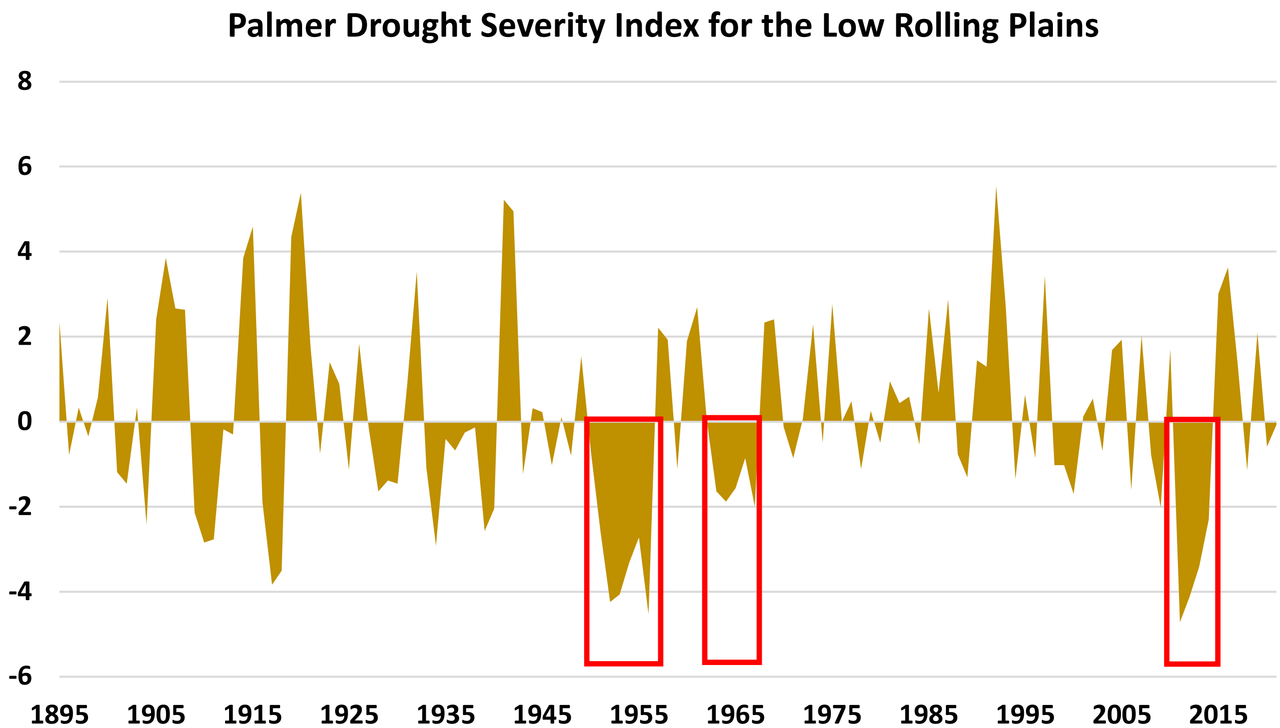


Figure 8. *Above is the Palmer Drought Severity Index for the Low Rolling Plains Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 3: North Central

North-Central Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 9 shows the annual temperature (top) and annual precipitation (bottom) in north-central Texas since 1895. The annual temperature for north-central Texas averages 64.68 degrees Fahrenheit, while precipitation averages 33.20 inches. Warmer-than-average periods have spanned the late 1900s, the 1920s through the 1930s, the 1950s, and the late 1990s through the early 2010s. Significant periods of drier-than-average conditions include the 1910s, the 1930s, the 1950s, the late 1970s, and the early 2010s.

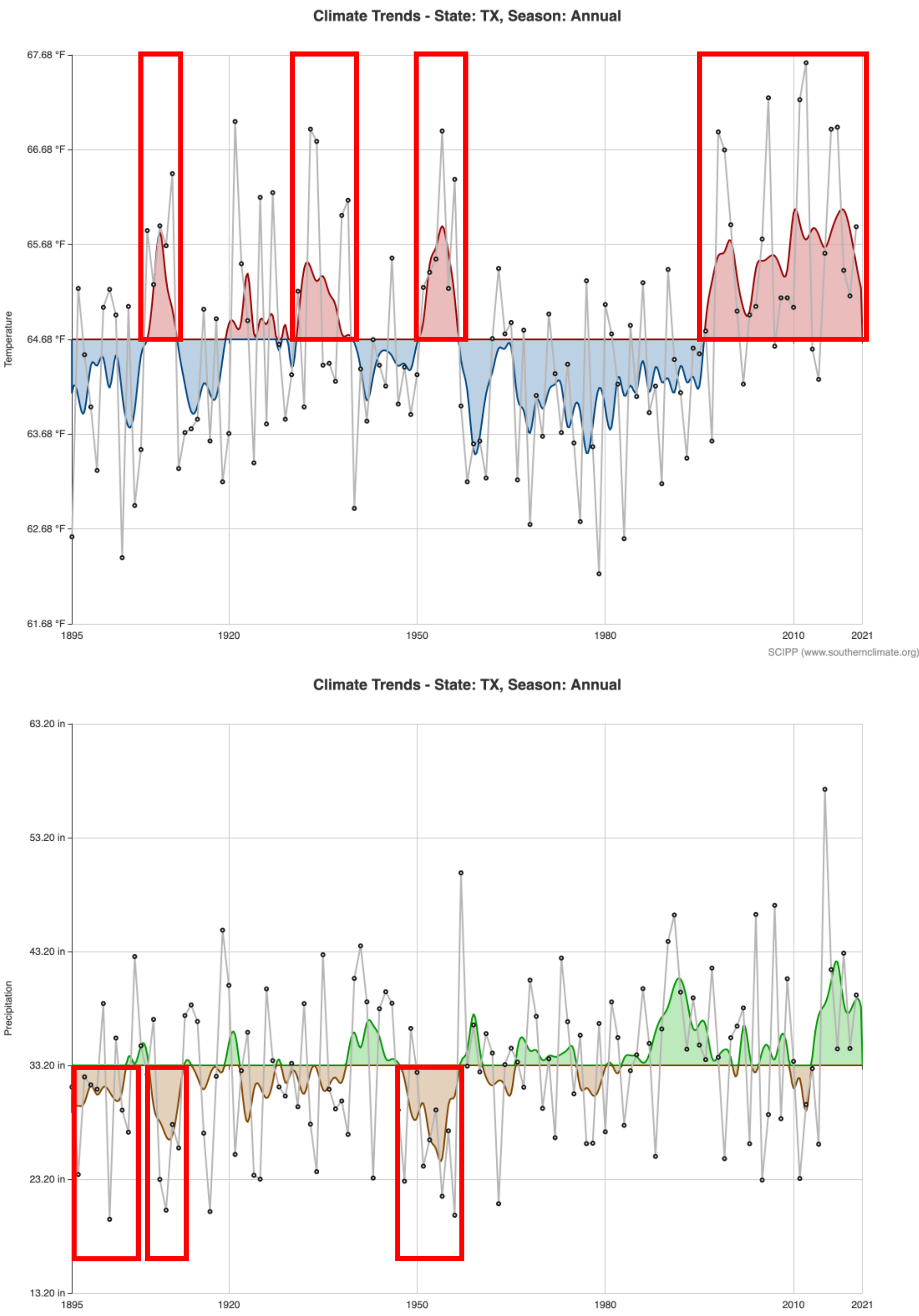
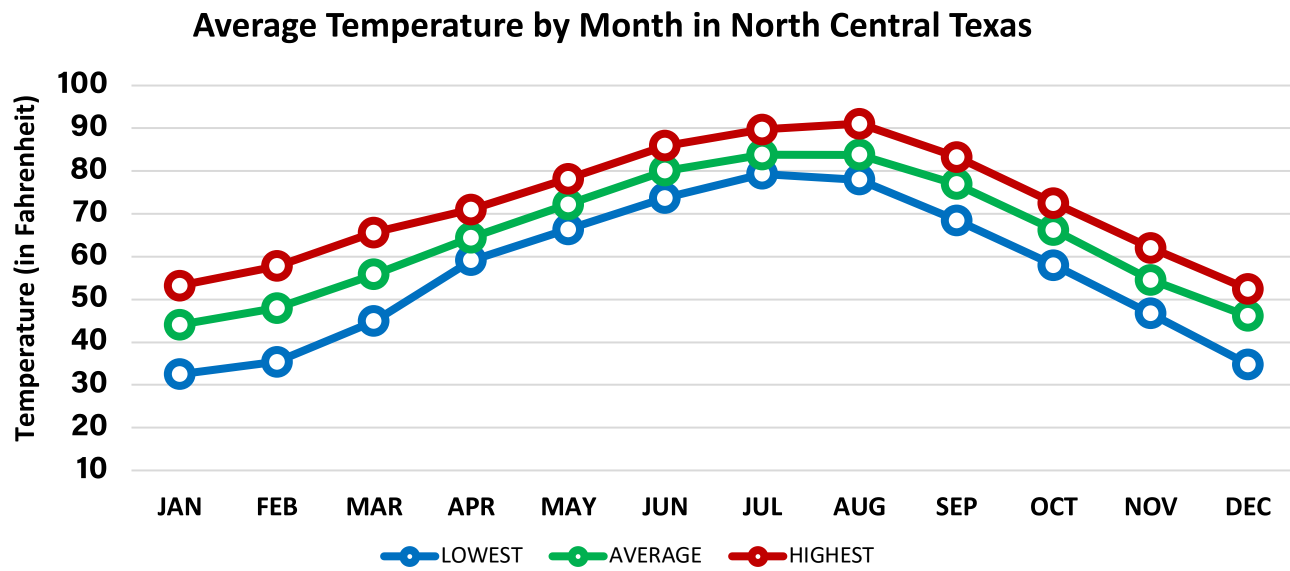


Figure 9. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in north-central Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for North Central Texas, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 10. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 10).



