



SOUTHERN CLIMATE *MONITOR*

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LSU



SCIPP
Southern Climate Impacts Planning Program



THE URBAN INFLUENCE ON PRECIPITATION IN THE SOUTHEASTERN UNITED STATES

Anna Trevino, Southern Climate Impacts Planning Program

Background

As cities around the world grow at a rapid rate, the need to understand their influence on the local and regional climate becomes more necessary. It is known that urban areas have an influence on their local climate (Arnfield 2003, Shepherd 2005), as changes in land use and land cover (LULC) continuously alter energy and moisture fields as well as circulation patterns above urban environments. Among the factors affecting urban climates are the expansion of urban heat islands (UHIs) and increases in surface roughness. In addition, pollution has been shown to increase the number of cloud condensation nuclei over urban regions, with a complex series of feedbacks to cloud formation and precipitation.

When changes in LULC occur in a growing urban area, changes in the frequency, intensity, and amount of precipitation received can occur (Shepherd 2005). This anthropogenic alteration is strongest in warm-season precipitation, when rain events are mainly convective, but effects are seen year-round (Changnon et al. 1991, Gero et al. 2006). The southeastern U.S. has been the focus of a number of urban precipitation studies (Huff & Changnon 1973, Bornstein & Lin 2000, Shepherd et al. 2002, Burian & Shepherd 2005, Diem & Mote 2005, Diem 2006, Mote et al. 2007, Hand & Shepherd 2009), where enhanced rainfall has been seen in Atlanta (Shepherd et al. 2002, Diem & Mote 2005, Mote et al. 2007), Austin (Shepherd et al. 2002), Dallas (Shepherd et al. 2002), Houston (Huff & Changnon 1973), Montgomery (Shepherd et al. 2002), Nashville (Shepherd et al. 2002), New Orleans (Huff & Changnon 1973), Oklahoma City (Hand & Shepherd 2009), San Antonio (Shepherd et al. 2002), and Waco (Shepherd et al. 2002).

Beyond the mechanisms of precipitation enhancement (UHI, increased aerosols and surface roughness), urban areas have a further,

and still poorly understood, effect on precipitation by altering the movement, growth, and demise of individual storm cells. Bornstein and Lin (2000) defined storm bifurcation as “a group of storms [that] move in two directions from a specific location (such as upwind of city)”. This phenomenon differs from storm splitting in that splitting is “a single initial storm [that] splits into two separated supercells, given appropriate vertical wind shear conditions” (Bornstein & Lin 2000, p. 515). While it is possible for storm splitting and bifurcation to occur in multiple types of rainfall events (frontal, convective, tropical), very few studies on the specific phenomenon of storm bifurcation have been undertaken. Even though individual synoptic situations in an urban area are complex, it can be concluded that when regional winds are strong, surface roughness of an urban area dominates the local synoptic regime (as opposed to a UHI-dominated regime in weaker synoptic settings).

The Research Question

The primary research question guiding this study is: How does the presence of urban areas across the southeastern United States influence precipitation? The study area includes the following states: Texas, Oklahoma, Louisiana, Arkansas, Mississippi, Alabama, Tennessee, Florida, Georgia, South Carolina, and North Carolina. From a socioeconomic perspective, the region is home to approximately thirty percent of the total U.S. population (U.S.A. Census Bureau: Population Division 2008) and a number of large urban centers. While many of these cities have already been shown to exhibit evidence of precipitation enhancement, synoptic variations in precipitation delivery mechanisms (e.g., frontal, tropical, convective) differ from city to city, thereby likely contributing to spatial variations in urban-precipitation interactions. Given the frequency with which extreme weather and climate impacts affect this region, an improved understanding of

precipitation variability in urban regions and its application to emergency management and hazards analysis is vital.

