

NWS FORM E-5 (11-88) (PRES. by NWS Instruction 10-924)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA (HSA)	
		Tulsa, Oklahoma (TSA)	
MONTHLY REPORT OF RIVER AND FLOOD CONDITIONS		REPORT FOR:	YEAR
		MONTH July	2016
TO: Hydrometeorological Information Center, W/OH2 NOAA / National Weather Service 1325 East West Highway, Room 7230 Silver Spring, MD 20910-3283		SIGNATURE Steven F. Piltz (Meteorologist-in-Charge)	
		DATE September 9, 2016	

When no flooding occurs, include miscellaneous river conditions, such as significant rises, record low stages, ice conditions, snow cover, droughts, and hydrologic products issued (NWS Instruction 10-924)

An "X" in the box indicates no flood stages were reached in this Hydrologic Service Area (HSA) during the month above.

July 2016 was marked by above normal rainfall for all but far southeast OK due to several multi-inch rain events. Normal rainfall for the month of July ranges from 2.6 inches in McIntosh County to 3.4 inches in Ottawa County. The Ozark region of northwest Arkansas averages 3.1 inches for the month. This report, past E-5 reports, and monthly hydrology and climatology summaries can be found at <http://www.srh.noaa.gov/tsa/?n=hydro-monthly-summary>.

Monthly Summary

Using the radar-derived estimated observed precipitation from the RFCs (Fig. 1a), rainfall totals for July 2016 ranged from around 0.50" to around 10". A large portion of the HSA received 4"-8" of rain this month, with the greatest deficits over Choctaw and southern Pushmataha Counties. This corresponds to 90% to near 300% of the normal July rain for most of eastern OK and northwest AR (Fig. 1b), but only 25%-90% across Choctaw and Pushmataha Counties

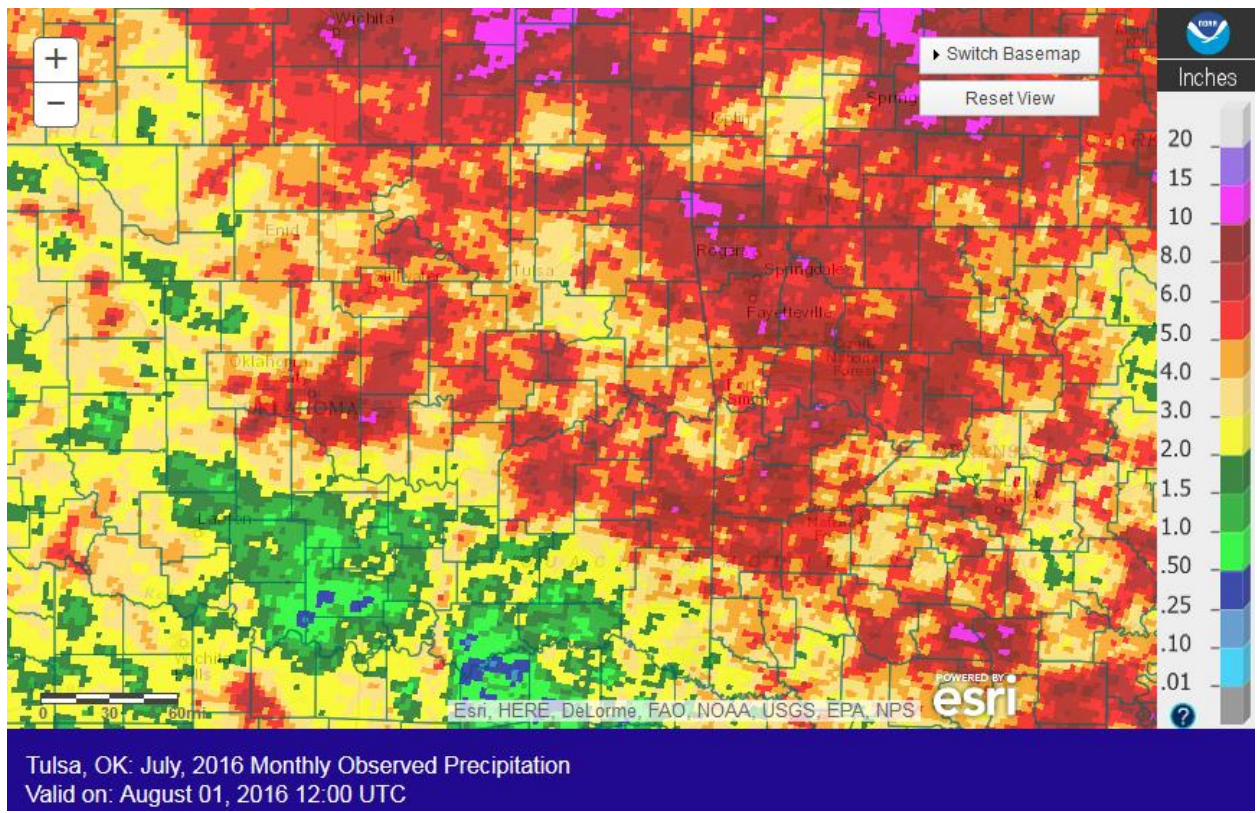


Fig. 1a. Estimated Observed Rainfall for July 2016

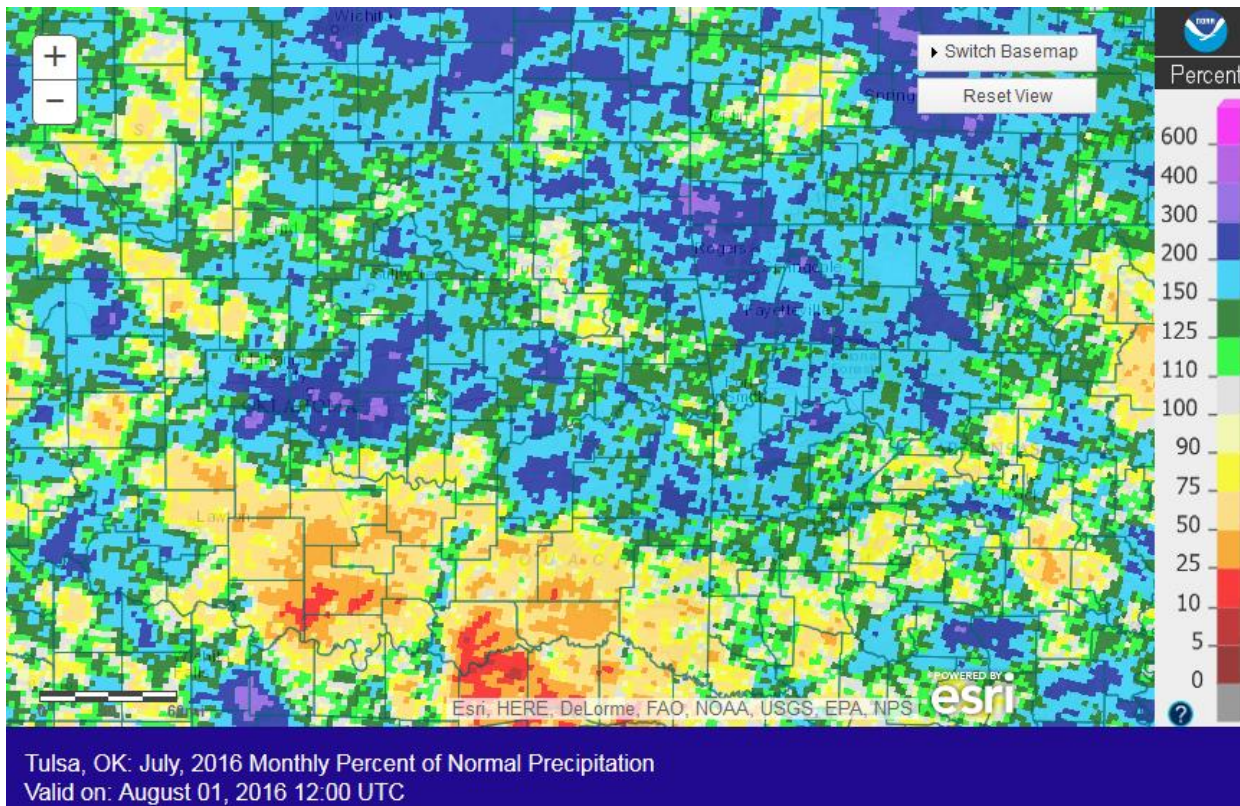


Fig. 1b. Estimated % of Normal Rainfall for July 2016

In Tulsa, OK, July 2016 ranked as the 21st warmest July (85.2°F, tied 1956; since records began in 1905) and the 46th wettest July (3.76"; since records began in 1888). Fort Smith, AR had the 25th warmest July (84.3°F, tied 1955; since records began in 1882) and the 41st wettest July (3.65"; since records began in 1882). Fayetteville, AR had the 27th warmest (78.8°F, tied 1982) and the 12th wettest (6.88") July since records began in 1950.