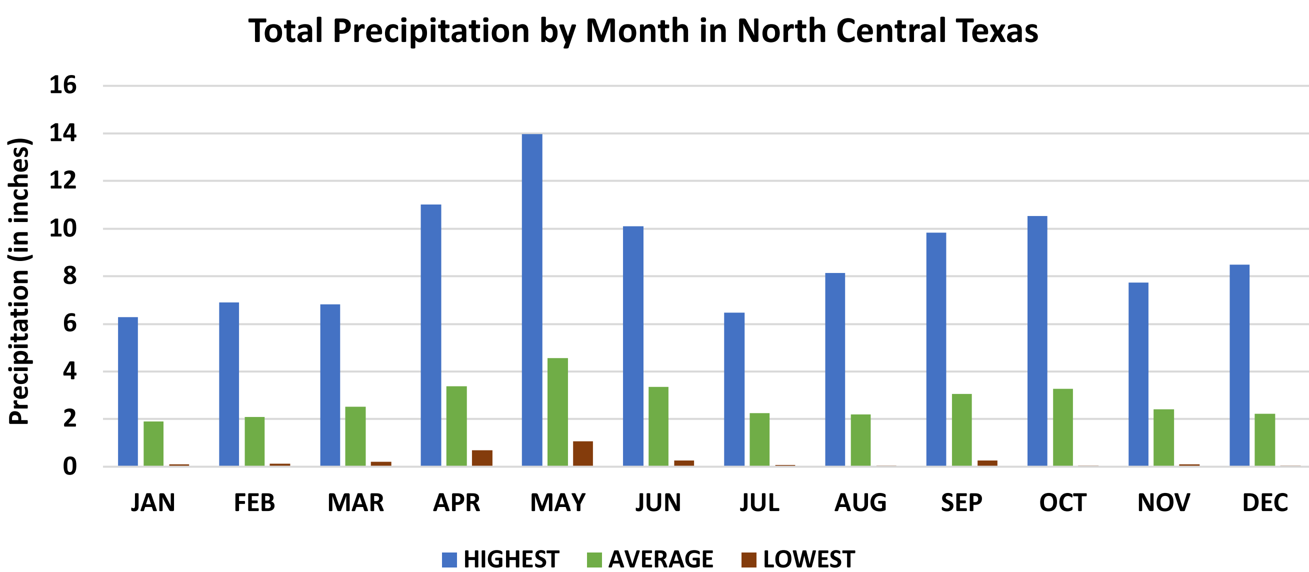


Figure 10. *Top graph: The monthly average temperature (in degrees Fahrenheit) North Central Texas using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. Bottom graph: The average total precipitation by month across North Central Texas using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

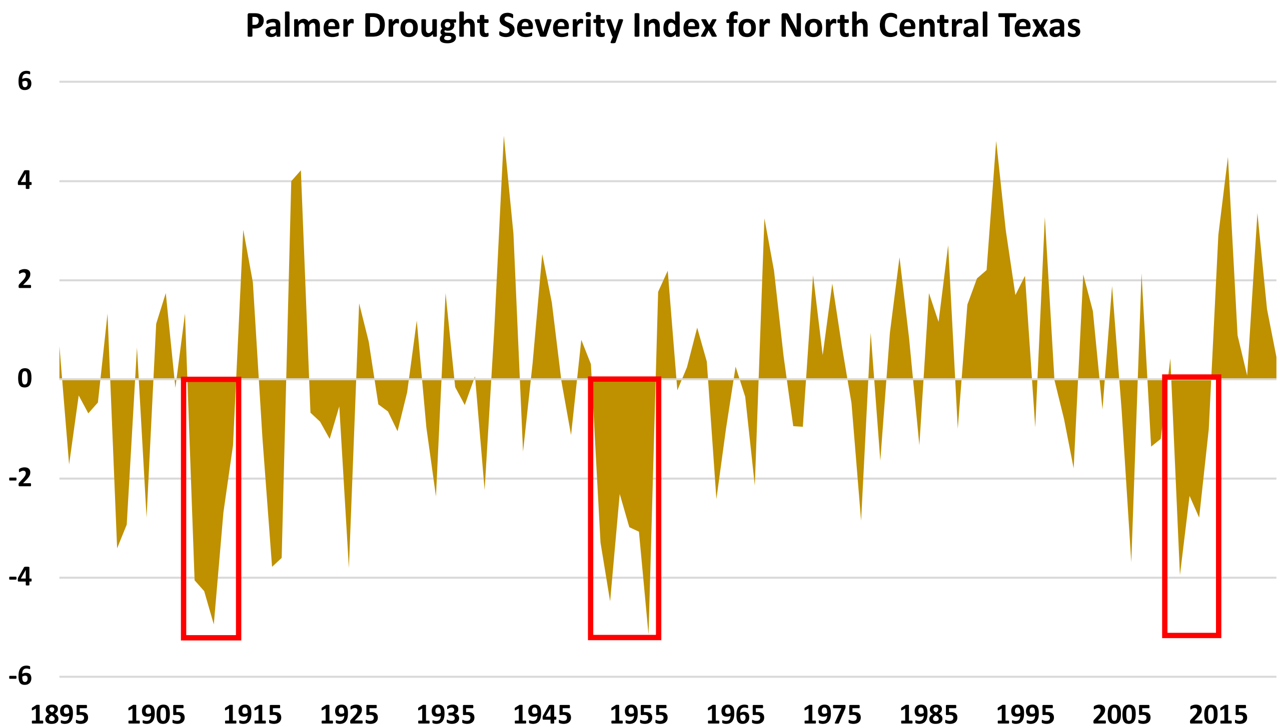


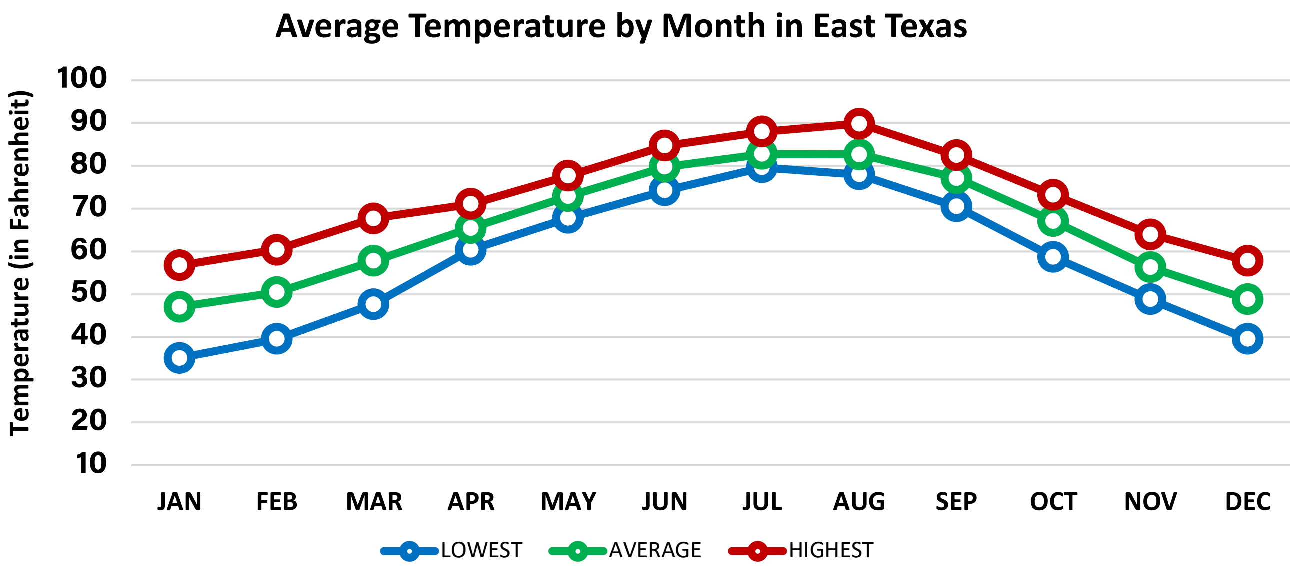
Figure 11. *Above is the Palmer Drought Severity Index for the North Central Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 4: East Texas

East Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 12 shows the annual temperature (top) and annual precipitation (bottom) in eastern Texas since 1895. The annual temperature for eastern Texas averages 65.68 degrees Fahrenheit, while precipitation averages 46.03 inches. Warmer-than-average periods have spanned the late 1900s through the early 1910s, the 1920s through the late 1950s, and the late 1990s through the early 2010s. Significant periods of drier-than-average conditions include the late 1890s through the early 1900s, the 1910s, the 1930s, the 1950s, the 1960s through the early 1970s, and the early 2010s.

Figure 12. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in eastern Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for East Texas, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 13. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 13).



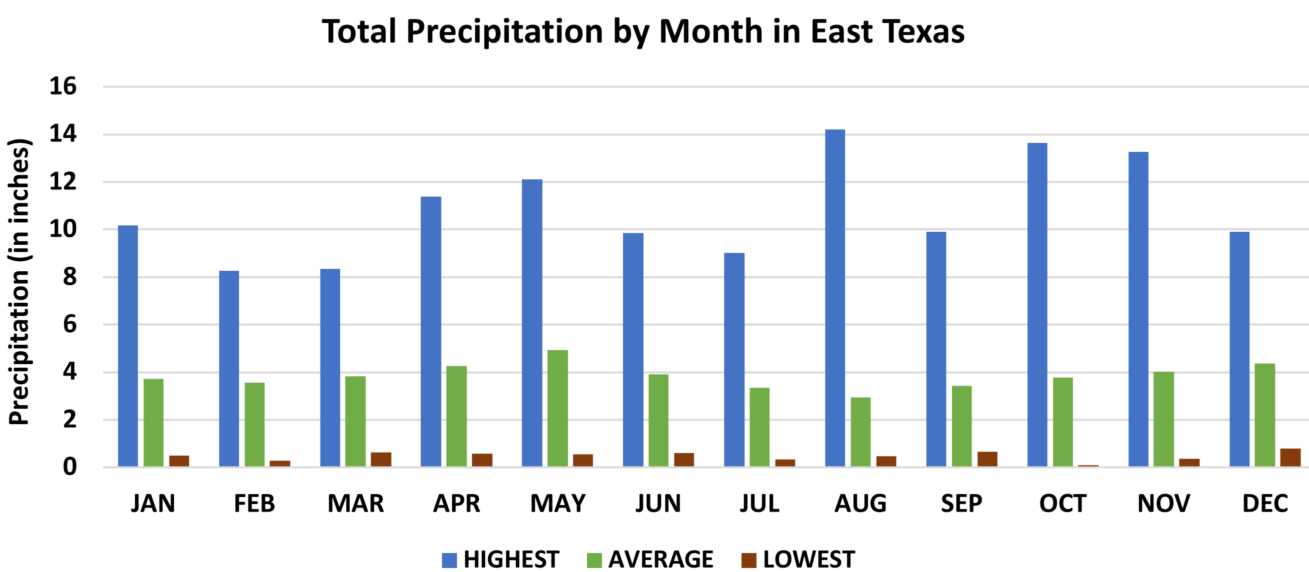


Figure 13. *<u>Top graph</u>: The monthly average temperature (in degrees Fahrenheit) across East Texas using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across East Texas using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

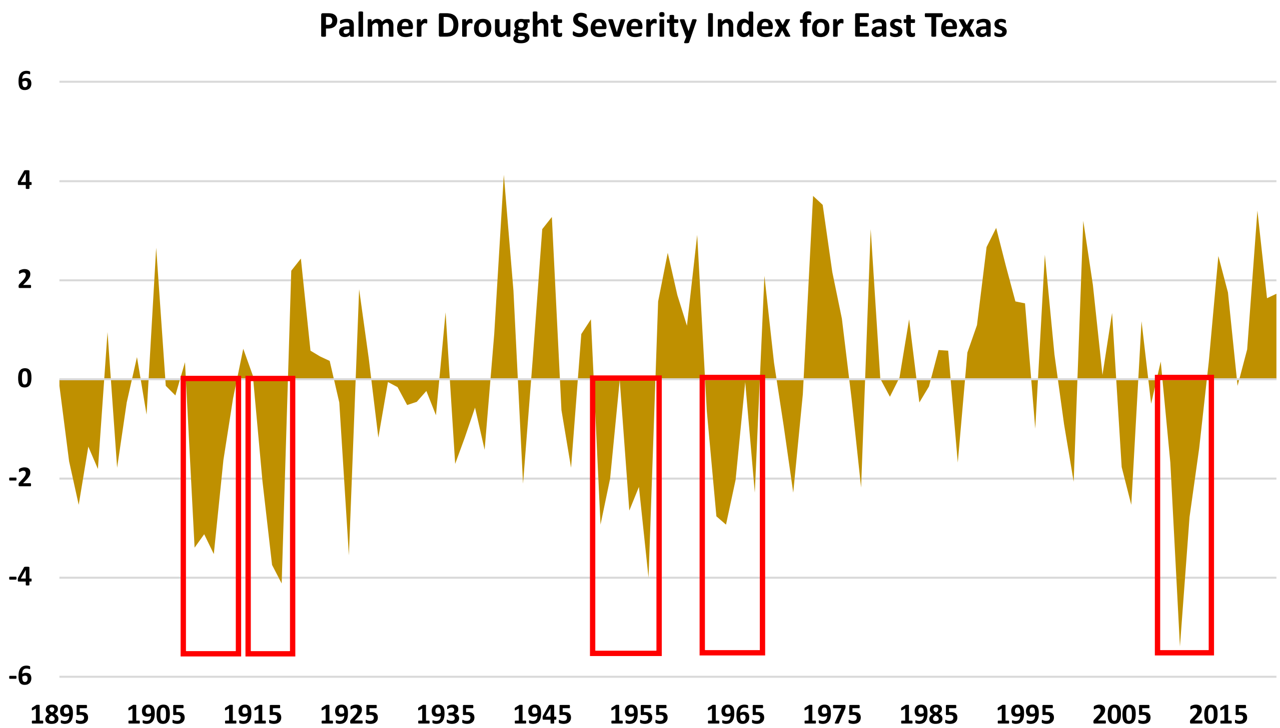


Figure 14. *Above is the Palmer Drought Severity Index for the Eastern Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 5: Trans Pecos

The Trans Pecos region of Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 15 shows the annual temperature (top) and annual precipitation (bottom) in the Trans Pecos of Texas since 1895. The annual temperature for the Trans Pecos of Texas averages 63.37 degrees Fahrenheit, while precipitation averages 12.58 inches. Warmer-than-average periods have spanned the 1900s, and the mid-1990s through the early 2010s. Significant periods of drier-than-average conditions include the early 1910s, the mid-1920s to the mid-1930s, the mid-1940s through the late 1960s, the mid-1990s through the mid-2000s, and the early 2010s.