Precipitation enhancement study

Because storm bifurcation often occurs in concert with urban precipitation enhancement, an analysis designed to detect enhancement in different urban centers across the region is an appropriate initial investigation. Once the selection of urban test sites has been made, three tests will be employed to detect the existence of precipitation enhancement: (1) downwind vs. upwind, (2) temporal analysis, and (3) the contour test. The downwind vs. upwind test requires mean wind direction for heavy precipitation days to spatially determine locations of upwind and downwind regions. If the downwind region receives more rainfall, it is possible that the precipitation has been enhanced by the previously discussed mechanisms of urbanization. The temporal analysis tests for trends in the inter-arrival times between events using the Poisson Process (Keim & Cruise 1998). If heavy precipitation events are occurring more frequently, then urban influences may be the cause. The contour test uses interpolated precipitation at non-urban stations to estimate precipitation within the urban core. Precipitation received at locations where observed precipitation exceeds the spatially interpolated value are likely candidates for urban enhancement. If these candidates are spatially biased toward the downwind side of the city center, a precipitation maximum may be a result of urban enhancement.

Bifurcation study

Because the analysis portion of this objective is expected to be very thorough and in-depth, the number of cities is restricted to two plus a non-urban location serving as a control site. Radar-derived precipitation estimates will be utilized, in addition 900 hPa flow to represent wind speed and direction across the urban core, to study the

spatial characteristics of each event for evidence of an urban signal in the form of bifurcation. It is expected that for bifurcation events, there will be a greater amount of rainfall received in the upwind, periphery, and downwind areas than within the city center. It is also possible that there will be an area of greater rainfall in the downwind region in the event that the storm has rejoined.

Synoptic link study

A circulation-to-environment manual classification (Yarnal 1993) of 500 mb daily composite geopotential height patterns will be conducted for each heavy precipitation event, and the corresponding synoptic-scale pattern will be classified as frontal, tropical (e.g. hurricane, tropical storm, or tropical disturbance), air mass, or transition to link bifurcation to the larger-scale synoptic processes that may either enhance or inhibit its occurrence. This approach will permit a comparative analysis of precipitation anomalies during different synoptic conditions as well as during bifurcation and non-bifurcation rain events.

Implications

By employing multiple detection methods at multiple locations within the southeastern U.S., this research will provide a new, robust, and comprehensive assessment of urban-precipitation relationships for this part of the United States. An improved understanding of bifurcation occurrence can also aid forecasters in urban regions, both on the meteorological level as well as for local and regional climate modeling. A broader understanding of precipitation variability across major urban centers in the southeastern U.S. will provide potential benefit to a range of stakeholders, such as city planners and emergency managers, whose work is informed by climate information. If urban influence on rainfall can be consistently predicted, then urban infrastructure can be zoned for green space or reservoirs to maximize rainfall capture.

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DROUGHT CONDITIONS

Luigi Romolo, Southern Regional Climate Center

Spatially variable April precipitation totals in the southern region have led to dramatic changes in drought conditions over the past month. Extremely wet conditions in Tennessee have kept the state drought free. Similar wetness in Arkansas has led to a considerable improvement in drought conditions. As of May 3, 2011, only a small strip along the southern tip of Arkansas is classified as drought. The majority of the state, which last

month was showing moderate to extreme drought, is now drought free. Drought conditions in Mississippi have not changed much over the past month. Anomalously high precipitation totals in the northern areas of the state has resulted in a one category improvement, while drier than normal conditions in the south led to a one category deterioration. Contrary to what has occurred in Tennessee and Arkansas, the remainder of the

region has shown dramatic deterioration in drought conditions. Much of west central Texas is now in exceptional drought, as is east central Texas. This is also the case for part of the Oklahoma panhandle and west central Louisiana. Extreme drought has also expanded in central Oklahoma, northern Texas, southern Louisiana and southern Mississippi. These dramatic changes in drought conditions are primarily the result of low precipitation totals, coupled with higher than normal temperatures and the subsequent high water demands with which warmer-than-normal conditions are associated. As of May 3, 2011, 14.68 percent of the Southern Region is experiencing exceptional drought, while 46.58 percent of the region is experiencing extreme drought conditions or worse. In addition, 64.13 percent of the region is experiencing severe

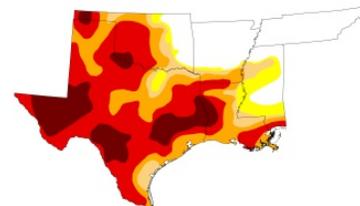
drought conditions or worse, and 71.52 percent of the region is in moderate drought or worse.