Some of the larger precipitation reports (in inches) for July 2016 included:

Pawnee, OK (coop)	12.39	Pawnee, OK (meso)	11.77	Winslow 7NE, AR (coop)	11.05
Hindsville 10NNE, AR (coop)	10.17	Bella Vista 1.0ESE, AR (coco)	9.95	Decatur 2.6ESE, AR (coco)	9.93
Springdale 5.8ENE, AR (coop)	8.64	Elkins 10.6SSE, AR (coco)	8.60	Nowata, OK (meso)	8.20

Some of the lowest precipitation reports (in inches) for July 2016 included:

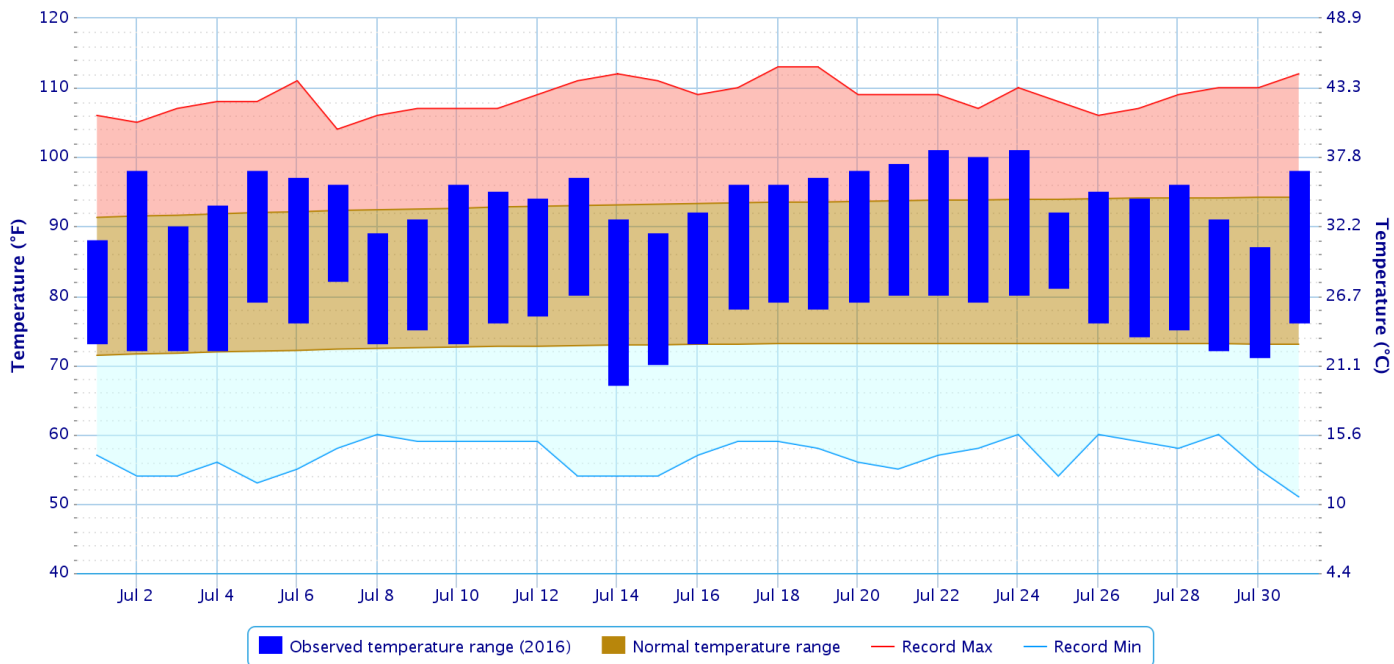
Antlers, OK (meso)	0.56	Hugo, OK (meso)	0.88	Antlers, OK (coop)	1.38
Cloudy, OK (meso)	1.90	Tulsa, OK (meso)	2.79	Muskogee, OK (ASOS)	3.20
Porter, OK (meso)	3.34	Tulsa 12.2SE, OK (coco)	3.50	Fort Smith, AR (ASOS)	3.65

According to statistics from the [Oklahoma Climatological Survey \(OCS\)](#) Mesonet:

Rank since 1921	Last 30 Days (Jul 2-31)	Summer (Jun 1 – Jul 31)	Last 90 Days (May 3 – Jul 31)	Last 120 Days (Apr 3 – Jul 31)	Warm Growing Season (Mar 1 – Jul 31)	Year-to-Date (Jan 1 – Jul 31)	Water Year-to-Date (Oct 1 – Jul 31)	Last 365 Days (Aug 2, 2015-Jul 31, 2016)
Northeast OK	19 th wettest	33 rd driest	46 th driest	40 th wettest	44 th wettest	28 th driest	16 th wettest	21 st wettest
East Central OK	15 th wettest	48 th driest	48 th driest	41 st wettest	41 st wettest	41 st driest	5th wettest	9th wettest
Southeast OK	44 th wettest	25 th driest	22 nd driest	38 th wettest	23 rd wettest	44 th wettest	4th wettest	5th wettest
Statewide	27 th wettest	44 th wettest	46 th driest	25 th wettest	33 rd wettest	44 th wettest	9th wettest	17 th wettest

Daily Temperature Data – Tulsa Area, OK (ThreadEx)

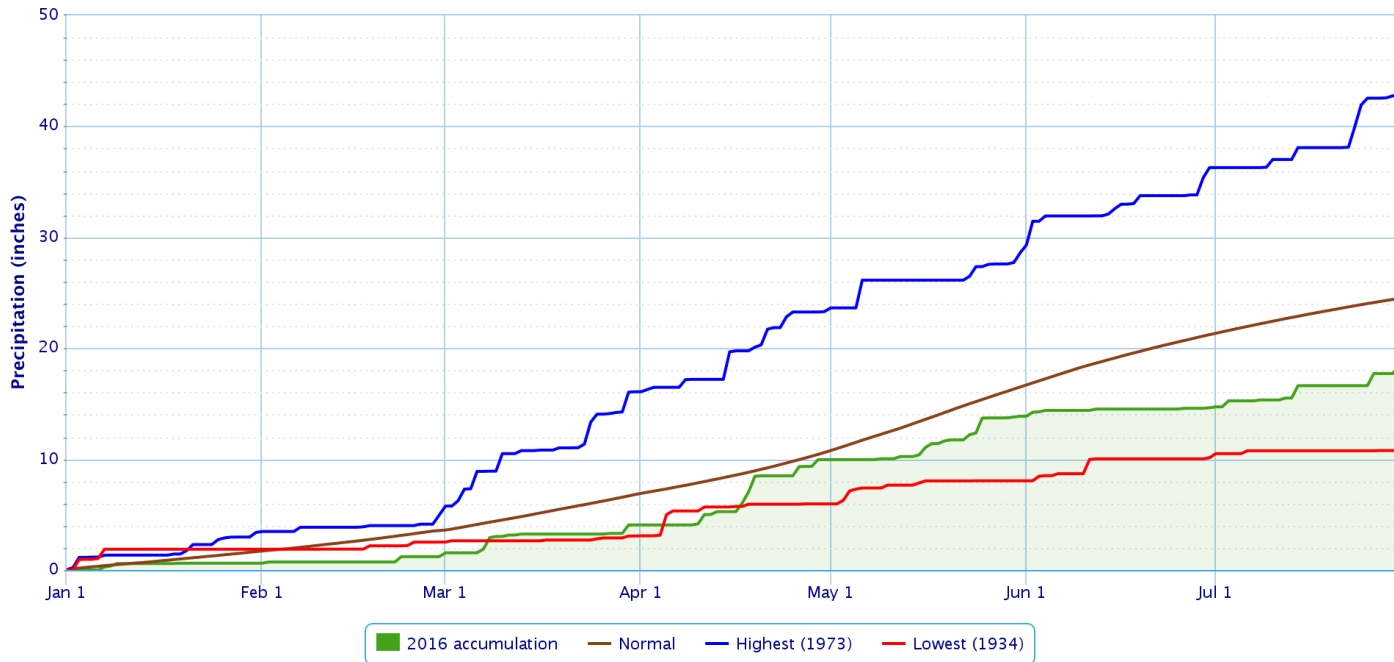
Period of Record – 1905-01-06 to 2016-08-31. Normals period: 1981-2010. Click and drag to zoom chart.