Figure 15*. The average annual temperature (top graph) and total annual precipitation (bottom graph) in the Trans Pecos of Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the Trans Pecos Region, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 16. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 16).

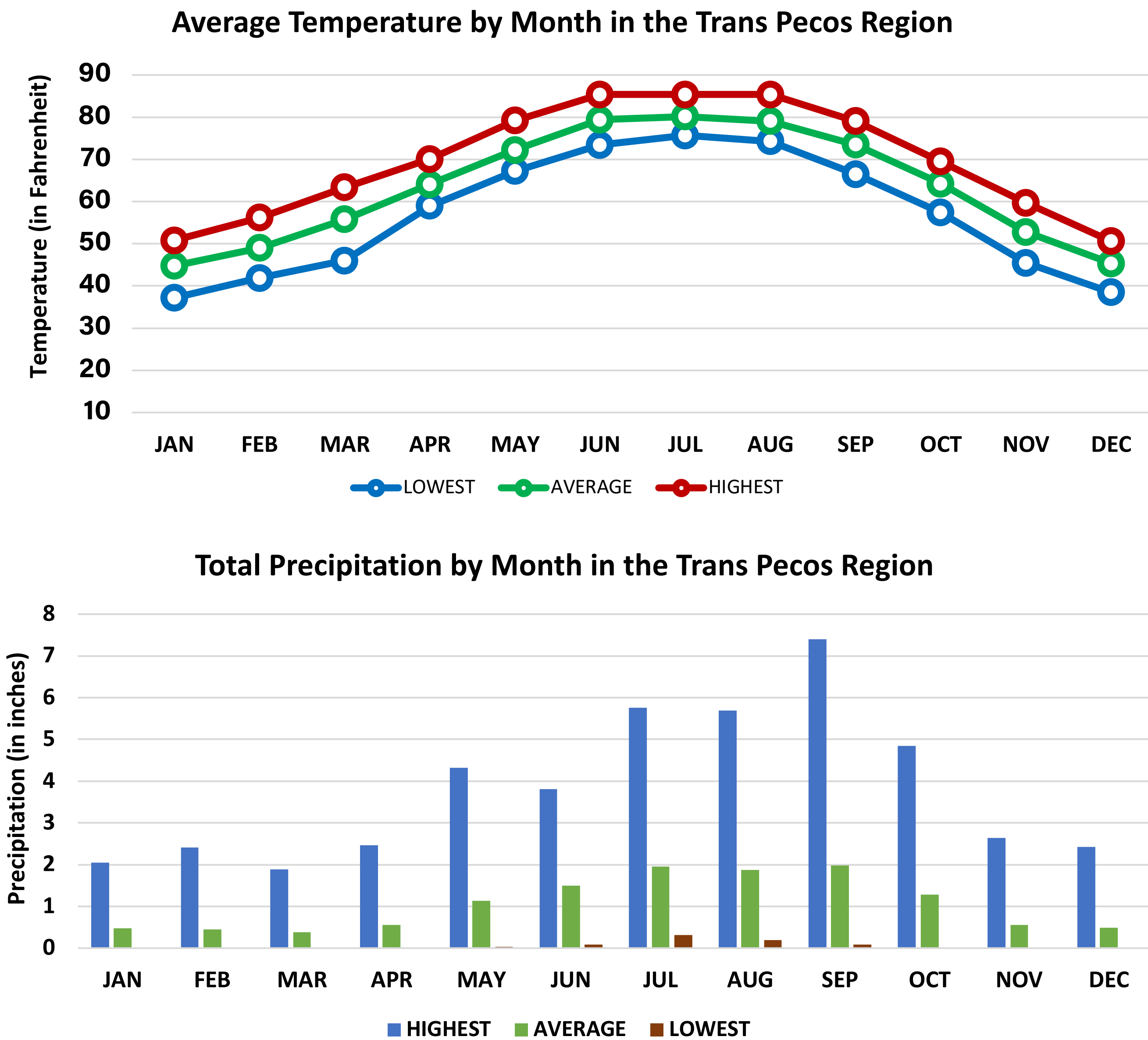


Figure 16. *<u>Top graph</u>**:** The monthly average temperature (in degrees Fahrenheit) across the Trans Pecos Region using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across the Trans Pecos Region using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

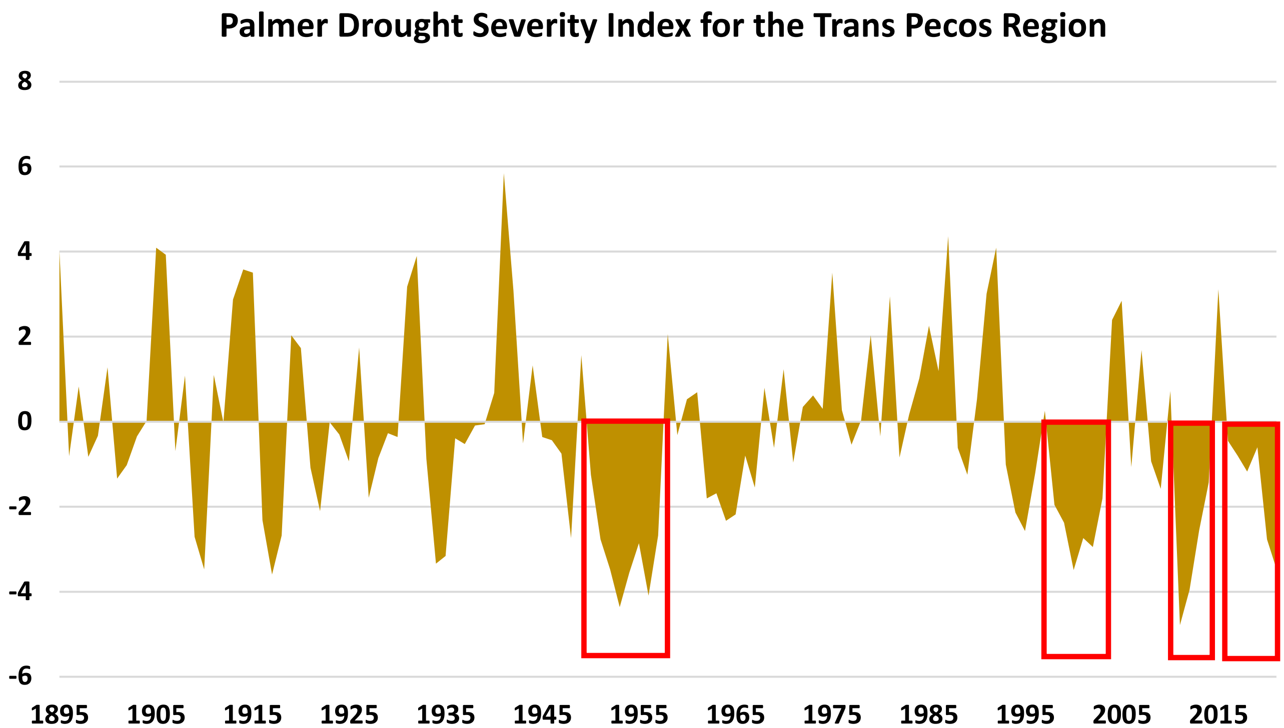


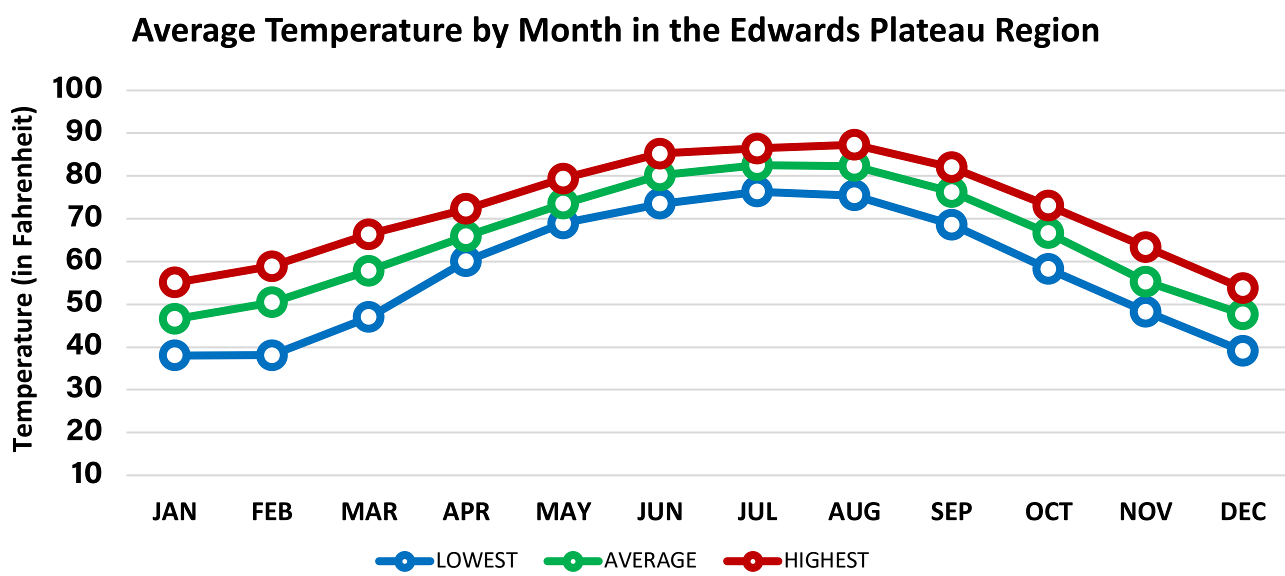
Figure 17. *Above is the Palmer Drought Severity Index for the Trans Pecos Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 6: Edwards Plateau

The Edwards Plateau has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 18 shows the annual temperature (top) and annual precipitation (bottom) in the Edwards Plateau of Texas since 1895. The annual temperature for the Edwards Plateau of Texas averages 65.42 degrees Fahrenheit, while precipitation averages 23.49 inches. Warmer-than-average periods have spanned the late 1900s through the mid-1910s, the 1920s through the 1930s, the mid-1950s, the mid-1990s through the early 2000s, and the early 2010s. Significant periods of drier-than-average conditions include the early 1910s, the late 1910s, the 1950s, the 1960s, and the early 2010s.