U.S. Drought Monitor

May 3, 2011
Valid 7 a.m. EST

South

	Drought Conditions (Percent Area)					
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	22.71	77.29	71.52	64.13	46.58	14.68
Last Week (04/26/2011 map)	17.47	82.53	74.25	64.80	44.26	9.51
3 Months Ago (02/01/2011 map)	14.66	85.34	58.97	31.56	6.59	0.00
Start of Calendar Year (12/29/2010 map)	8.86	91.14	67.65	35.21	10.17	0.00
Start of Water Year (09/28/2010 map)	54.23	45.77	20.04	6.79	0.83	0.00
One Year Ago (04/27/2010 map)	83.06	16.94	1.26	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, May 5, 2011
Rich Tinker, NOAA/NWS/NCEP/CPC

Drought conditions in the Southern Region. Map is valid for April 2011. Image courtesy of the National Drought Mitigation Center.

EXTREME WEATHER

Luigi Romolo, Southern Regional Climate Center; Charlotte Lunday, Southern Climate Impacts Planning Program

April saw plenty of noteworthy extreme weather. Not only was there widespread drought across the SCIPP region, but there have also been many other devastating events. The number of tornadoes reported this April greatly exceeded the 1974 April record of the most tornadoes (267) occurring in the month, and it is expected to overtake the all-time record number of tornadoes recorded in a single month once review of the 875 (353 of those were from SCIPP states) national storm reports has finished. The previous record was set in May 2003 with 542 confirmed tornadoes.

Heavy rainfall in the eastern part of the SCIPP region produced catastrophic flooding along the Mississippi River. Many places along the river bordering SCIPP states are approaching or have surpassed previous flood records. The Arkansas Democrat Gazette also reported that the Black River in Arkansas also flooded. Impacts of severe weather prompted Gov. Mike Beebe to declare 63 of Arkansas' 75 counties as disaster areas.

Finally, wildfires plagued the state of Texas throughout the month. Several fires have burned hundreds of thousands of acres. The most significant fire has been the Rockhouse fire. This fire began on April 9, located just outside the town of Marfa, Texas. This fire has destroyed over forty homes and has burned over 313,000 acres (1266.67 square kilometers) of land. Odessa American Online has reported that this is the largest wildfire in Texas history. Other fires include: one near Aspermont, Texas, which has burned over 122,000 (493.72 square kilometers) acres of land; one fire in Tom Green County which has burned over 160,000 acres (647.50 square kilometers) of land; one just outside of San Angelo which has burned over 12,000 acres (48.56 square kilometers) of land; one fire in Kent, Fisher, Scurry and Stonewall Counties which has burned over 160,000 acres (647.50 square kilometers) of land; and another fire in Val Verde County which has burned over 150,000 acres (607.03 square kilometers) of land.

