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# Water System Innovation in Oklahoma: Climate Change Adaptation Strategy?

Travis Gliedt, Jeffrey Widener, Preston Hartman - University of Oklahoma

Is climate change influencing water utilities in Oklahoma to implement innovations? New research with 38 water managers in Oklahoma suggests that it is. This study hypothesized that utilities experiencing larger annual decreases in precipitation during the study period (2010-2014) relative to the 30-year trend would create higher numbers of innovations. This was based on the notion that a major challenge to Oklahoma's water utilities is climate induced drought, meaning that the greatest need for water system innovation is likely to occur in utilities within regions characterized by larger precipitation decreases relative to the norm. Other factors considered in the innovation decision-making process included vulnerability of the water infrastructure, population size and median income levels of the water system, and the educational/knowledge backgrounds of the water manager. The results supported the hypothesis *only* when controlling for population size, as higher innovations *per capita* were associated with larger precipitation declines.

All 38 water utilities experienced a decline in average annual precipitation during the study period relative to the 30-year norm, ranging from 3 to 37 percent (Widener et al., *forthcoming*). A significant difference ( $\chi^2$  sig.  $\alpha = 0.01$ ) was found between the high innovation per capita utilities, which experienced a 25 percent average decline, and the low innovation per capita

utilities, which experienced a 16 percent average decline. Nearly half of the high innovation per capita utilities were located in the already drought stricken Southwest and Northwest regions of Oklahoma (Figure 1). This suggests that many water managers in Oklahoma are responding to measured climate changes. But what was their real motivation?

Water managers believed that their systems were the most vulnerable to decreased annual precipitation levels, followed by excess regulations, and the current poor quality of the municipal water infrastructure. When asked about infrastructure quality, for example, one manager said that "the water source lines should have been replaced 20 years ago... it should have been dug up and replaced." Another manager described the inflexible state of the infrastructure: "when we have a leak, we cannot even isolate it because the valves are not working or locatable." These infrastructure

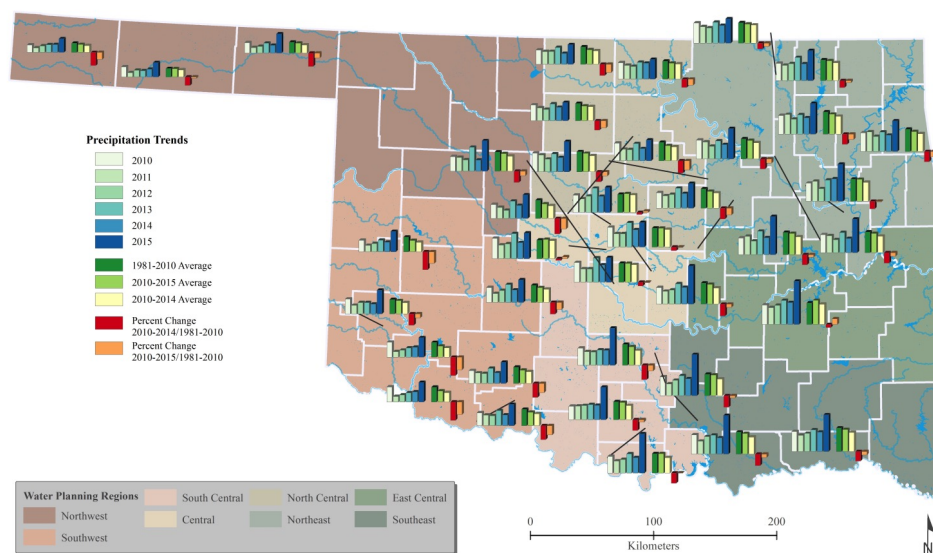


Figure 1. Map of Oklahoma Precipitation Trends by Study Locations Compared to Innovativeness

problems make adapting to precipitation changes even more challenging. On the other hand, water managers were motivated to implement innovations by the need to ensure an adequate water supply for the community and for their children's generation, the availability of funding, and compliance with regulations if regulations existed (Widener et al., *forthcoming*). As one manager stated, "unfortunately it usually requires threats from the Department of Environmental Quality to get anything done. We would rather spend money on an upgrade than on fines." The lowest rated motivations for innovation included concerns about future changes to the climate, citizen pressures, and promoting environmental sustainability. It is striking that managers of water utilities that experienced the impacts of climate change as measured by precipitation deviations from the norm, and created and implemented the most innovations per capita, did not personally

believe that climate change and environmental sustainability were important motivating factors in the innovation process.