Powered by ACIS

Accumulated Precipitation – Tulsa Area, OK (ThreadEx)

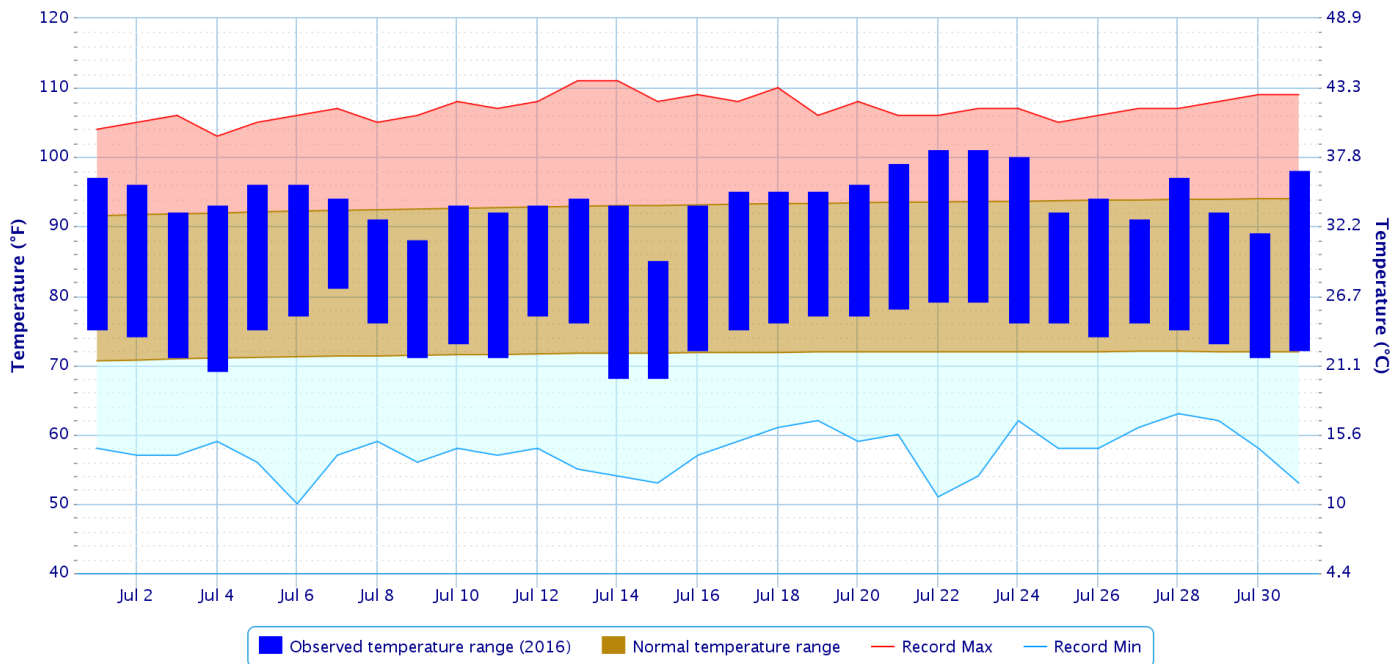
Click and drag to zoom to a shorter time interval; green/black diamonds represent subsequent/missing values



Powered by ACIS

Daily Temperature Data – Fort Smith Area, AR (ThreadEx)

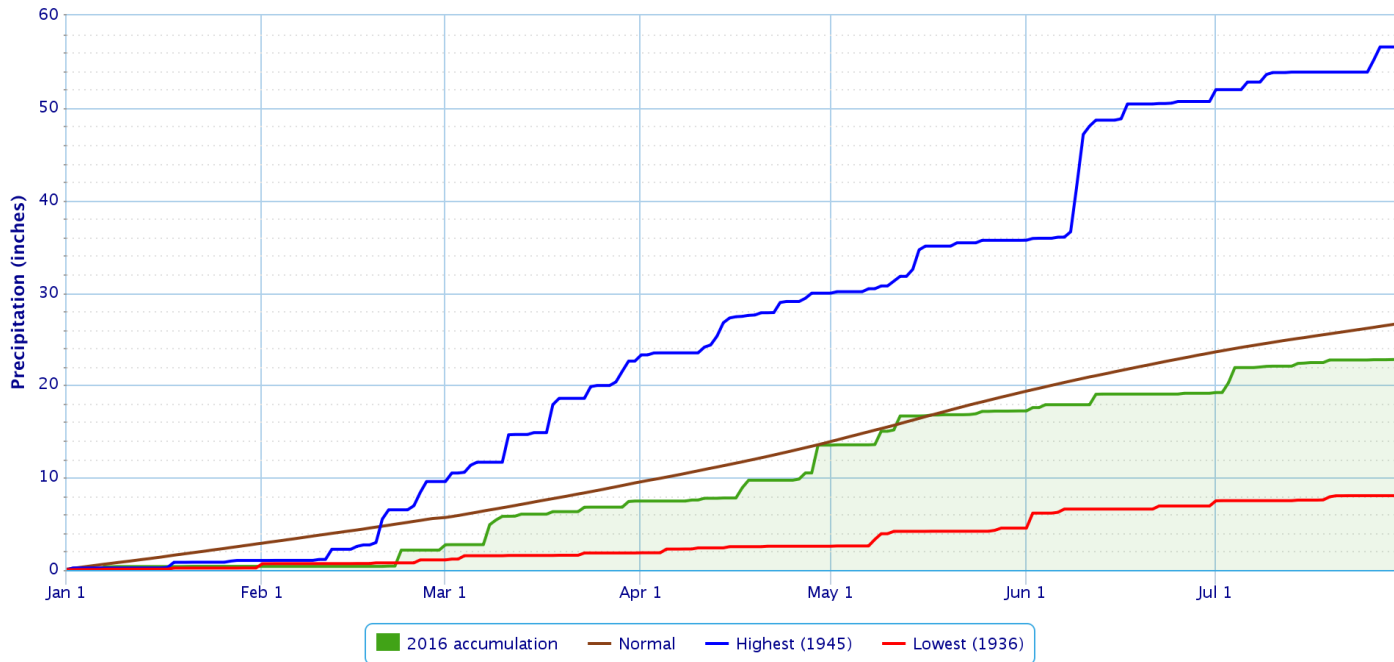
Period of Record – 1882-06-01 to 2016-08-31. Normals period: 1981-2010. Click and drag to zoom chart.



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Accumulated Precipitation – Fort Smith Area, AR (ThreadEx)

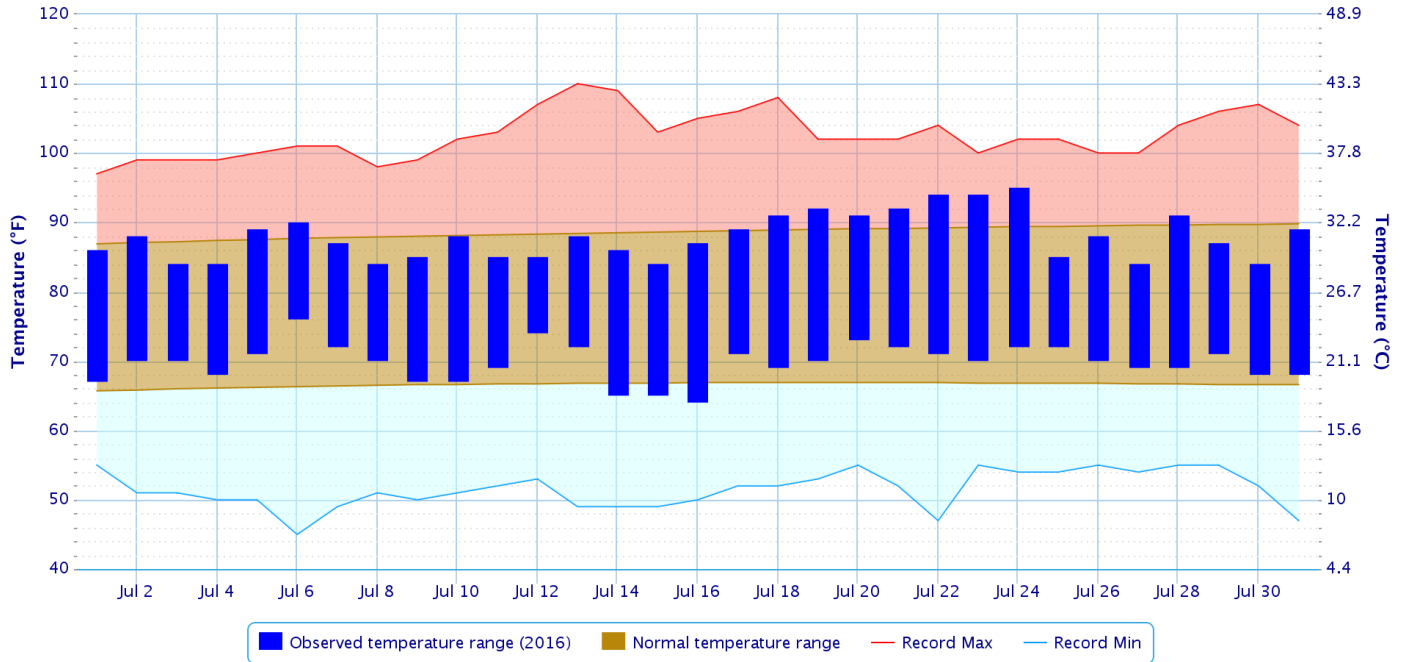
Click and drag to zoom to a shorter time interval; green/black diamonds represent subsequent/missing values