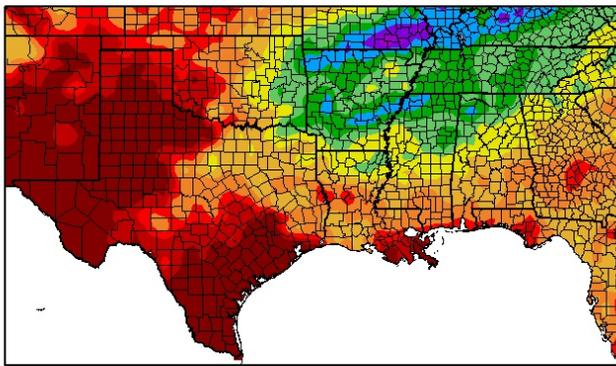
PRECIPITATION SUMMARY

Luigi Romolo, Southern Regional Climate Center

April precipitation totals varied considerably across the Southern Region. Arkansas and Tennessee experienced extreme wetness, while extreme dryness dominated southern and western Texas. In Arkansas and Tennessee, April precipitation totals for the majority of stations varied between 150 and 400 percent of normal. This was also the case for the northern quarter of Mississippi and the eastern tip of Oklahoma. Most of the stations in Tennessee reported over 7 inches (177.80 mm) of precipitation for the month, with many reporting over 10 inches (254.00 mm). In Arkansas, conditions were equally as wet, with most stations reporting over 8 inches (203.2 mm) of precipitation. In fact, in Arkansas, over a dozen stations reported over 14 inches (355.60 mm) of precipitation for the month. The state of Tennessee averaged a total of 9.22 inches (234.19 mm), making it the third wettest April on

record (1985-2011). For Arkansas, it was the fourth wettest April on record (1895-2011) with a state average precipitation value of 10.46 inches (265.68 mm). Mississippi and Oklahoma averaged near normal precipitation totals with values of 6.13 inches (155.70 mm) and 3.30 inches (83.82 mm), respectively. In Louisiana, conditions were relatively dry throughout the month. The state averaged only 2.61 inches (66.29 mm) of precipitation, making it the twenty-first driest April on record (1895-2011). In Texas, it was even drier. The state averaged only 0.75 inches (19.05 mm), which is the fifth driest April on record (1895-2011). For the state, the majority of stations in the High Plains, Trans Pecos, Rolling Plains, South Central, Southern and Lower Valley Climate divisions reported a precipitation total of 0 inches (0 mm).

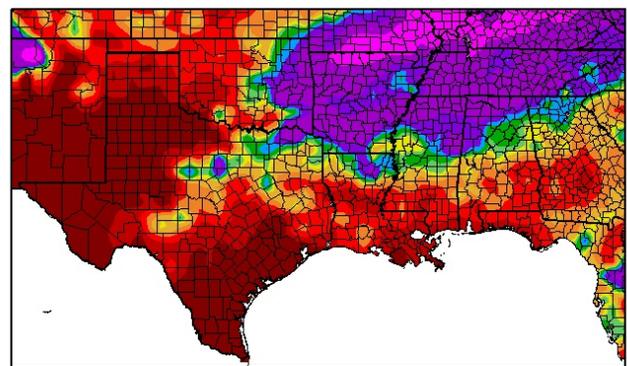
Precipitation (in)
4/1/2011 - 4/30/2011



Generated 5/2/2011 at HPRCC using provisional data.

Regional Climate Centers

Percent of Normal Precipitation (%)
4/1/2011 - 4/30/2011



Generated 5/2/2011 at HPRCC using provisional data.

Regional Climate Centers

Total precipitation values (left) and the percent of 1971-2000 normal precipitation totals (right) for April 2011.