An innovativeness index was created as a comprehensive measure of *change* (as measured by the # of innovations) and the *capacity for change* (as measured by the # of dynamic capabilities). Dynamic capabilities were identified as important factors for creating innovations by each water utility (Hartman et al., *forthcoming*). If the innovativeness value is greater than 1, the water utility is considered to be more innovative than the state average. Water utilities characterized by having larger populations, higher median income, a higher manager certification level, and a higher level of awareness of the Oklahoma Water for 2060 Act (2016) had higher innovativeness values (Table 1). For example, 73 percent of the high innovativeness utilities have a water

Table 1: Dynamic Capabilities, Innovations and Innovativeness Index

		Average Number of Dynamic Capabilities and Innovations per Water Utility		
		Dynamic Capabilities	Innovations	Innovativeness Index
		Total	Total	
Oklahoma n = 38	% of n	34	13	1.00
Population				
Large	10%	78	28	1.50
Medium	45%	30	12	0.94
Small	45%	27	11	0.90
Average Household Income				
High	24%	46	17	1.16
Medium	45%	30	12	0.95
Low	31%	29	12	0.93
Water Manager Certification Level				
A, PE, A+PE	34%	47	18	1.18
B	24%	26	10	0.88
C	34%	27	11	0.90
D	8%	29	11	0.93
Knowledge of Water for 2060				
High	47%	40	16	1.09
Low	53%	27	11	0.90

manager with the highest level of certification (A-level and/or professional engineering degree), as compared to 18 percent of the low innovativeness utilities. Larger water systems had more capabilities and thus innovations, and were more likely to have a better educated and trained water manager.

Highly innovative utilities were able to use dynamic capabilities more efficiently, benefiting from synergies that resulted from the interaction between different types of capabilities. The high innovation per capita utilities 'over-innovated' relative to their levels of resources and capabilities because they experienced significant precipitation changes and because their water managers perceived that these changes would threaten the resilience of their water systems. The innovativeness index can be examined in future studies for its ability to predict adaptive capacity as well as measure progress towards infrastructure change. A multi-year survey of water managers in the Southern Climate Impacts Planning Program region will address this by measuring progress towards sustainability while controlling for state-level differences in institutions and infrastructure.

## References:

Hartman P, Gliedt T, Widener J, Loraamm R W, *forthcoming*, "Dynamic capabilities for water system transitions in Oklahoma" *Environmental Innovation and Societal Transitions*.

Water for 2060. (2016). Oklahoma Water for 2060 Act. Oklahoma Water Resources Board. House Bill 3055. Available at: <http://www.owrb.ok.gov/2060/index.php>.

Widener J, Gliedt T, Hartman P, *forthcoming*, "Visualizing dynamic capabilities as adaptive capacity for municipal water governance" *Sustainability Science*.



# Drought Update

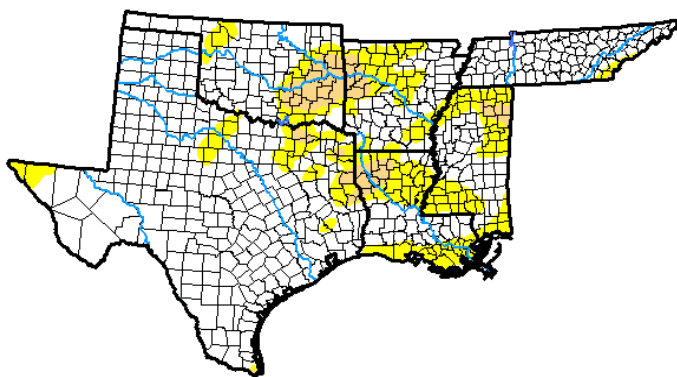
Kyle Brehe and Rudy Bartels  
Southern Regional Climate Center

Over the month of April 2017, drought conditions improved for most parts of the region, such as areas in Oklahoma and Texas. There were no areas that entered drought from March to April. The area of extreme drought in Oklahoma during March has improved to normal conditions in April. Areas of Oklahoma, northeastern Louisiana, western Arkansas, and northwestern Mississippi are still experiencing moderate drought conditions. At this time, there are no areas experiencing extreme or exceptional drought.