Figure 18. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in the Edwards Plateau of Texas from 1895 to 2012. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the Edwards Plateau Region, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 19. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 19).



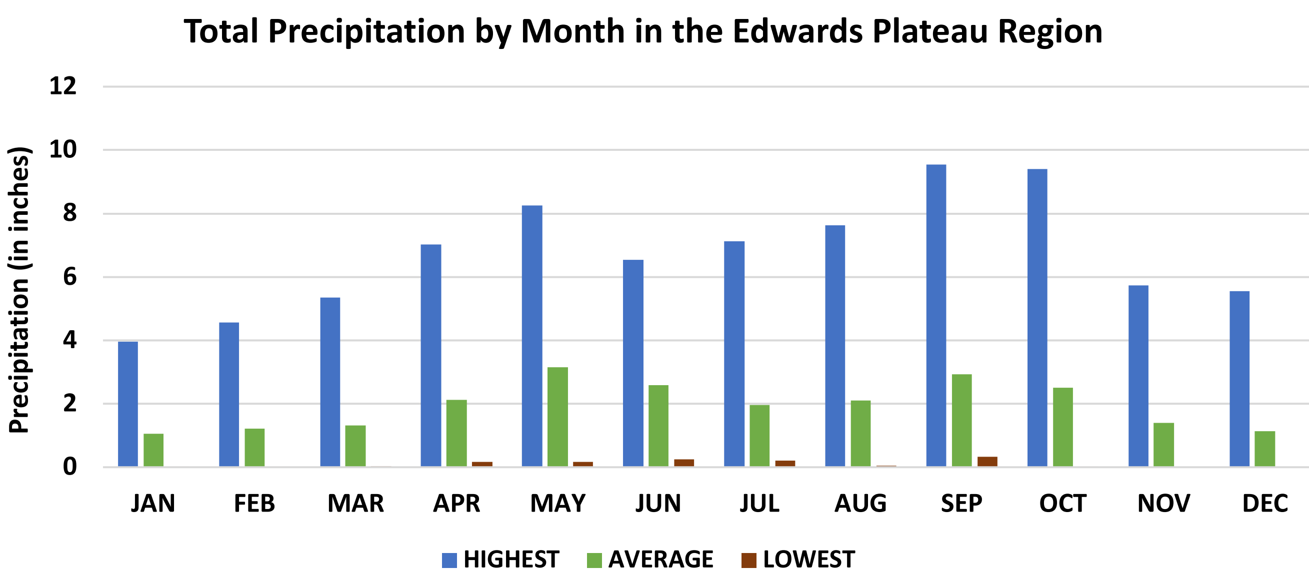


Figure 19. *<u>Top graph</u>**:** The monthly average temperature (in degrees Fahrenheit) across the Edwards Plateau Region using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across the Edwards Plateau Region using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

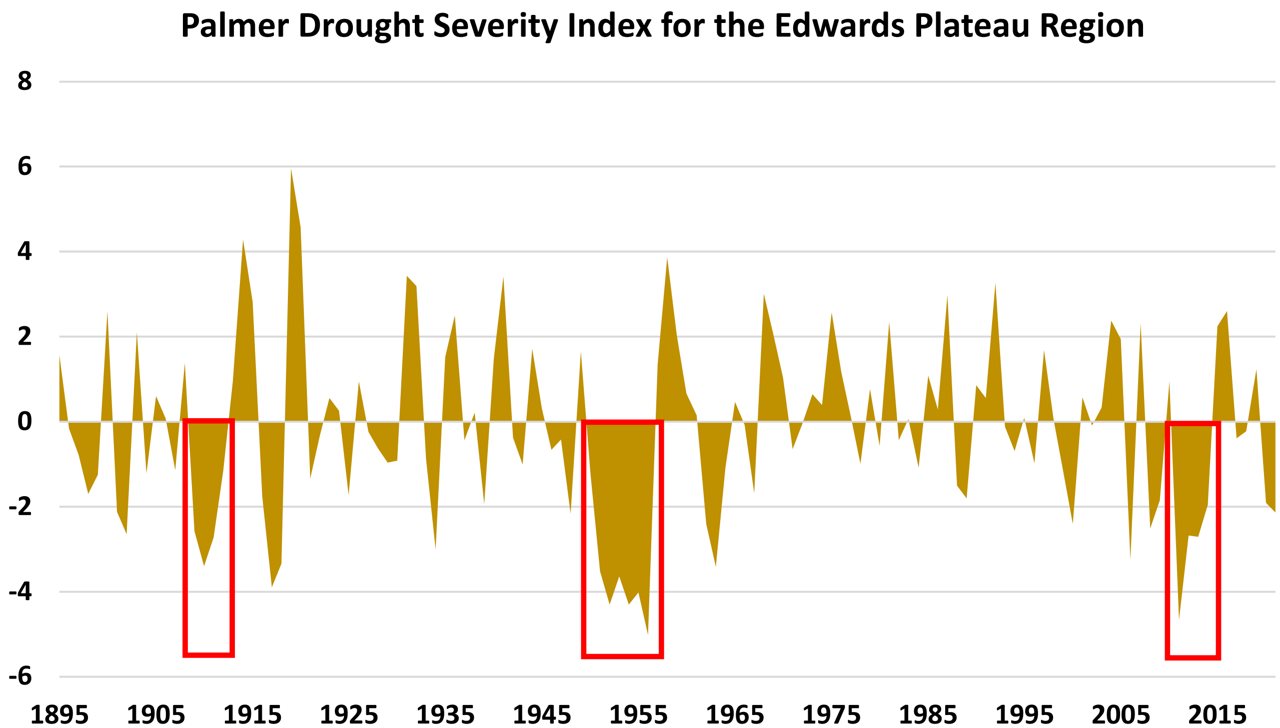


Figure 20. *Above is the Palmer Drought Severity Index for the Edwards Plateau Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 7: South Central

South Central Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 21 shows the annual temperature (top) and annual precipitation (bottom) in south-central Texas since 1895. The annual temperature for south-central Texas averages 68.92 degrees Fahrenheit, while precipitation averages 33.27 inches. Warmer-than-average periods have spanned the late 1900s through the mid-1910s, the 1920s, the 1950s, and the late 1990s through the early 2010s. Significant periods of drier-than-average conditions include the late 1910s, the 1950s, the 1960s, and the early 2010s.

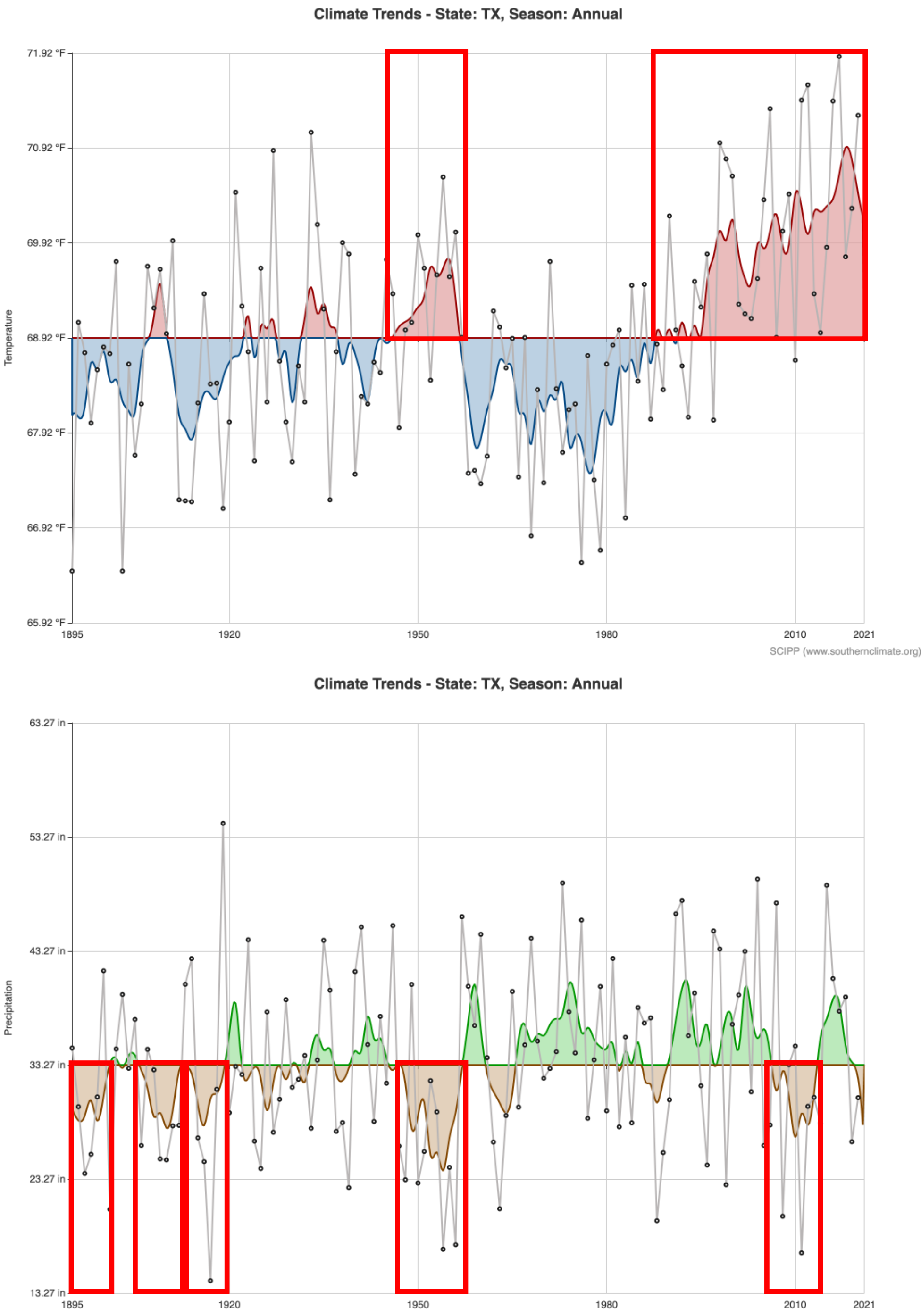
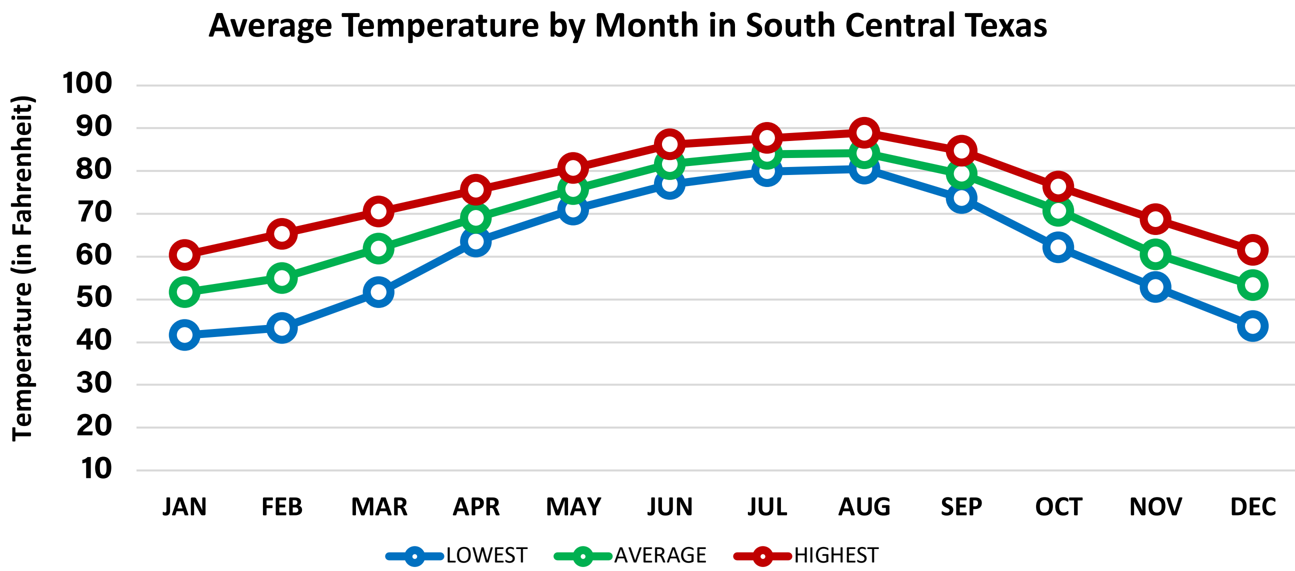


Figure 21. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in south-central Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for South Central Texas, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 22. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 22).