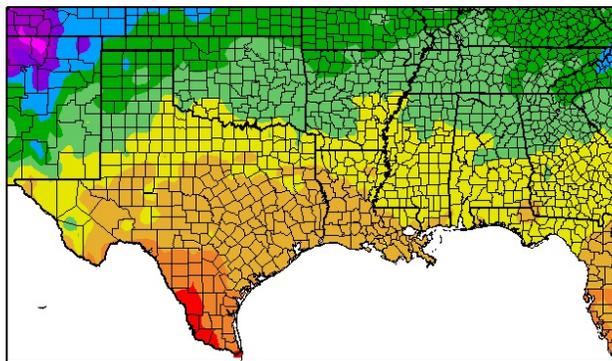
TEMPERATURE SUMMARY

Luigi Romolo, Southern Regional Climate Center

In accordance with last month, April was a consistently warmer than normal month throughout the Southern Region. In Arkansas, Tennessee, Mississippi and Oklahoma, average daily temperatures for the month ranged between 2-6 degrees F (1.11- 3.33 degrees C) above expected values. In Louisiana and most of Texas, temperatures averaged between 4-6 degrees F (2.22-3.33 degrees C) above normal. The warmest part of the region for the month was in central Texas, where daily temperatures averaged 6-8 degrees F (3.33-4.44 degrees C) above normal. With an average temperature of 70.10 (21.17 degrees C), Texas experienced its fifth warmest April on record (1895-2011). Louisiana experienced its seventh warmest April

on record (1895-2011) with a state average temperature of 70.40 degrees F (21.33 degrees C). Elsewhere in the region, Tennessee averaged 61.10 degrees F (16.17 degrees C), Mississippi averaged 66.70 degrees F (19.28 degrees C), Oklahoma averaged 61.70 degrees F (16.5 degrees C) and Arkansas averaged 63.30 degrees F (17.39 degrees C). For Tennessee, it was the thirteenth warmest April on record (1895-2011), while for Mississippi, it was the eighteenth warmest on record (1895-2011). Arkansas experienced its twentieth warmest April on record (1895-2011) and Oklahoma experienced its twenty-fourth warmest April (1895-2011).

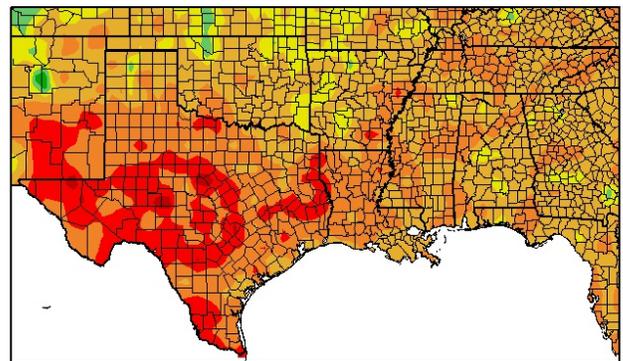
Temperature (F)
4/1/2011 - 4/30/2011



Generated 5/2/2011 at HPRCC using provisional data.

Regional Climate Centers

Departure from Normal Temperature (F)
4/1/2011 - 4/30/2011



Generated 5/2/2011 at HPRCC using provisional data.

Regional Climate Centers

Average temperatures (left) and departures from 1971-2000 normal average temperatures (right) for April 2011, across the South.

CLIMATE PERSPECTIVE

State	Temperature	Rank	Precipitation	Rank
Arkansas	63.3	20 th Warmest	10.46	4 th Wettest
Louisiana	70.4	7 th Warmest	2.61	21 st Driest
Mississippi	66.7	18 th Warmest	6.13	38 th Wettest
Oklahoma	61.7	24 th Warmest	3.3	51 st Wettest
Tennessee	61.1	13 th warmest	9.22	3 rd Wettest
Texas	70.1	5 th Warmest	0.75	5 th Driest

State temperature and precipitation values and rankings for April 2011. Ranks are based on the National Climatic Data Center's Statewide, Regional and National Dataset over the period 1895-2011.