On April 2, 2017, 31 tornadoes touched down in the southern part of the region including Eastern

Texas, Louisiana, and Southern Mississippi. One tornado caused two deaths in St. Martin, Louisiana when a mobile home was blown off its foundation and destroyed. The tornadoes also caused four injuries in Louisiana. There were over 100 strong wind reports in the region as well, snapping numerous trees and power lines. Hail in Texas caused multiple vehicles to be dented and killed chickens.

On April 30, 2017, there were 15 tornadoes reported in Mississippi and Louisiana. There were over 70 wind reports in Louisiana, Mississippi, and Tennessee. There was one death in Fayetteville, Tennessee when wind causes a tree to fall on a person.



Released Thursday, April 27, 2017  
Eric Luebehusen, U.S Department of Agriculture

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
<b>Current</b>	76.16	23.84	5.13	0.00	0.00	0.00
<b>Last Week</b> 04-18-2017	67.36	32.64	9.61	1.80	0.00	0.00
<b>3 Months Ago</b> 01-24-2017	68.83	31.17	17.65	6.40	0.73	0.00
<b>Start of Calendar Year</b> 01-03-2017	53.95	46.05	27.69	11.09	1.11	0.00
<b>Start of Water Year</b> 09-27-2016	76.89	23.11	6.74	1.89	0.28	0.11
<b>One Year Ago</b> 04-26-2016	79.83	20.17	2.52	0.35	0.00	0.00



## Intensity:

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

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

Above: Drought conditions in the Southern Region. Map is valid for April 25, 2017. Image is courtesy of National Drought Mitigation Center.

## Southern Climate Monitor

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# Temperature Summary

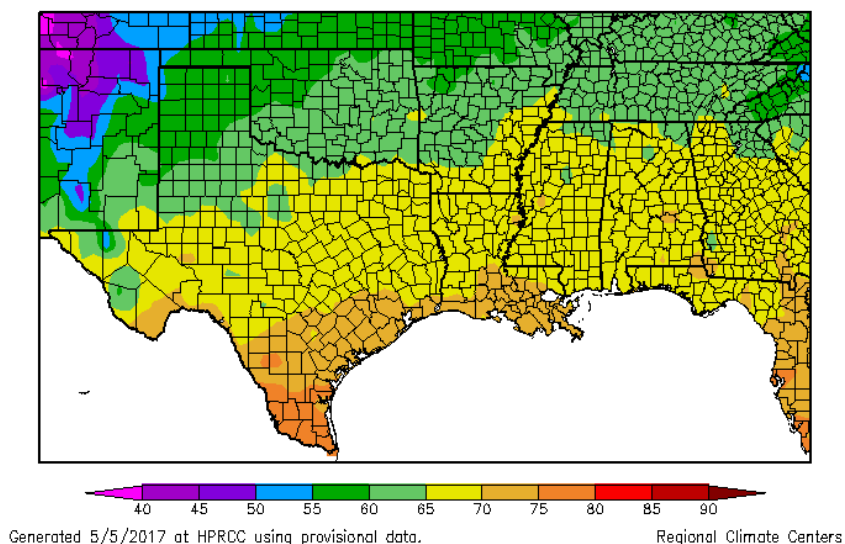
Kyle Brehe and Rudy Bartels  
Southern Regional Climate Center

April was a warmer than normal month for all states in the southern region. Temperatures generally averaged between 2 to 6 degrees F (1.11 to 3.33 degrees C) above normal in all of the southern region states. The eastern portion of the region, Mississippi and Tennessee, exhibited temperature anomaly clusters of 6 to 10 degrees F (3.33 to 5.55 degrees C) above normal. In contrast, the temperatures were close to normal for central Texas and western Oklahoma. There were a few parts of Texas that reported slightly below normal temperatures.

The statewide monthly average temperatures were as follows: Arkansas reporting 64.00 degrees F (17.78 degrees C), Louisiana reporting 69.40 degrees F (20.78 degrees C), Mississippi reporting 67.40 degrees F (19.67 degrees C), Oklahoma reporting 61.20 degrees F (16.22 degrees C), Tennessee reporting 63.20 degrees F (17.33 degrees C), and Texas reporting 67.10 degrees F (19.50 degrees C).