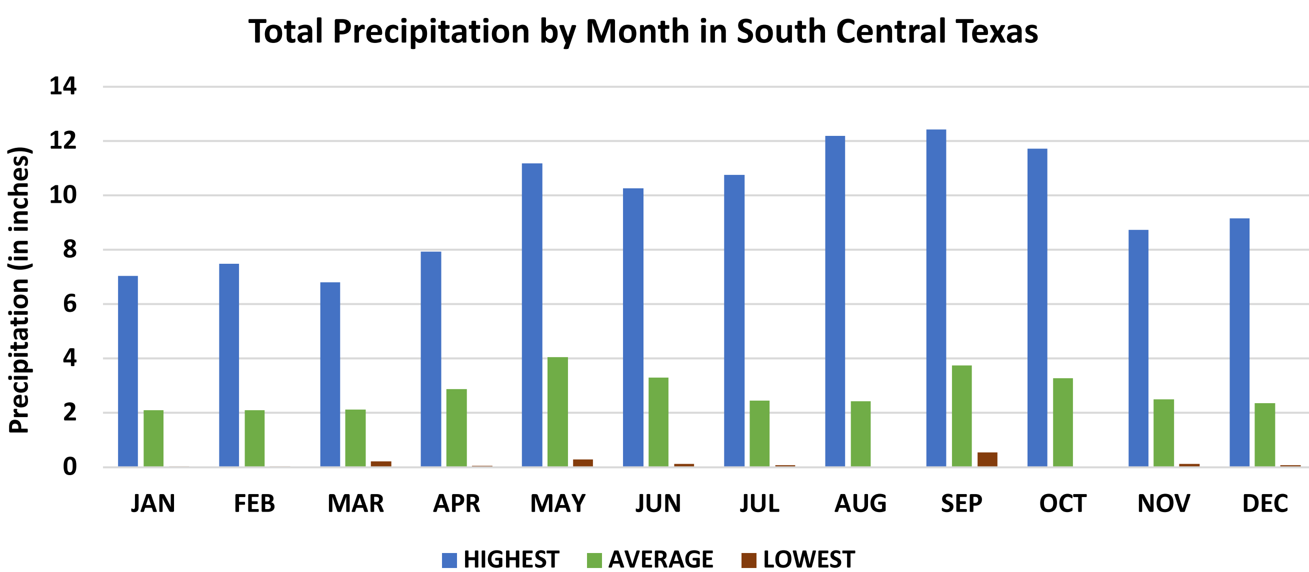


Figure 22. *Top graph: The monthly average temperature (in degrees Fahrenheit) across South Central Texas using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. Bottom graph: The average total precipitation by month across South Central Texas using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

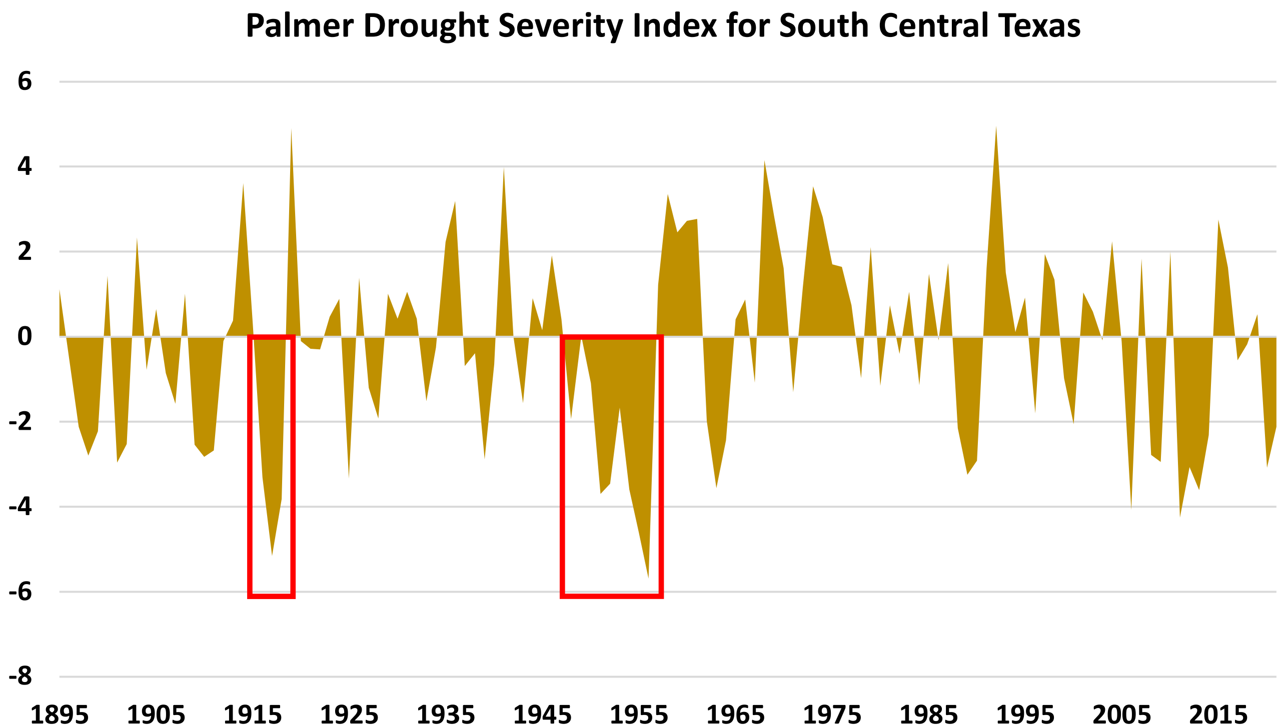


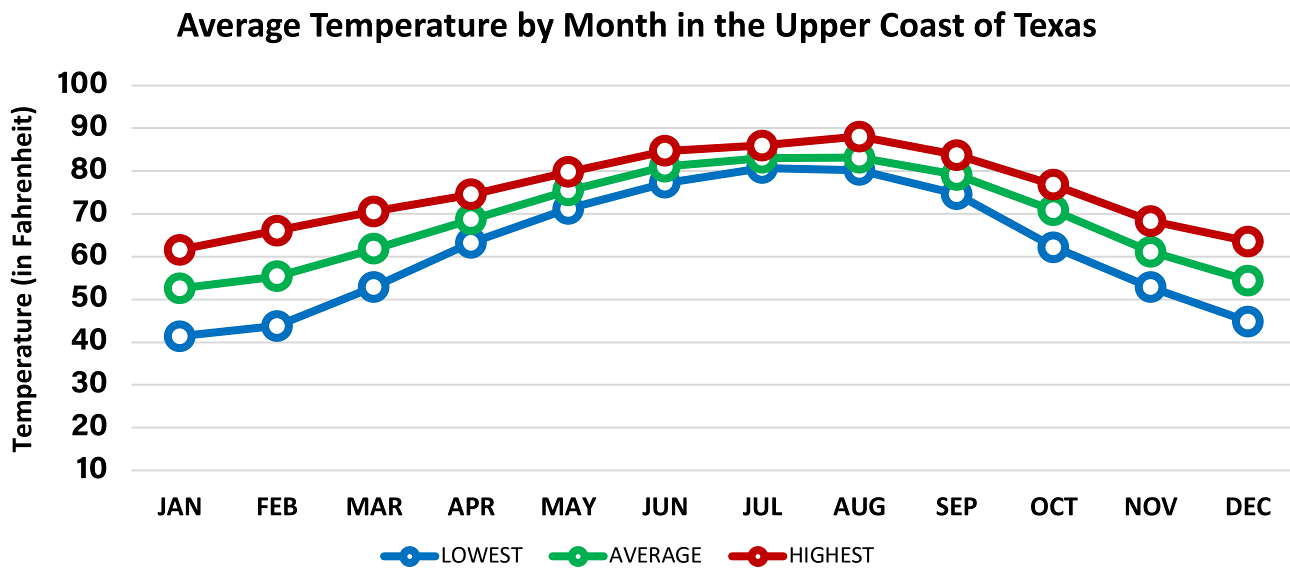
Figure 23. *Above is the Palmer Drought Severity Index for the South Central Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 8: Upper Coast

The Upper Coast of Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 24 shows the annual temperature (top) and annual precipitation (bottom) in the Upper Coast of Texas since 1895. The annual temperature for the Upper Coast of Texas averages 68.88 degrees Fahrenheit, while precipitation averages 45.83 inches. Warmer-than-average periods have spanned the late 1900s through the early 1910s, the 1920s, the 1950s, and the late 1990s through the early 2010s. Significant periods of drier-than-average conditions include the late 1910s, the 1950s, the 1960s, and the early 2010s.

Figure 24. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in the Upper Coast of Texas. from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the Upper Coast, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 25. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 25).