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Daily Temperature Data – FAYETTEVILLE DRAKE FLD, AR

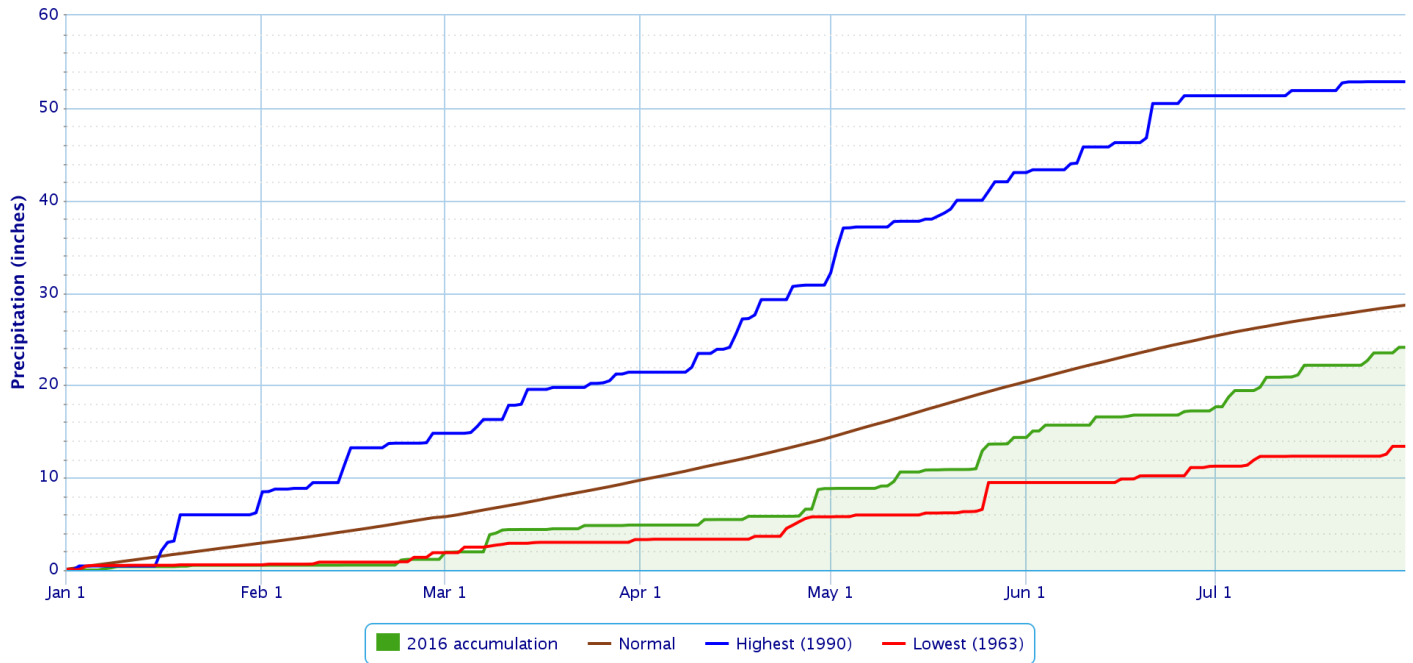
Period of Record – 1949-07-14 to 2016-08-31. Normals period: 1981-2010. Click and drag to zoom chart.



Powered by ACIS

Accumulated Precipitation – FAYETTEVILLE DRAKE FLD, AR

Click and drag to zoom to a shorter time interval; green/black diamonds represent subsequent/missing values



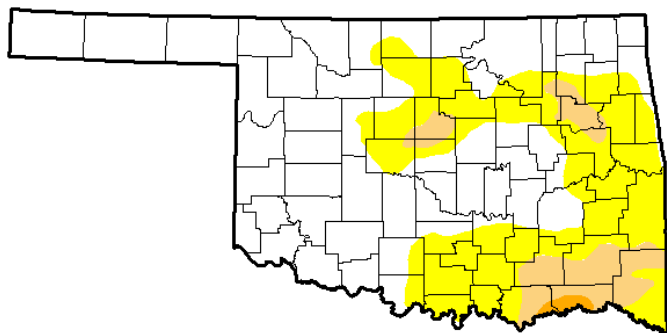
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Drought

According to the [U.S. Drought Monitor](#) (USDM) from August 2, 2016 (Figs. 2, 3), D2 (Severe Drought) had developed over southern Choctaw County. D1 (Moderate Drought) conditions existed over portions of Tulsa, Rogers, Wagoner, Muskogee, and Pushmataha Counties in northeast OK. D0 (abnormally dry conditions but not in drought) were present across portions of Osage, Pawnee, Creek, Tulsa, Rogers, Mayes, Muskogee, Okmulgee, McIntosh, Pittsburg, Haskell, Latimer Delaware, Cherokee, Adair, Sequoyah, Pushmataha, and Le Flore Counties in OK, and Sebastian County in AR.

U.S. Drought Monitor Oklahoma

August 2, 2016
(Released Thursday, Aug. 4, 2016)
Valid 8 a.m. EDT



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	61.98	38.02	8.18	0.56	0.00	0.00
Last Week 7/26/2016	61.25	38.75	10.00	0.53	0.00	0.00
3 Months Ago 5/9/2016	87.75	12.25	1.67	0.00	0.00	0.00
Start of Calendar Year 12/29/2015	100.00	0.00	0.00	0.00	0.00	0.00
Start of Water Year 9/29/2015	52.60	47.40	16.79	6.37	0.97	0.00
One Year Ago 8/4/2015	98.66	1.34	0.00	0.00	0.00	0.00

Intensity:

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

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

Author:
Richard Tinker
CPC/NOAA/NWS/NCEP

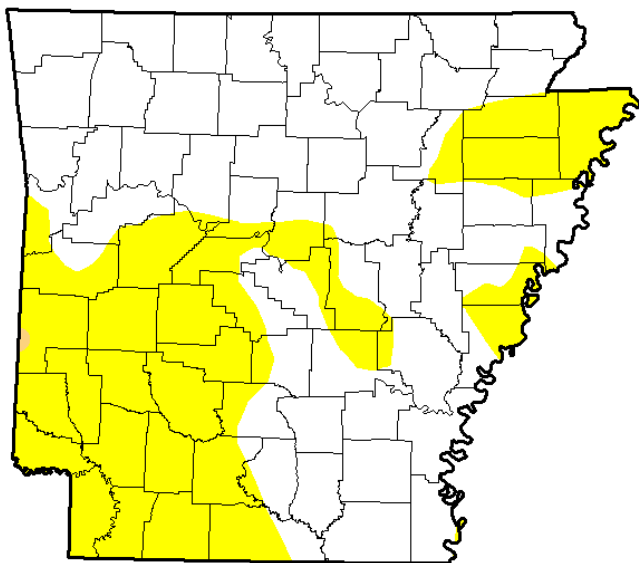


<http://droughtmonitor.unl.edu/>

Fig. 2. Drought Monitor for Oklahoma

U.S. Drought Monitor Arkansas

August 2, 2016
(Released Thursday, Aug. 4, 2016)
Valid 8 a.m. EDT



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	62.71	37.29	0.08	0.00	0.00	0.00
Last Week 7/26/2016	56.75	43.25	1.09	0.00	0.00	0.00
3 Months Ago 5/9/2016	82.09	17.91	0.00	0.00	0.00	0.00
Start of Calendar Year 12/29/2015	100.00	0.00	0.00	0.00	0.00	0.00
Start of Water Year 9/29/2015	39.30	60.70	42.41	16.89	4.64	0.00
One Year Ago 8/4/2015	94.31	5.69	0.00	0.00	0.00	0.00