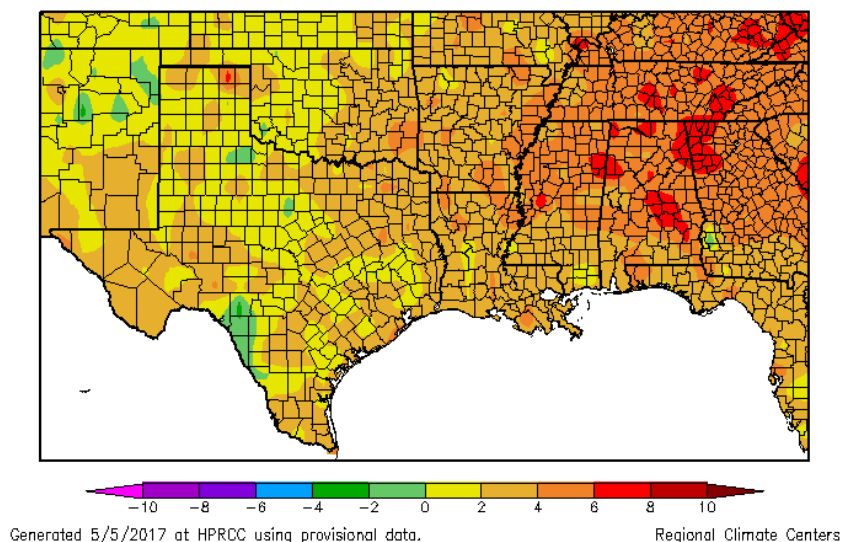
The state-wide temperature rankings for April are as follows: Arkansas (fourteenth warmest), Louisiana (eighteenth warmest), Mississippi (eleventh warmest), Oklahoma (thirty-sixth warmest), Tennessee (second warmest), and Texas (twenty-fourth warmest). All state rankings are based on the period spanning 1895-2017.

Temperature (F)  
4/1/2017 - 4/30/2017



Average April 2017 Temperature across the South

Departure from Normal Temperature (F)  
4/1/2017 - 4/30/2017



Average Temperature Departures from 1981-2010 for April 2017 across the South

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# Precipitation Summary

Kyle Brehe and Rudy Bartels  
Southern Regional Climate Center

Precipitation values for the month of April varied spatially across the Southern Region. Precipitation totals in parts of Texas, northern Oklahoma, central Louisiana, and northern Arkansas were 300 percent of normal. Each of the six states in the region had areas 150 to 300 percent of normal precipitation. In contrast, conditions were quite dry across southern Louisiana, northern Mississippi, and parts of Texas with stations reporting between 5 to 70 percent of normal. All states had clusters of normal, below normal and above normal levels of precipitation values. Most of Oklahoma and Arkansas reported above normal precipitation values. Whereas three states, Texas, Louisiana, and Mississippi, had great contrasts of precipitation reports throughout their states.

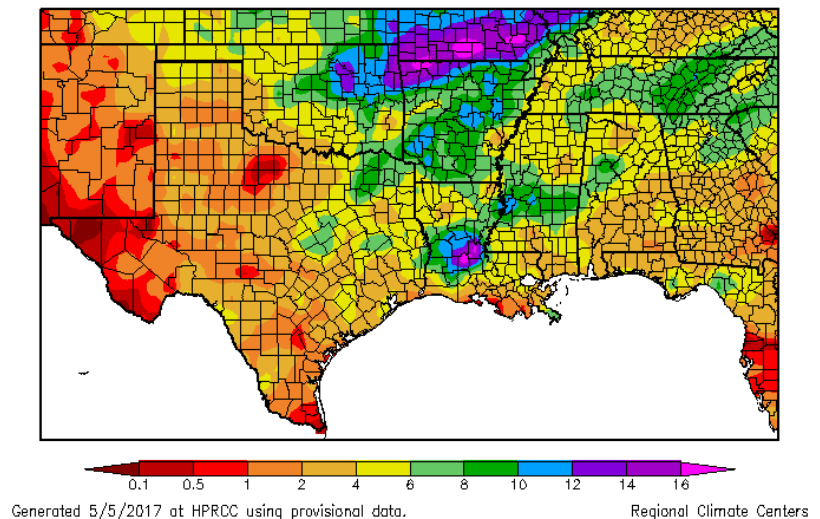
The state-wide precipitation totals for the month are as follows: Arkansas reporting 8.46 inches (214.88 mm), Louisiana reporting 5.40 inches (137.16 mm), Mississippi reporting 5.91 inches (150.11 mm), Oklahoma reporting 6.48 inches (164.59 mm), Tennessee reporting 6.37 inches (161.80 mm), and Texas reporting 2.62 inches (66.55 mm).