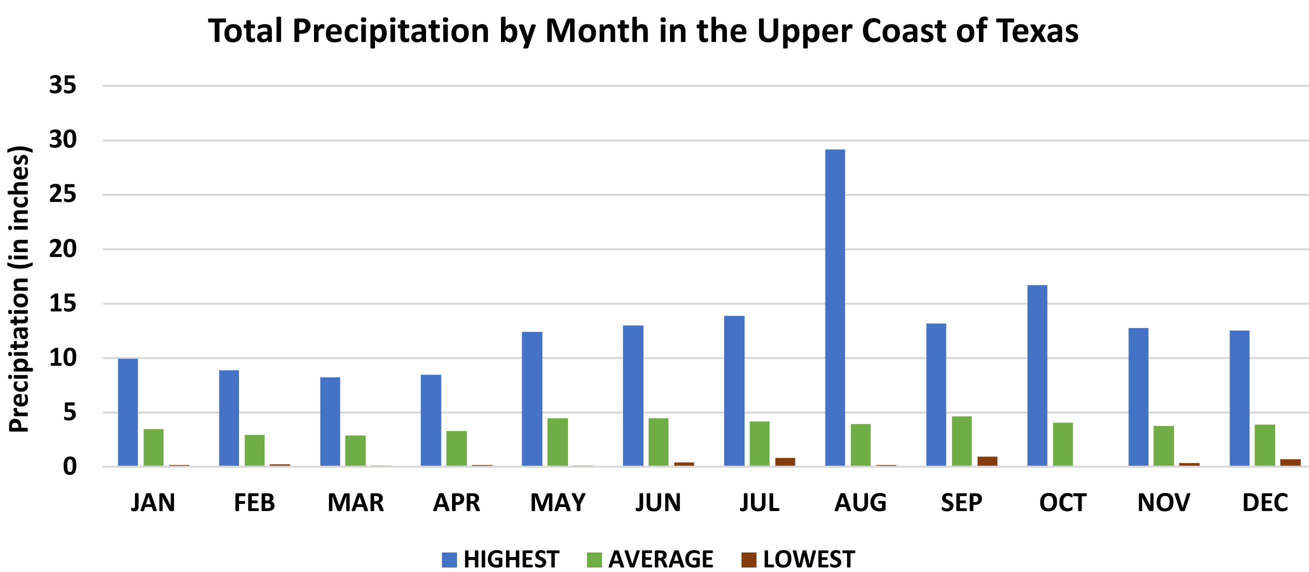


Figure 25. *<u>Top graph</u>**:** The monthly average temperature (in degrees Fahrenheit) across the Upper Coast using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across the Upper Coast using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

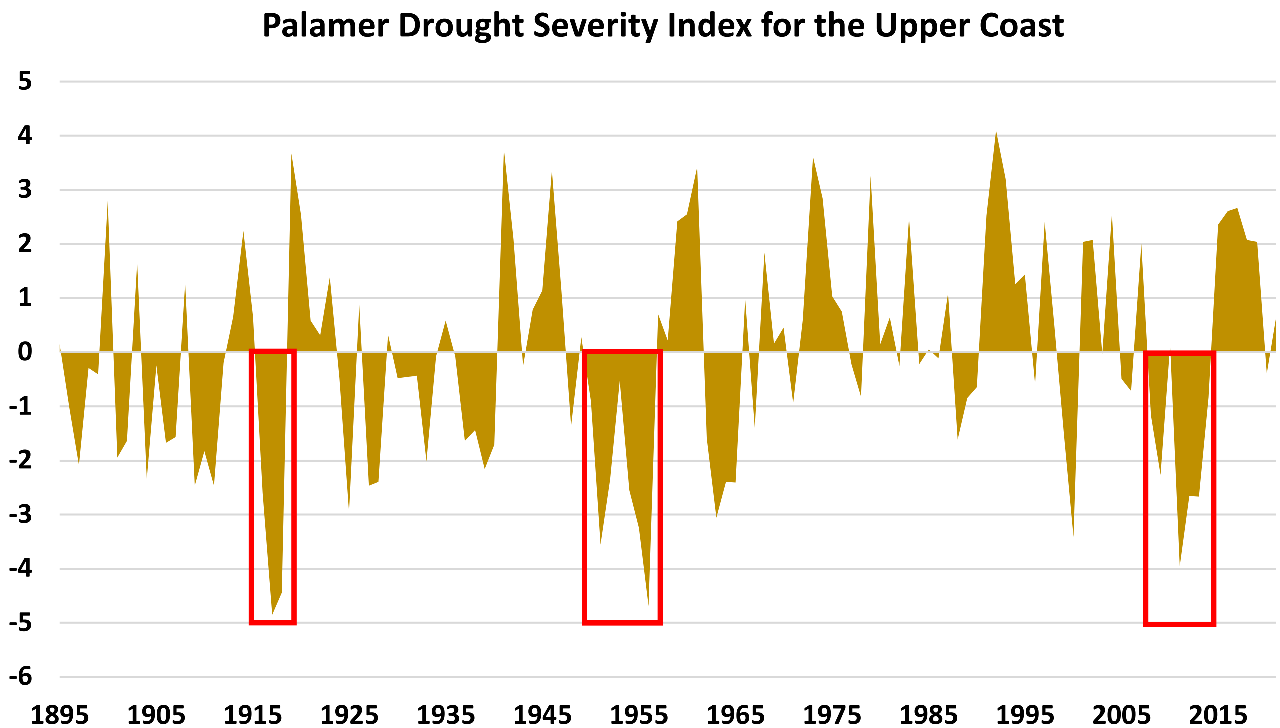


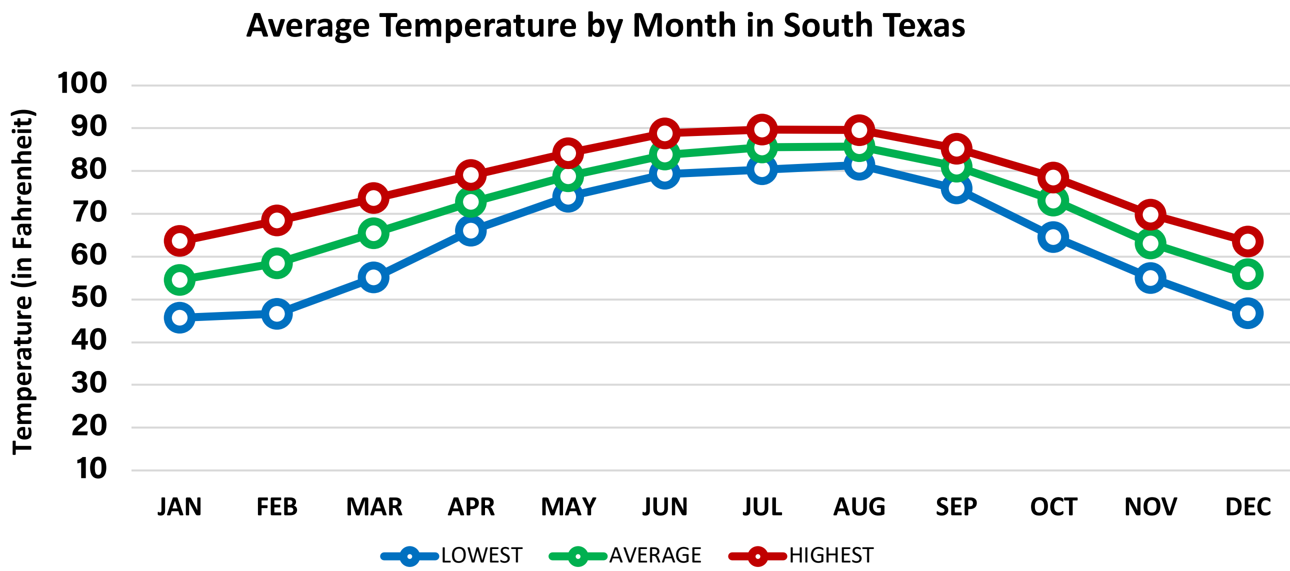
Figure 26. *Above is the Palmer Drought Severity Index for the Upper Coast Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 9: South

South Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 27 shows the annual temperature (top) and annual precipitation (bottom) in south Texas since 1895. The annual temperature for south Texas averages 71.50 degrees Fahrenheit, while precipitation averages 22.67 inches. Warmer-than-average periods have spanned the late 1900s through the early 1910s, the late 1910s through the 1920s, the 1950s, and the mid-1990s through the early 2010s. Significant periods of drier-than-average conditions include the early 1910s, the late 1910s, the mid-1940s through the 1950s, the 1960s, and the early 2010s.

Figure 27. *The average annual temperature (top graph) and total annual precipitation (bottom graph) in south Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for South Texas, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 28. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 28).



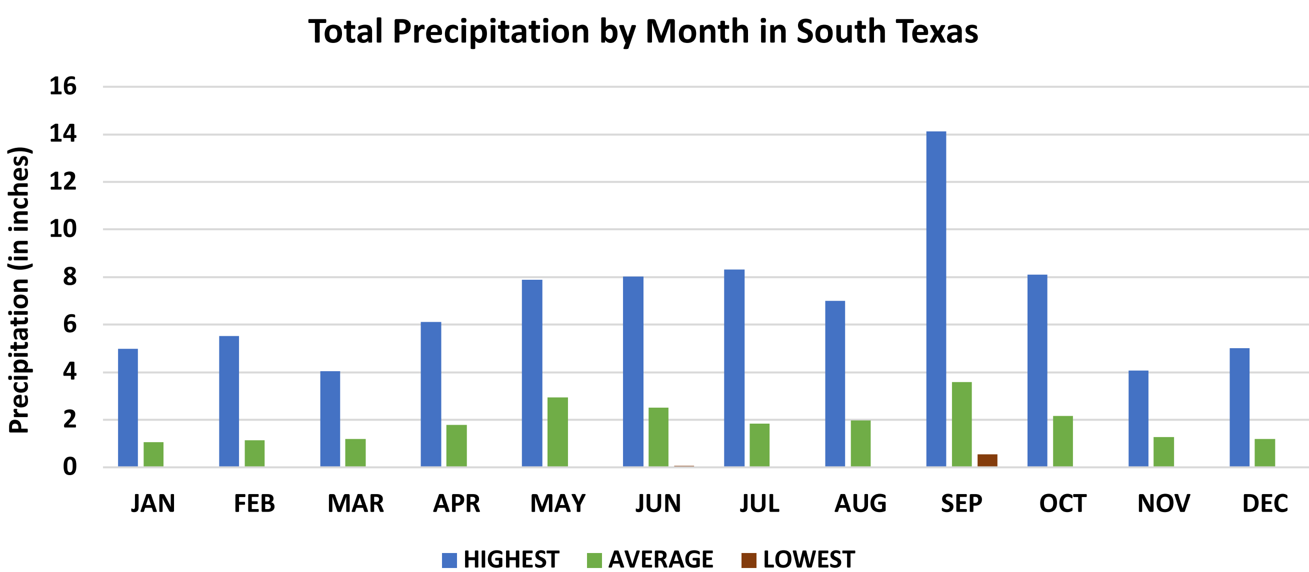


Figure 28. *__Top graph__: The monthly average temperature (in degrees Fahrenheit) across South Texas using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. __Bottom graph:__ The average total precipitation by month across South Texas using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