Intensity:

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

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

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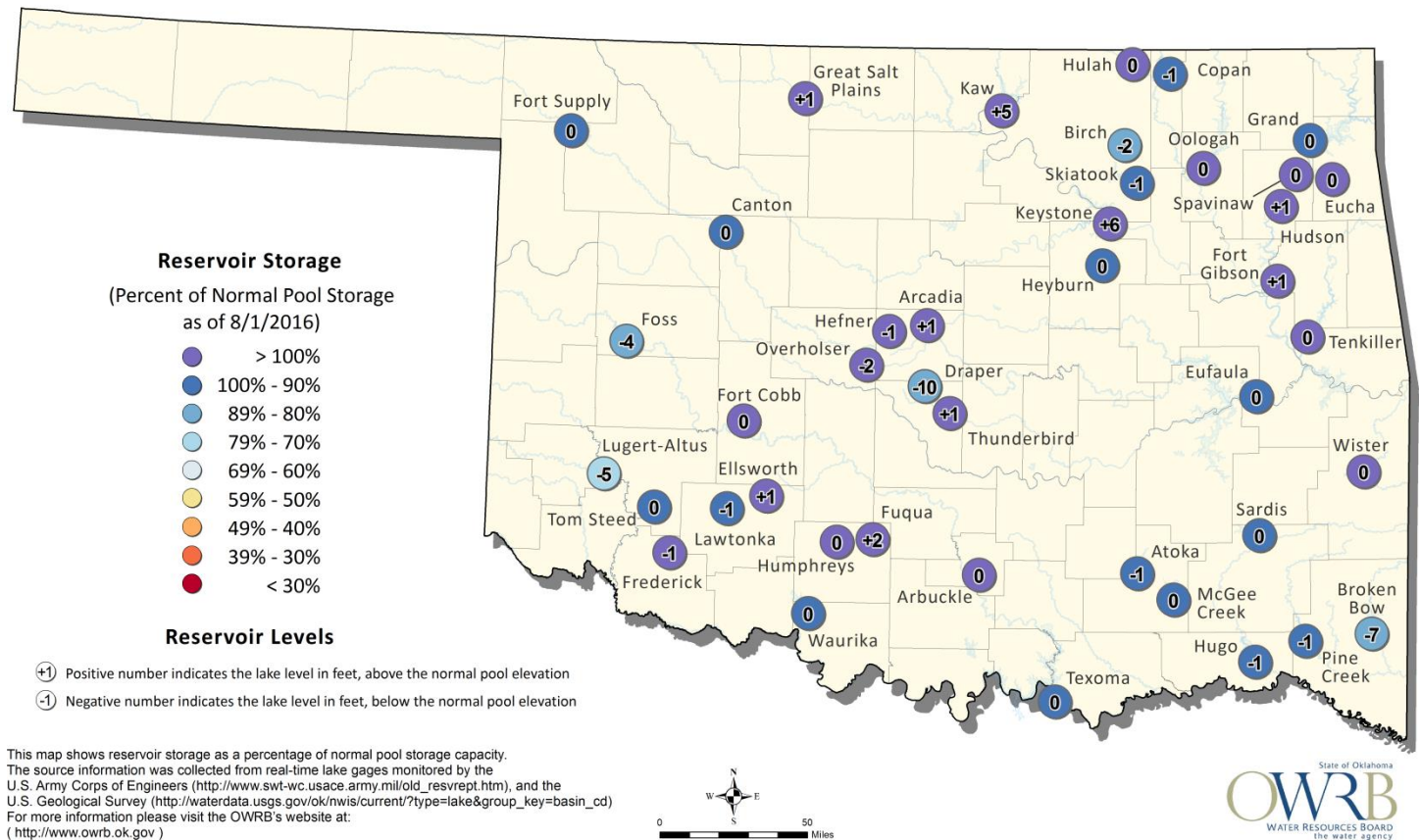
<http://droughtmonitor.unl.edu/>

Fig. 3. Drought Monitor for Arkansas

Reservoirs

Oklahoma Surface Water Resources

Reservoir Levels and Storage as of 8/1/2016



According to the USACE, all of the major reservoirs in the HSA were operating within $\pm 3\%$ of the top of their conservation pool levels as of 08/4/2016. Reservoirs operating above 5% of the top of their conservation level include: Keystone Lake 110% and Kaw Lake 106%. Reservoirs operating below 5% of the top of their conservation level include: Hugo Lake 87%, Birch Lake 88%, Beaver Lake 90%, Copan Lake 92%, and Skiatook Lake 95%.

Outlooks

The [Climate Prediction Center](#) (CPC) outlook for August 2016 (issued July 31, 2016) indicates a slightly enhanced chance of above normal temperatures across all of eastern OK and northwest AR. This outlook also calls for a slightly enhanced chance for below median rainfall over southeast OK and equal chances for above, near, and below median precipitation elsewhere across eastern OK and northwest AR. This outlook is based on both short- and extended-range weather forecasts.

For the 3-month period August-September-October 2016, CPC is forecasting an equal chance for above, near, and below median precipitation and an enhanced chance for above normal temperatures across all of eastern OK and northwest AR (outlook issued July 21, 2016). According to CPC, Pacific sea surface temperatures along the equator indicate ENSO-neutral conditions (near average). This outlook is based primarily on both statistical and dynamical forecast tools and decadal timescale climate trends. Outlooks for October-November-December and through the winter include impacts due to the transition to La Niña. The chance of La Niña conditions by August-September-October was reduced to 50%, with probabilities increasing above 60% by the 2016-17 Winter.

Summary of Precipitation Events Daily quality controlled rainfall maps can be found at: http://water.weather.gov/precip/index.php?location_type=wfo&location_name=tsa

July 1-15

Thunderstorms moved out of KS and MO and into northeast OK and northwest AR during the afternoon of the 30th. These storms moved south and dissipated in the early evening before reaching I-40 in eastern OK. However, the showers and thunderstorms lingered later into the evening hours over northwest and west central AR. Additional activity developed along and north of a diffuse boundary in northeast OK during the early morning hours of July 1st. Training storms with heavy rain produced 5"-8" of rain over Pawnee and southern Osage through the morning (Figs. 4, 5). The Oklahoma Mesonet site in Pawnee measured 5.78". This resulted in high water over roadways and flooding a portion of the Pawnee Public Library. The Pawnee rainfall occurred after midnight, but mostly before 7am on July 1st. Prior to this rainfall, the Pawnee Mesonet station had only recorded 0.53" for the month of June, ranking as the second driest Mesonet station this month. (Note: the NWS will count rainfall through 7am July 1st as June rain, while other agencies, such as the Oklahoma Climatological Survey/Mesonet, will count it in July.) Elsewhere, rainfall totals ranged from around 0.25" to near 1.5" (Fig. 4). Rainfall lingered through the morning hours over Osage, Pawnee, Tulsa, and northern Creek Counties. By early afternoon, thunderstorms developed over northwest AR near a stalled frontal boundary and under the influence of the left over MCV from the early north central OK convection. Additional isolated storms formed elsewhere in east central and southeast OK by early evening, and the storms over Osage/Pawnee Counties from earlier fired back up and moved east across northeast OK. While most of the activity ended by midnight, showers persisted across northeast OK and northwest AR through the pre-dawn hours of the 2nd. Additional rainfall totals ranged from 0.10" to around 1.5", with isolated totals of 1.5" - 3" (Fig. 6).