The state precipitation rankings for the month are as follows: Arkansas (ninth wettest), Louisiana (forty-fifth wettest), Mississippi (forty-third wettest), Oklahoma (fourth wettest), Tennessee (seventeenth wettest), and Texas (fortieth wettest). All state rankings are based on the period spanning 1895-2017.

## Southern Climate Monitor

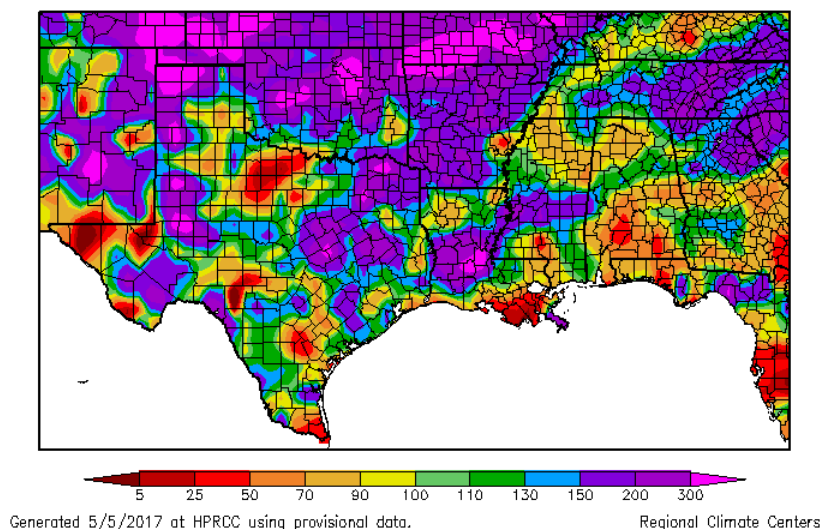
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Precipitation (in)  
4/1/2017 - 4/30/2017



### April 2017 Total Precipitation across the South

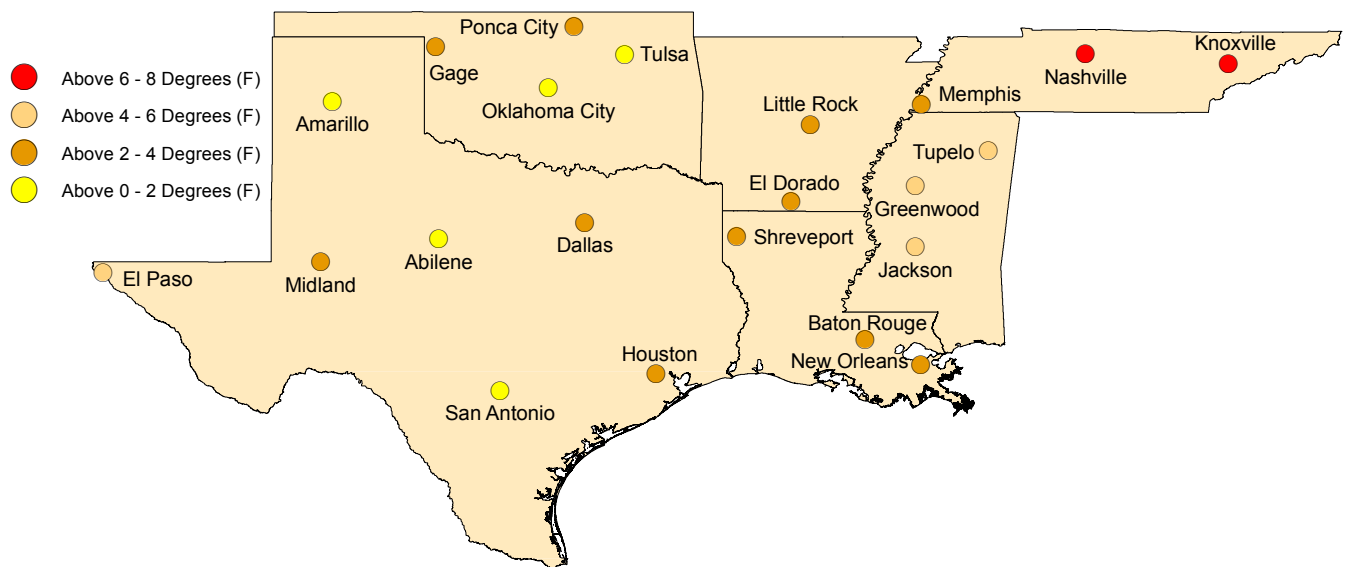
Percent of Normal Precipitation (%)  
4/1/2017 - 4/30/2017