STATION SUMMARIES ACROSS THE SOUTH

Station Name	Temperatures (degrees F)								Precipitation (inches)		
	Averages				Extremes				Totals		
	Max	Min	Mean	Depart	High	Date	Low	Date	Obs	Depart	%Norm
El Dorado, AR	80.1	52.8	66.5	2.8	90.0	4/19+	31.0	4/5	8.29	3.74	182
Little Rock, AR	77.8	54.2	66.0	4.6	91.0	4/19	37.0	4/5	7.23	1.76	132
Baton Rouge, LA	83.5	59.2	71.3	4.8	89.0	4/25+	42.0	4/6	0.99	-4.57	18
New Orleans, LA	82.9	65.1	74.0	5.8	89.0	4/20	49.0	4/6	0.35	-4.67	7
Shreveport, LA	83.3	58.3	70.8	5.6	92.0	4/19	36.0	4/5	2.85	-1.57	64
Greenwood, MS	79.6	54.4	67.0	3.3	88.0	4/19+	36.0	4/5	5.79	0.13	102
Jackson, MS	81.0	56.5	68.7	5.3	88.0	4/20+	39.0	4/6	4.08	-1.90	68
Tupelo, MS	77.1	53.8	65.5	4.6	89.0	4/9	39.0	4/17	9.00	4.06	182
Oklahoma City, OK	78.5	50.6	64.5	4.8	93.0	4/22	33.0	4/5	0.99	-2.01	33
Ponca City, OK	75.3	47.3	61.3	2.4	91.0	4/9	31.0	4/5+	1.14	-2.37	32
Tulsa, OK	75.2	51.6	63.4	2.6	90.0	4/22+	36.0	4/5	5.41	1.46	137
Knoxville, TN	75.5	51.2	63.3	5.5	88.0	4/10	33.0	4/1	9.08	5.09	228
Memphis, TN	76.3	55.3	65.8	3.7	88.0	4/19+	40.0	4/5	11.76	5.97	203
Nashville, TN	74.7	51.0	62.9	4.4	91.0	4/9	35.0	4/17	7.51	3.58	191
Amarillo, TX	77.7	42.6	60.1	3.9	94.0	4/29	32.0	4/16	0.05	-1.28	4
El Paso, TX	83.8	56.8	70.3	5.7	94.0	4/29	39.0	4/11	0.00	-0.23	0
Dallas, TX	82.3	59.2	70.8	5.8	91.0	4/19+	38.0	4/5	2.46	-0.74	77
Houston, TX	85.5	64.4	74.9	6.4	93.0	4/27	41.0	4/5	0.11	-3.49	3
San Antonio, TX	87.9	63.4	75.7	7.1	96.0	4/26	40.0	4/5	0.03	-2.57	1

Summary of temperature and precipitation information from around the region for April 2011. 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. Blue-shaded boxes represent cooler than normal temperatures; red-shaded boxes denote warmer than normal temperatures; tan shades represent drier than normal conditions; and green shades denote wetter than normal conditions.

SOUTHERN CLIMATE 101

Have a question about Southern U.S. climate? Let us know and we may feature the answer in a future issue of the Monitor!

In future issues of the Monitor, we will select a user submitted climate question and provide a reply, to appear in this spot on the back page of the Monitor. Though any aspect of climate is fair game, we will give greatest consideration to questions pertaining to extreme weather & climate events, recent conditions, and climate-related issues relevant to the South Central U.S. - specifically the states of Oklahoma, Texas, Arkansas, Louisiana, Tennessee, and Mississippi. For instance, perhaps you recently experienced a significant winter storm and you were curious how rare it was from a historical perspective. Contact us at monitor@southernclimate.org and we will consider your question among all the others we receive. In the subject line of your message, please use "Southern Climate 101." We look forward to your submissions!

Have a climate question, but do not want it to be answered in a public forum? No problem! Feel free to contact us at one of the options listed below, and we will do our best to address your question.

CONTACT US

The *Monitor* is an experimental climate outreach and engagement product of the Southern Regional Climate Center and Southern Climate Impacts Planning Program. To provide feedback or suggestions to improve the content provided in the *Monitor*, please contact us at monitor@southernclimate.org. We look forward to hearing from you and tailoring the *Monitor* to better serve you. You can also find us online at www.srcc.lsu.edu and www.southernclimate.org.

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 225-578-502. For questions or inquiries regarding research, experimental tool development, and engagement activities at the Southern Climate Impacts Planning Program, please contact us 405-325-7809 or 225-578-8374.

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