Highest rainfall measurements ending 7am CDT 7/01/2016 include:

Pawnee, OK	5.35	Pawnee 3ENE, OK	3.83	Ralston, OK	2.65
Bella Vista 0.6 WSW, AR	2.15	Ralston 1ENE, OK	2.01		

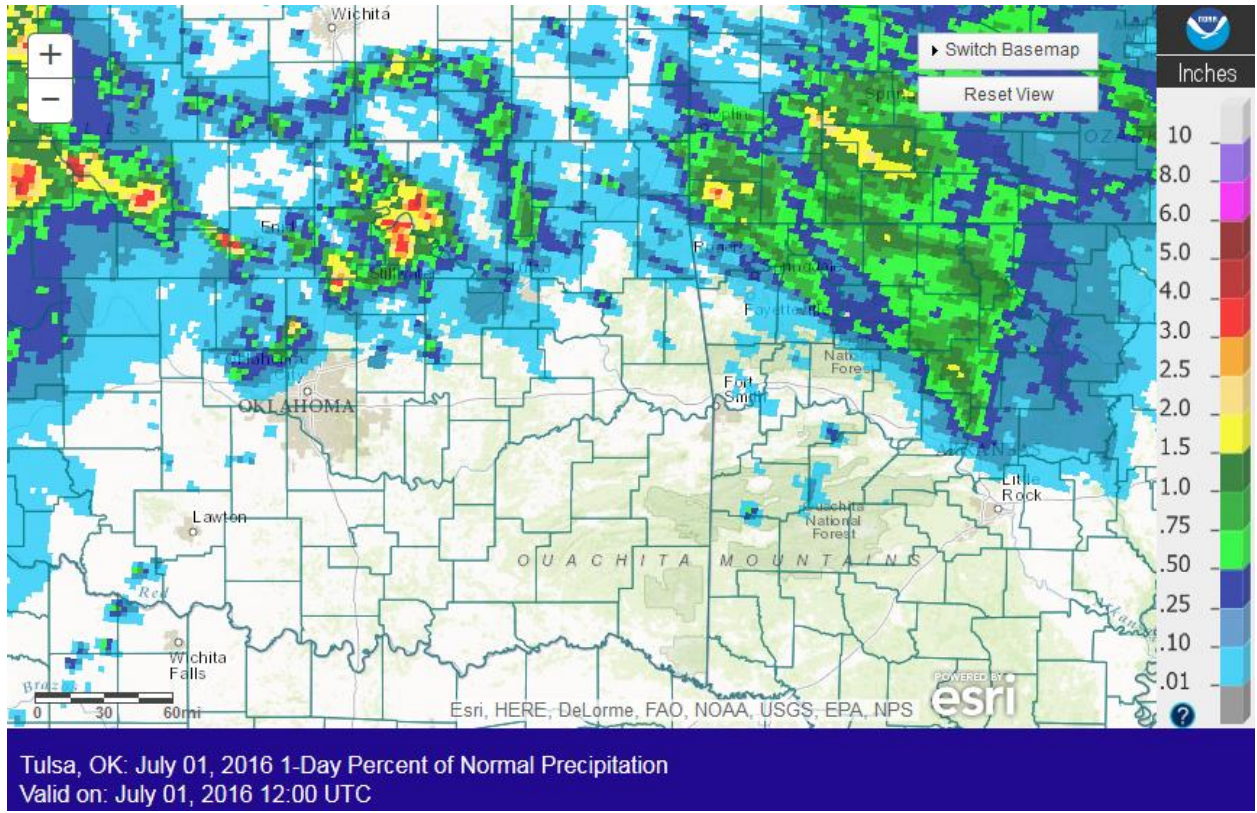
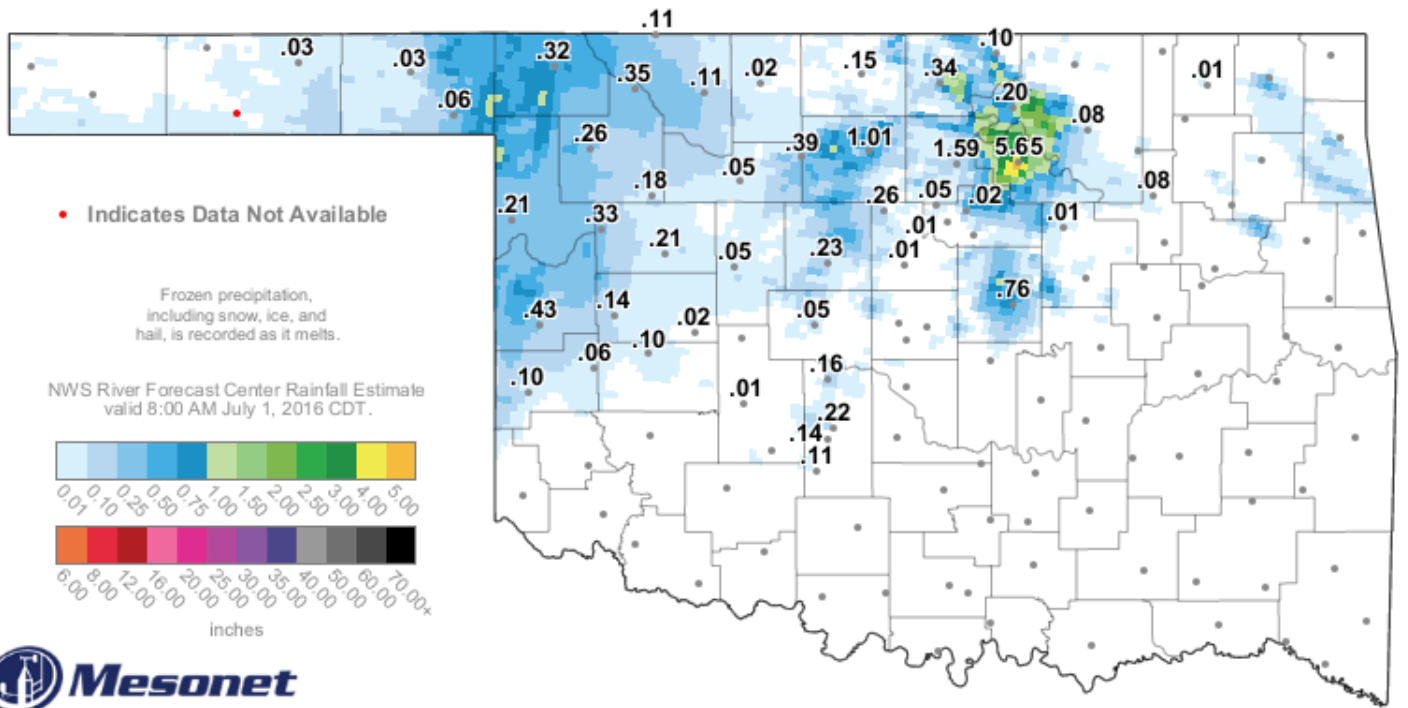


Fig. 4. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/01/2016.



6-Hour Rainfall Accumulation (inches)

9:35 AM July 1, 2016 CDT

Created 9:39:30 AM July 1, 2016 CDT. © Copyright 2016

Fig. 5. 6-hr Estimated Observed Rainfall (image) and OK Mesonet measurements ending at 9:35am CDT 07/01/2016.