### Percent of 1981-2010 normal precipitation totals for April 2017 across the South

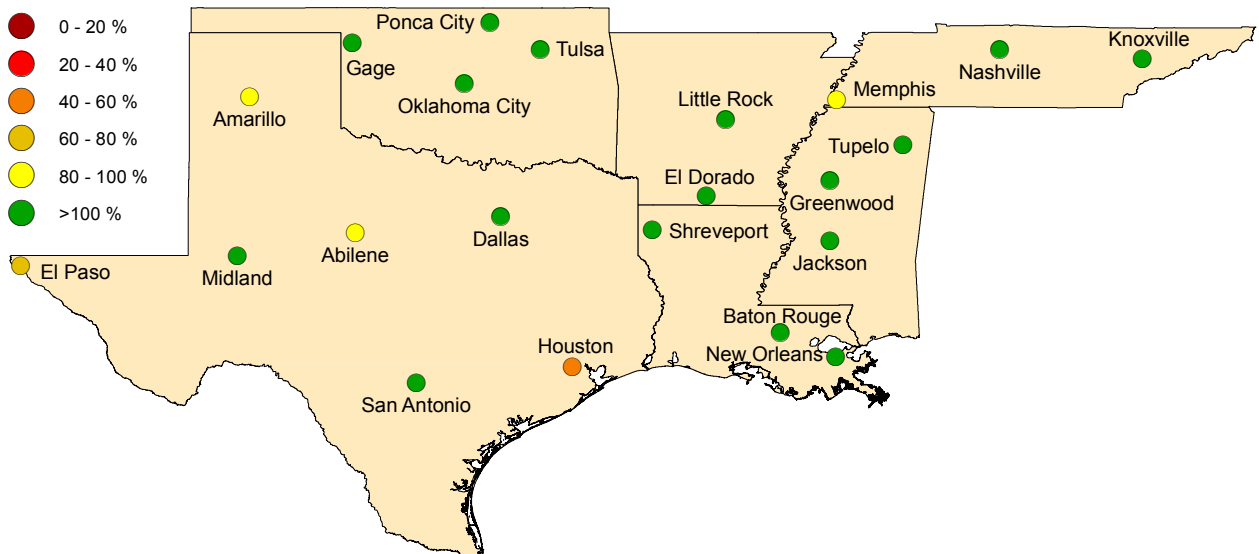
# Regional Climate Perspective in Pictures

## April Temperature Departure from Normal



April 2017 Temperature Departure from Normal from 1981-2010 for SCIPP Regional Cities

## April Percent of Normal Precipitation



April 2017 Percent of 1981-2010 Normal Precipitation Totals for SCIPP Regional Cities



# Climate Perspective

State	Temperature	Rank (1895-2017)	Precipitation	Rank (1895-2017)
Arkansas	64.00	14th Warmest	8.46	9th Wettest
Louisiana	69.40	18th Warmest	5.40	45th Wettest
Mississippi	67.40	11th Warmest	5.91	43rd Wettest
Oklahoma	61.20	36th Warmest	6.48	4th Wettest
Tennessee	63.20	2nd Warmest	6.37	17th Wettest
Texas	67.10	24th Warmest	2.62	40th Wettest

State temperature and precipitation values and rankings for April 2017. Ranks are based on the National Climatic Data Center's Statewide, Regional, and National Dataset over the period 1895-2017.