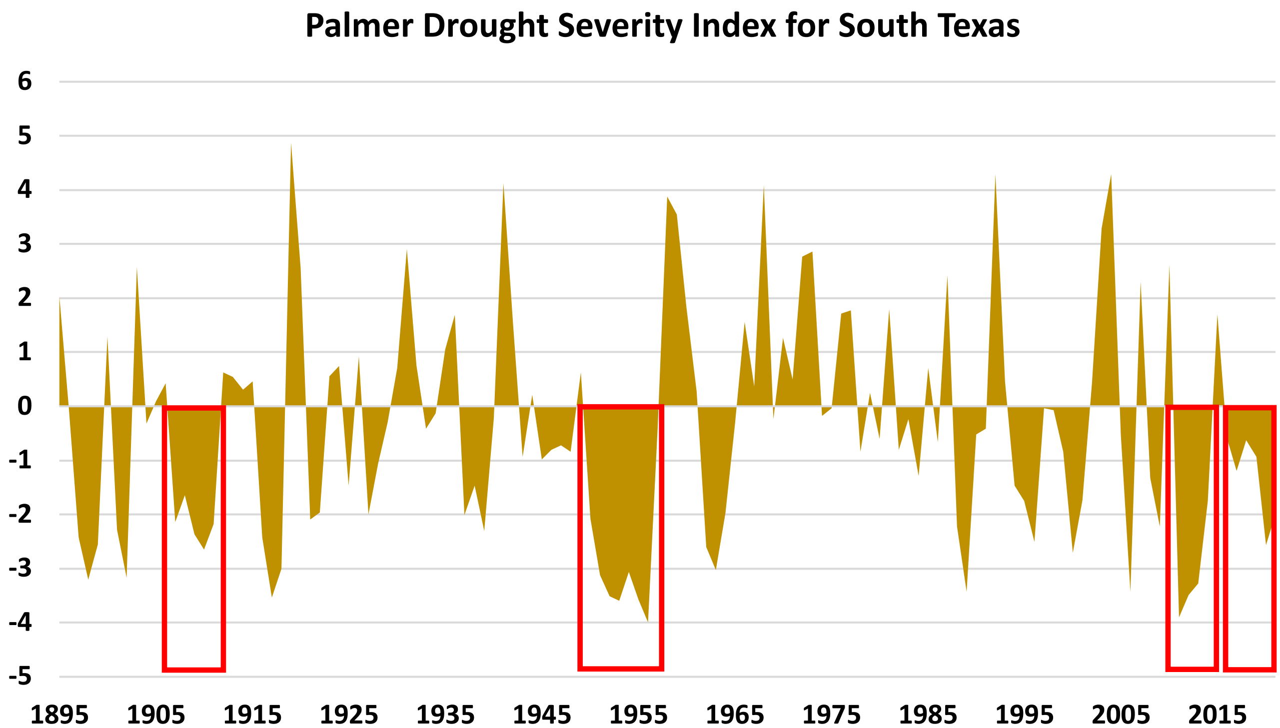


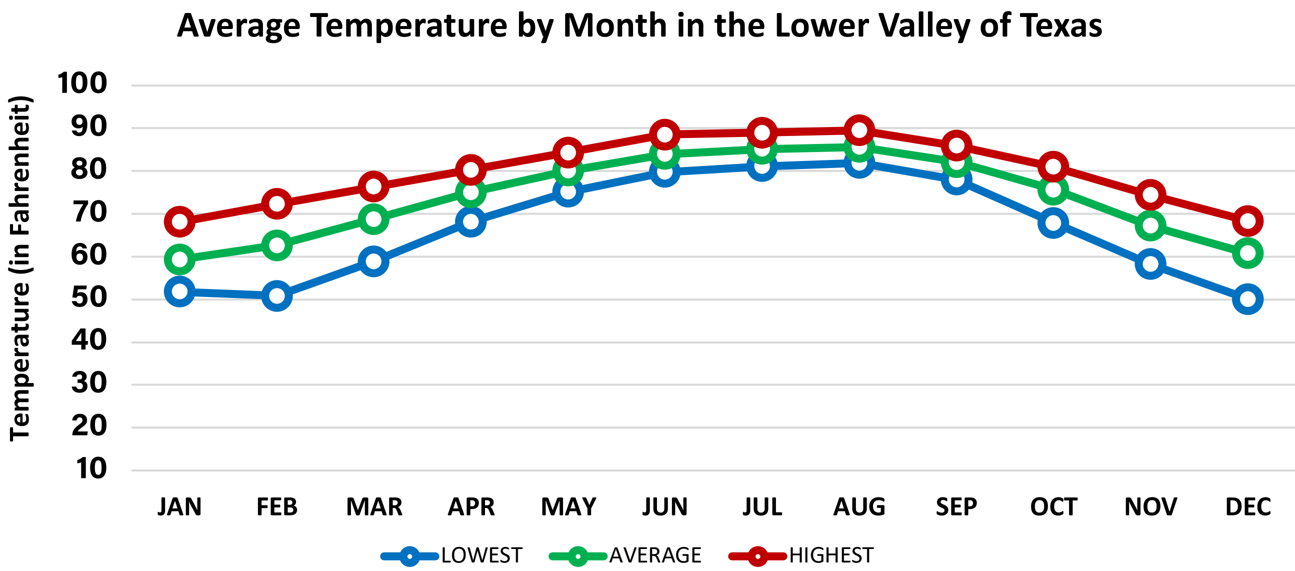
Figure 29. *Above is the Palmer Drought Severity Index for the Southern Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Climate Division 10: Lower Valley

The Lower Valley of Texas has experienced a wide range of temperatures and precipitation over the past several decades. Abnormally hot and dry conditions have occurred multiple times since the early 1900s. Figure 30 shows the annual temperature (top) and annual precipitation (bottom) in the Lower Valley of Texas since 1895. The annual temperature for the Lower Valley of Texas averages 73.85 degrees Fahrenheit, while precipitation averages 23.53 inches. Warmer-than-average periods have spanned the late 1900s through the early 1910s, the late 1910s through the 1920s, the mid-1940s through the 1950s, and the mid-1990s through the early 2010s. Significant periods of drier-than-average conditions include the mid-1940s through the 1950s, the early 1960s through the mid-1960s, and the early 2010s.

***Figure 30**. The average annual temperature (top graph) and total annual precipitation (bottom graph) in the Lower Valley of Texas from 1895 to 2021. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for the Lower Valley, the average monthly temperature and precipitation, as well as their average highest and lowest monthly values, are shown in Figure 31. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 31).



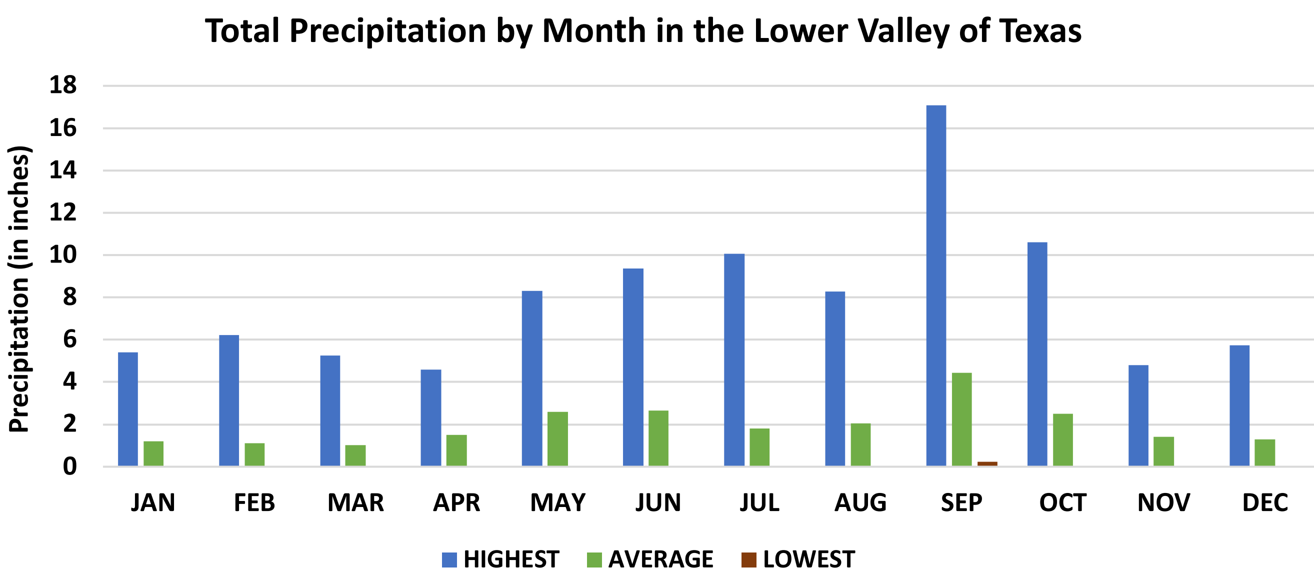


Figure 31. *<u>Top graph</u>: The monthly average temperature (in degrees Fahrenheit) across the Lower Valley using data from 1895 to 2021. The green line is the average of all climate-division average temperatures for that time period. The red line is the highest monthly average, and the blue line is the lowest. <u>Bottom graph:</u> The average total precipitation by month across the Lower Valley using data from 1895 to 2021. The blue bar is the highest monthly precipitation; the green is the average precipitation total recorded for that month; the gold is the lowest precipitation total recorded for that month.*

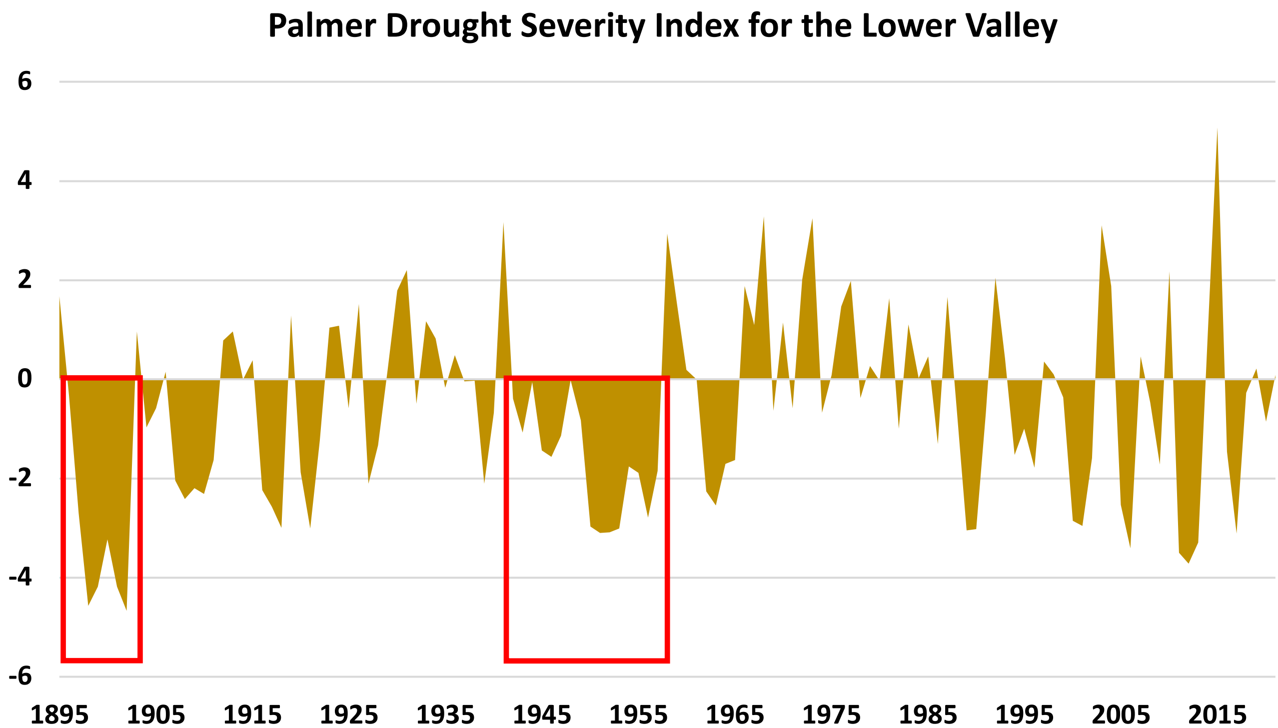


Figure 32. *Above is the Palmer Drought Severity Index for the Lower Valley Climate Region. Note how any regions below the zero line indicate dry conditions, with any instance less than –4 being categorized as extreme drought. Graph readings between –2 and –3 indicate moderate drought.*

Our Changing Climate

As documented by the Intergovernmental Panel on Climate Change (IPCC), the Earth's climate has warmed during the past 100 years. Climatic changes are expected to impact water supplies. Although the annual totals of rainfall may remain fairly constant, or even slightly increase, there may be less water available for public consumption. This is possible if precipitation is more intense and less frequent, water may need to be discharged from reservoirs to avoid flooding. Intense runoff during extreme precipitation events will likely pollute the water, rendering large volumes unsuitable for human consumption.