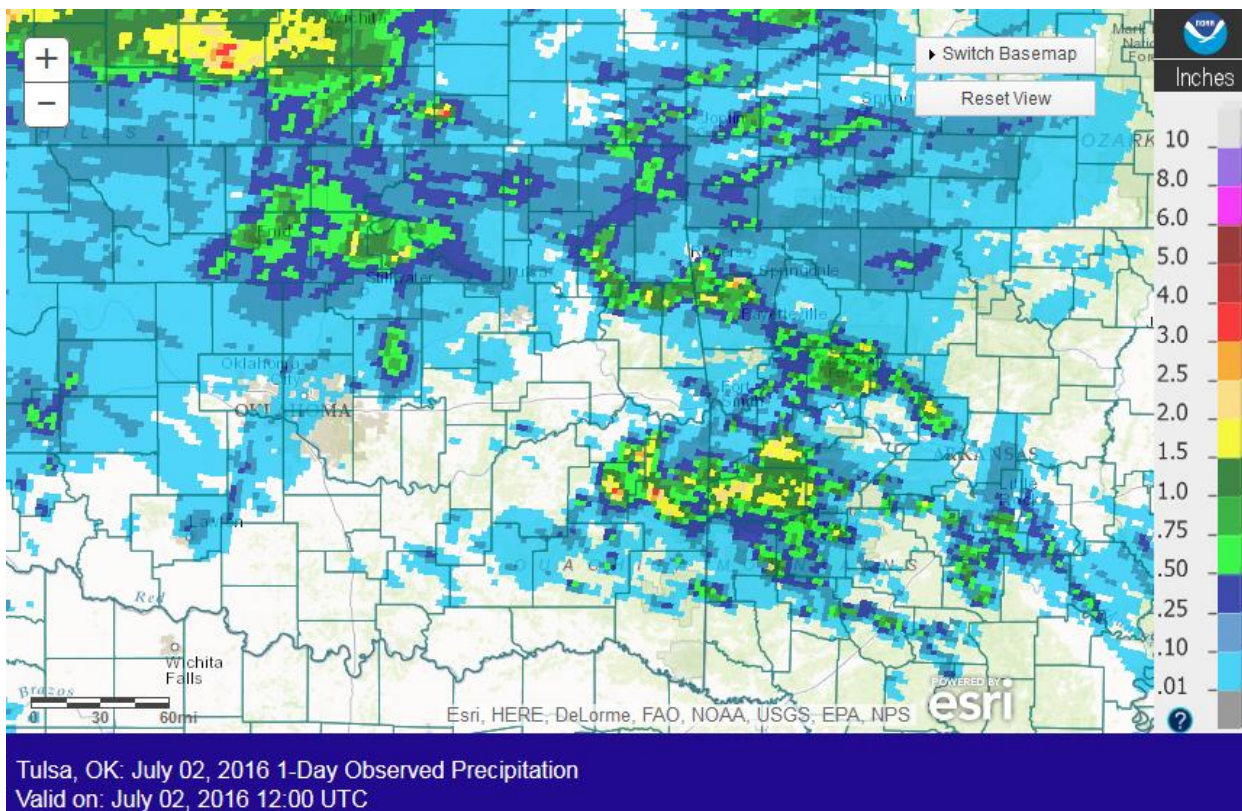


Fig. 6. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/02/2016.

Shortly after midnight on the 3rd, a line of thunderstorms moved southeast out of KS into northeast OK in response to the low-level jet. This line of storms swept through the entire HSA except Choctaw County and was east of the area by early afternoon. The heaviest rain affected northeast OK and northwest AR. By mid-afternoon, showers and thunderstorms redeveloped over northeast OK, between the KS state line and I-44, along a frontal zone. The line of storms then began to move southeast during the evening, bringing rain to the remainder of eastern OK and northwest AR through the evening and overnight hours. However, Choctaw

County once again missed out on the rain. Most of the activity had moved east of the HSA by sunrise on the 4th, though a few showers lingered over northwest AR through mid-morning. The rest of the July 4th holiday was dry. Rainfall totals were heavy from the two rounds of rain, with several areas receiving a total of 3"-7" of rainfall (Figs. 7-10). Most locations saw around 0.75" to around 1.5" of rain, except Choctaw County, which had little to no rain from these storms.

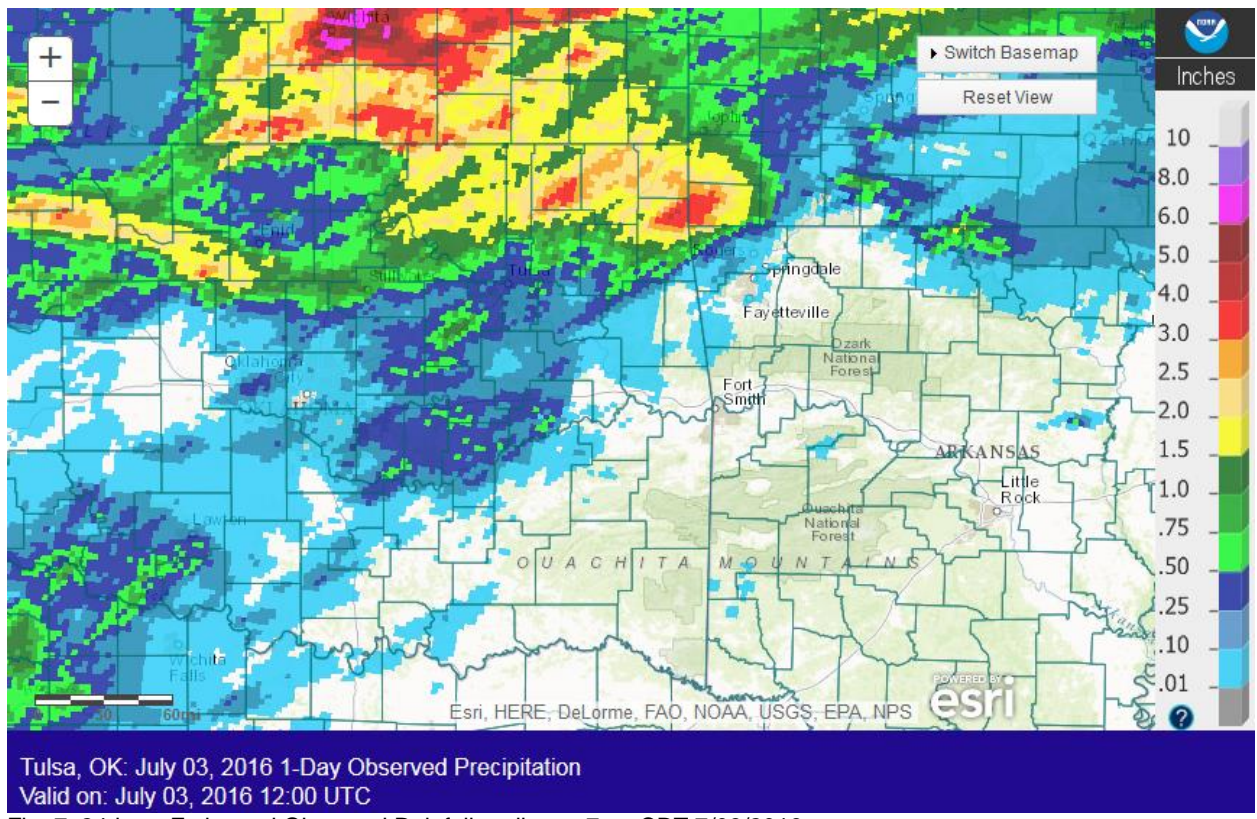


Fig. 7. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/03/2016.