## Station Summaries Across the South

Station Summaries Across the South											
Station Name	Temperatures								Precipitation (inches)		
	Averages				Extremes				Totals		
	Max	Min	Mean	Depart	High	Date	Low	Date	Obs	Depart	%Norm
El Dorado, AR	78.0	54.6	66.6	3.2	87	04/28	38	04/07	9.00	4.91	220
Little Rock, AR	75.7	53.8	64.8	2.7	85	04/29	42	04/07	10.13	4.99	197
Baton Rouge, LA	82.7	59.4	71.0	3.0	90	04/29	47	04/08	7.40	2.94	166
New Orleans, LA	80.5	62.1	71.3	2.2	86	04/05	50	04/07	5.45	0.84	118
Shreveport, LA	80.7	57.1	68.9	3.7	89	04/28	42	04/06	4.26	0.07	102
Greenwood, MS	79.4	56.3	67.8	4.5	90	04/29	39	04/08	5.96	0.83	116
Jackson, MS	80.7	56.0	68.3	4.2	89	04/29+	40	04/08	10.46	5.50	211
Tupelo, MS	78.3	55.3	66.8	4.7	87	04/28	37	04/08	5.49	0.71	115
Gage, OK	71.8	46.8	59.3	2.5	93	04/08	32	04/06	4.54	2.80	261
Oklahoma City, OK	72.1	50.5	61.3	0.3	85	04/25	37	04/06	6.19	3.12	202
Ponca City, OK	71.1	50.1	60.6	2.2	83	04/25+	36	04/27+	6.23	2.79	181
Tulsa, OK	73.2	52.1	62.6	2.0	84	04/08	39	04/27+	10.44	6.65	275
Knoxville, TN	76.0	54.2	65.1	6.3	89	04/29	36	04/08	7.61	3.60	190
Memphis, TN	76.9	56.4	66.6	3.7	88	04/29	44	04/08+	5.36	-0.14	97
Nashville, TN	77.3	54.4	65.9	6.9	91	04/29	37	04/08	7.40	3.40	185
Abilene, TX	77.6	53.2	65.4	0.8	95	04/25	39	04/06	1.34	-0.30	82
Amarillo, TX	71.9	44.1	58.0	1.7	90	04/19	32	04/29+	1.34	-0.06	96
El Paso, TX	82.8	55.1	69.0	4.4	91	04/24+	39	04/30	0.14	-0.09	61
Dallas, TX	79.8	58.7	69.3	3.8	91	04/29	46	04/27	3.38	0.35	112
Houston, TX	82.3	61.2	71.8	2.2	91	04/26	50	04/06	1.68	-1.63	51
Midland, TX	81.4	54.1	67.8	3.6	95	04/24	39	04/30	2.48	1.83	382
San Antonio, TX	82.0	60.2	71.1	1.8	92	04/29+	45	04/06	2.89	0.79	138

Summary of temperature and precipitation information from around the region for April 2017. Data provided by the Applied Climate Information System. On this chart, "depart" is the average's departure from the normal average, and "% norm" is the percentage of rainfall received compared with normal amounts of rainfall. Plus signs in the dates column denote that the extremes were reached on multiple days. Blueshaded boxes represent cooler than normal temperatures; redshaded boxes denote warmer than normal temperatures; tan shades represent drier than normal conditions; and green shades denote wetter than normal conditions.

# Warmer than Normal May is Forecast

Barry D. Keim - Louisiana State Climatologist, Louisiana State University

May is a curious time in South Louisiana. The month opens up with the Jazz and Heritage Festival in full swing - there are festivals going on everywhere - and we also transition quickly into a summer-like pattern regarding temperatures. Oh, and some of the heaviest rain events in New Orleans history have occurred in May - think May 3, 1978 and May 8-10, 1995. Also, I'm also sure that many of you regulars at the New Orleans Jazz and Heritage Festival have been in ankle-deep water and mud while shuffling to and fro at the Fest. So what is expected for this May? Well, the Climate Prediction Center recently put out their forecast and they are calling for warmer than normal

temperatures for Louisiana and much of Eastern United States east of the Mississippi River, as well as the Desert Southwest. As for rainfall, much of coastal Louisiana along with the bulk of Texas are in a zone with heightened chances for above normal rainfall. This is consistent with the recent patterns in Louisiana where January, February, March were all significantly above normal with temperature in Louisiana, with more mixed results for precipitation. Given the propensity for catastrophic rainfall in May, let's hope we slip through this one unscathed, but with normal rains spread across the month! Please contact me with any questions at [keim@lsu.edu](mailto:keim@lsu.edu).