To investigate what the future might look like in Texas we use global climate models (GCMs) to project future conditions based on trends of global emissions. The global climate models use physics to calculate temperature, moisture, wind, pressure, etc. at each point in a grid that covers the globe. GCMs are not used to predict the weather on any given day; rather, they help us understand how weather on average might change. Typically, a single grid cell in a GCM covers an area of 100-500 km (62-310 miles). This can make it difficult to obtain useful information at regional-to-local scales. Using downscaling techniques, we can take the coarse resolution (i.e., 100-500 km area) of the GCM to a finer resolution that provides detailed information at more regional-to-local scales. We've used statistical downscaling techniques, rather than dynamical downscaling techniques, to obtain finer resolution climate projections for our region (i.e., 10 km (6 miles) area).

Statistical downscaling refers to a group of downscaling techniques that build a relationship between the regional/local (represented by historical observations) and global scales using statistical methods. Most statistical downscaling approaches begin by comparing GCM output for a particular time period in the past with historical observations during that same historical time period. By comparing GCM output and actual climate observations, our researchers can see the relationships between global and regional climate patterns, and ultimately describe these relationships using statistics. Historical observations often include temperature and precipitation measurements from networks like the Oklahoma Mesonet, the Community Collaborative Rain, Hail, & Snow Network (CoCoRaHS), NOAA's Cooperative Observer Network, etc.

Emissions scenarios are used to show how future trajectories of key greenhouse gases may impact the climate system. For our datasets, we show how the climate responds to the low scenario (e.g., a drastic reduction in global emissions) and the high scenario (e.g., business as usual).

Figures 33 and 34 present mid-century (2036-2065) and end-of-century (2070-2099) downscaled climate projections for drought related events across the south-central U.S. Each figure includes projections for a low emissions scenario on the left and a high emissions scenario on the right.

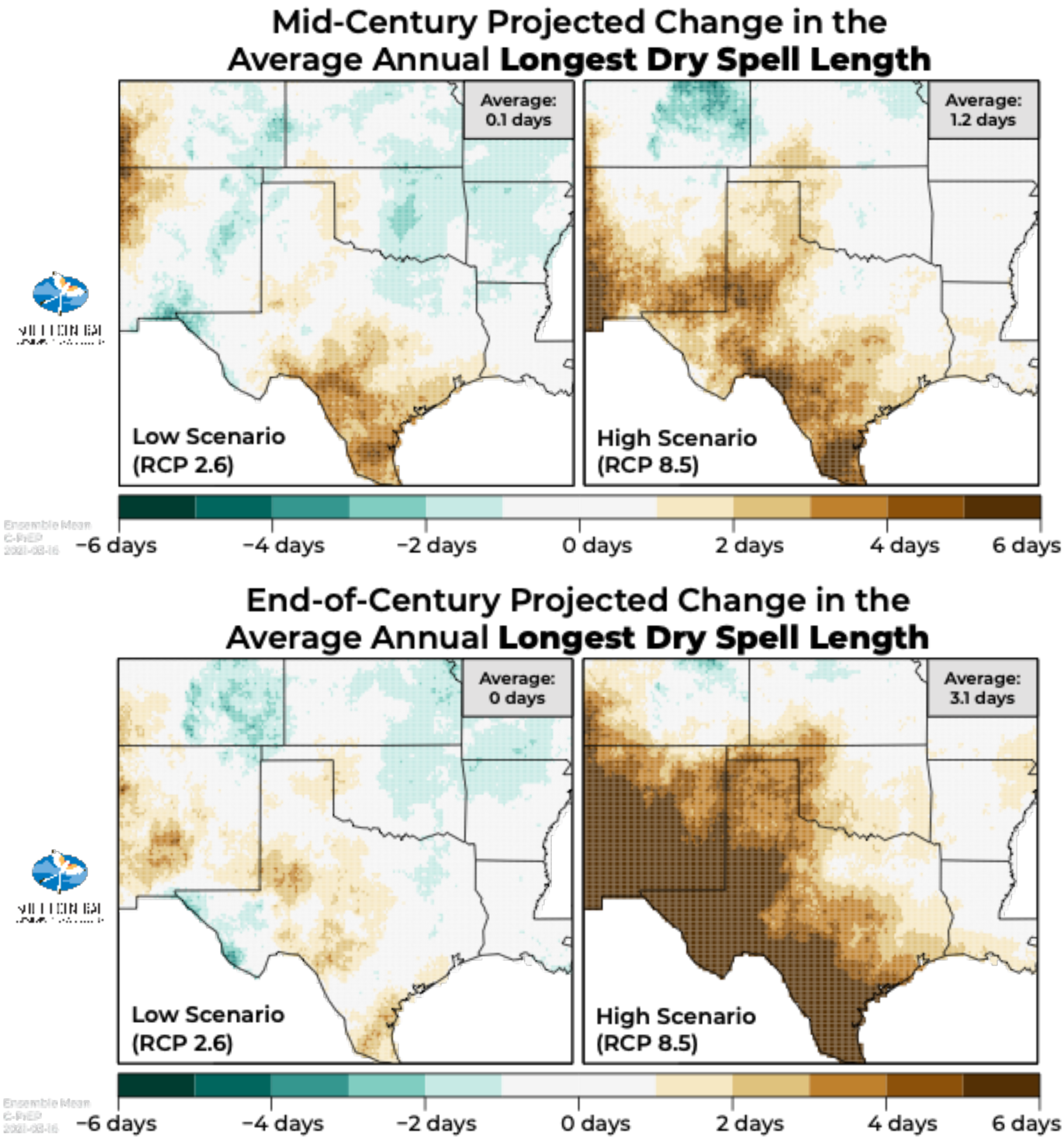


Figure 33: *The length of the longest dry spell in Texas is expected to be six days for the mid-century low emissions scenario. This affected region is small and concentrated in the northwest corner of the state. However, in the mid-century high emissions scenario, this dry spell duration extends along the whole state's western border. As one can see, the magnitude of these annual average dry spells is significantly greater in the high emissions scenario compared to the low emissions scenario, regardless of which part of the century's projections you are examining.*

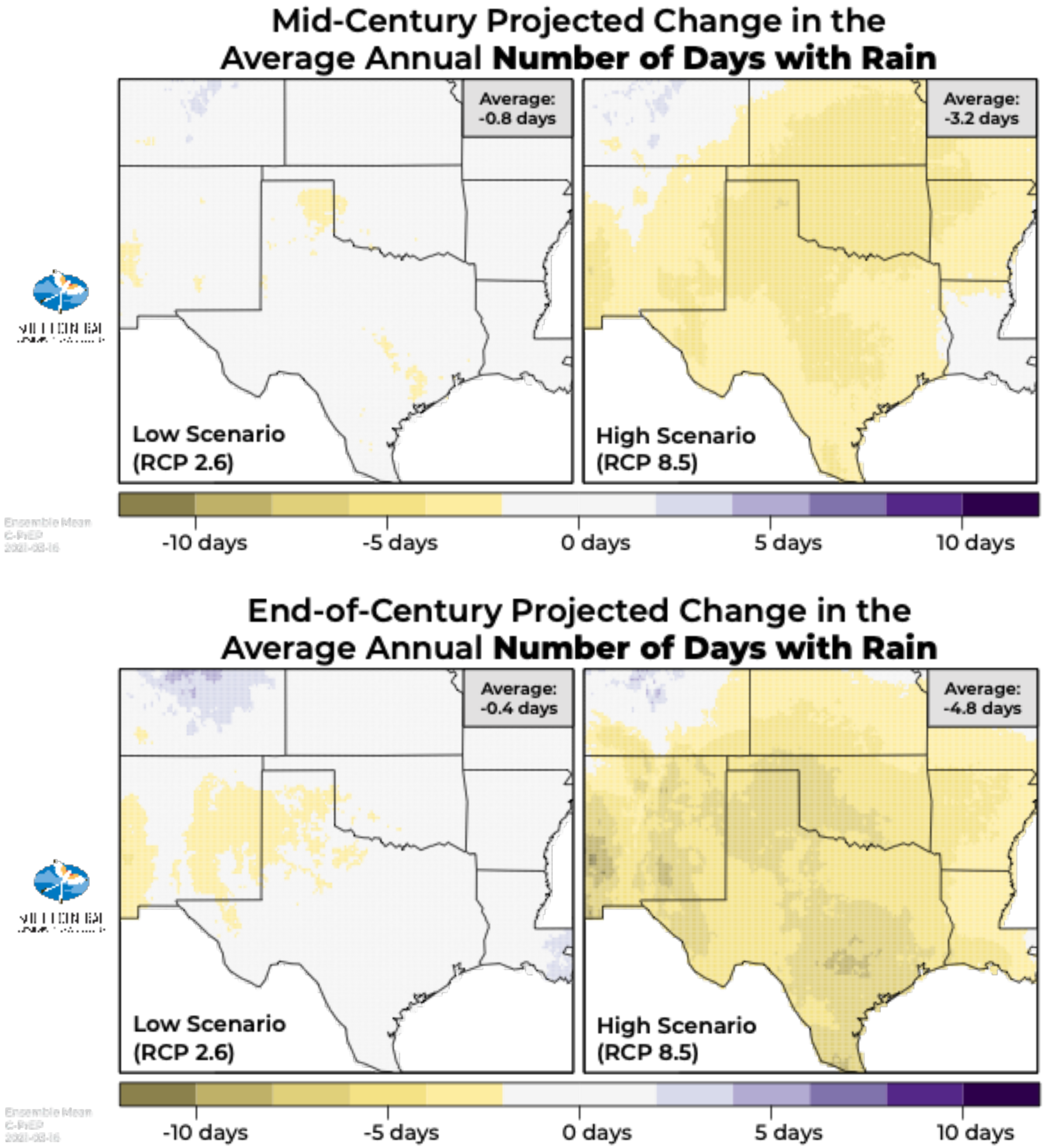


Figure 34: *These projections show how the yearly average number of days with rain will be affected over time. The mid-century low emissions scenario projection shows miniscule change overall, while its corresponding high emissions scenario projection predicts approximately 4 and 5 day decreases in number of days with rain for much of the state. These reductions in rainfall are exacerbated in the end of the century high emissions scenario, with some parts of Texas seeing as much as a ten day decrease in the number of days with rain.*

Drought Resources

There are several excellent sources of information for drought monitoring and reporting, ranging from national to local (Table 1). These resources are designed to help you plan and prepare for drought conditions in you region.

Table 1 summarizes several excellent sources of information for drought monitoring and reporting, ranging from national to local.

Table 1: Sources of Drought Information & Tools

Source	Web Address	Uses
Major Sources of Information		
National Integrated Drought Information System	drought.gov/	Consolidated source of drought information, monitoring & reporting tools, including many of the other sources listed below
National Drought Mitigation Center	drought.unl.edu/	Consolidated source of drought information, including drought planning, monitoring reporting, risks, and impacts
The Office of the Texas State Climatologist (OSC)	climatexas.tamu.edu	Consolidated source of Texas climate information
West Texas Mesonet	http://www.mesonet.ttu.edu/	Regional weather observing network specific to west Texas
Specific Drought-Related Tools		
U.S. Drought Monitor: *National Drought Mitigation Center*	droughtmonitor.unl.edu	Current and past diagnoses of drought conditions, both nearby and across the United States
Texas Drought Monitoring Website: *Office of the State Climatologist*	climatexas.tamu.edu/drought/	Current drought conditions and research on previous drought impacts within Texas
U.S. Seasonal Drought & Precipitation Outlooks: *Climate Prediction Center*	cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.php	Large-scale trends in drought across the U.S. for the next few months; Expert assessments (not forecasts) of possible changes in precipitation conditions over a range of times (6-10 days, 8-14 days, 1 month, & 3 months)

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NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). https://www.ncdc.noaa.gov/billions/