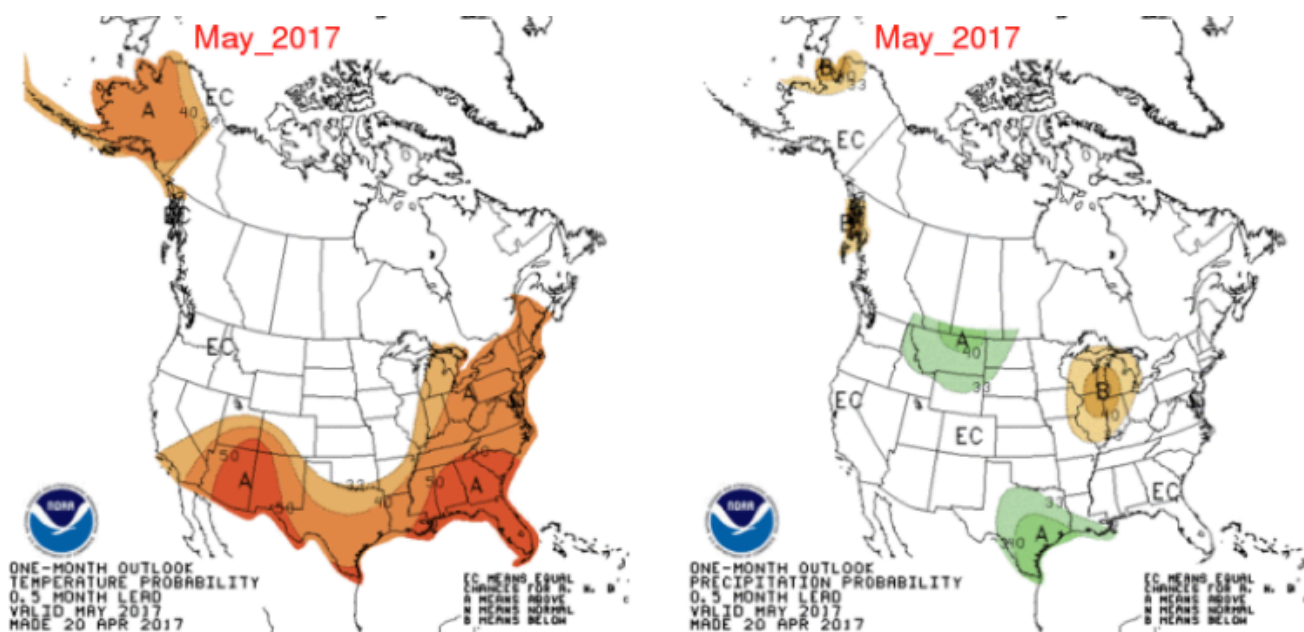


Figure 1. Climate forecast for May 2017 from the Climate Prediction Center. Image can be found at [http://www.cpc.ncep.noaa.gov/products/predictions/multi\\_season/13\\_seasonal\\_outlooks/color/page2.gif](http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/page2.gif).

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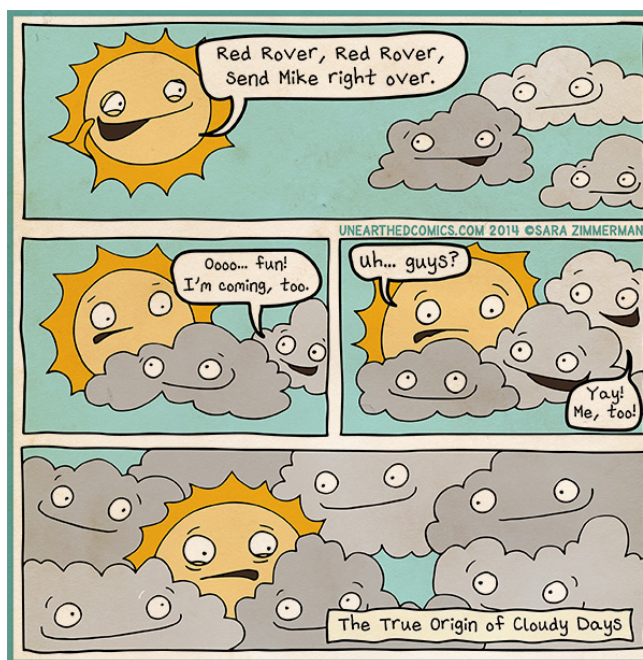
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For any questions pertaining to historical climate data across the states of Oklahoma, Texas, Arkansas, Louisiana, Mississippi, or Tennessee, please contact the Southern Regional Climate Center at 225-578-5021.

For questions or inquiries regarding research, experimental tool development, and engagement activities at the Southern Climate Impacts Planning Program, please contact us at 405-325-7809 or 225-578-8374.

## Monthly Comic Relief



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