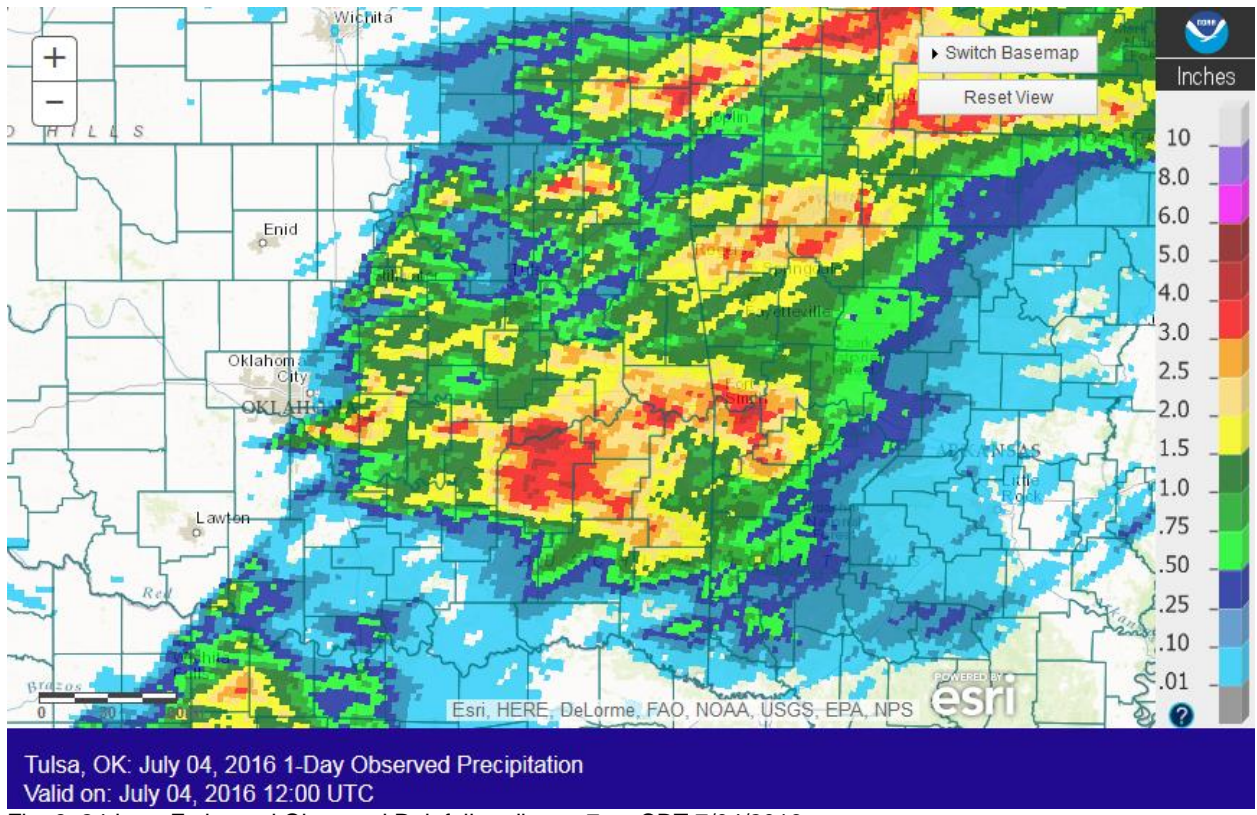
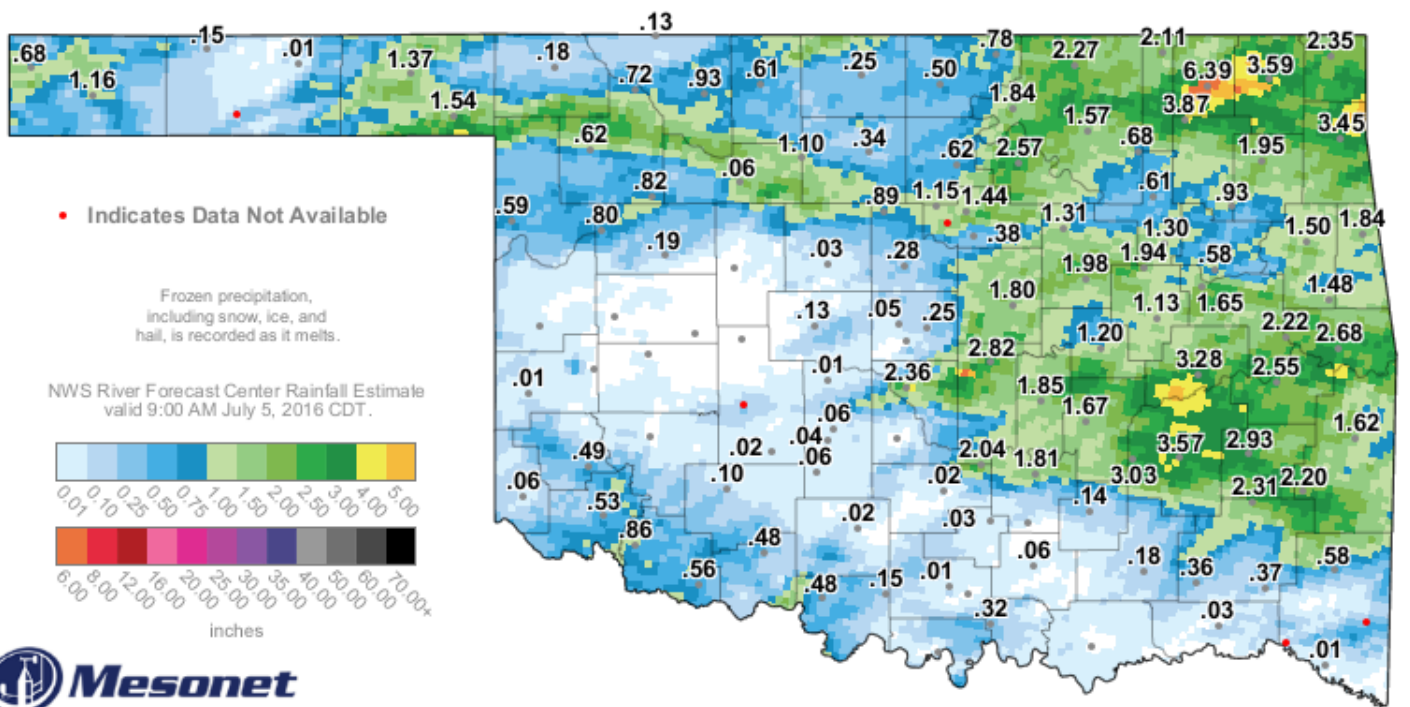


Fig. 8. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/04/2016.

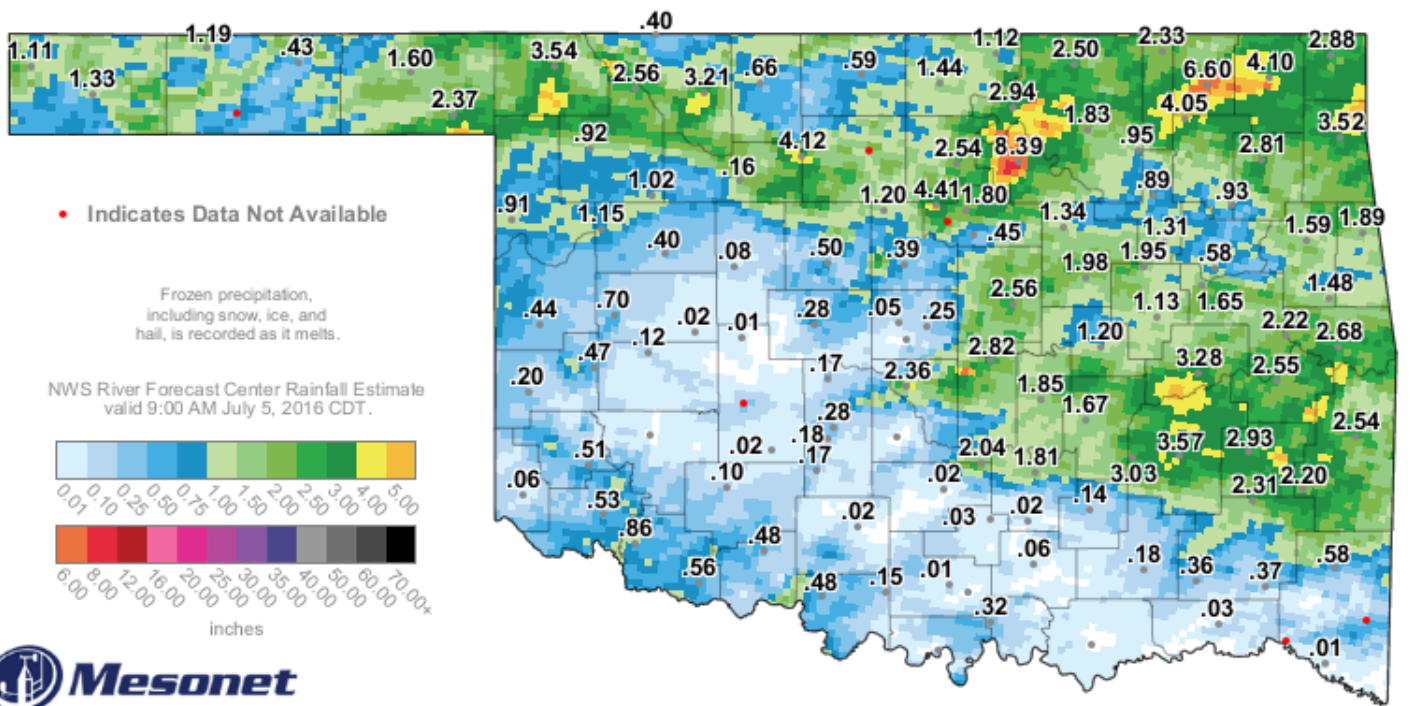


3-Day Rainfall Accumulation (inches)

10:00 AM July 5, 2016 CDT

Created 10:05:24 AM July 5, 2016 CDT. © Copyright 2016

Fig. 9. 3-Day Estimated Observed Rainfall (image) and OK Mesonet measurements ending at 10am CDT 07/05/2016.



5-Day Rainfall Accumulation (inches)

10:00 AM July 5, 2016 CDT

Created 10:05:25 AM July 5, 2016 CDT. © Copyright 2016

Fig. 10. 5-Day Estimated Observed Rainfall (image) and OK Mesonet measurements ending at 10am CDT 07/05/2016.

Another round of overnight convection moved southeast out of KS just before sunrise on the 6th. The more widespread portion of this activity affected locations north of Hwy 412, while more widely scattered showers and thunderstorms affected locations further south to near I-40. Most of the storms were east of the HSA by mid-morning, with just isolated showers and thunderstorms remaining through noon. Rainfall totals were mostly 0.10" to 0.50", with a few areas getting 0.50"-0.75".

Showers developed over northeast OK and northwest AR around sunrise on the 7th in an area of low-level warm air advection. This activity ended by late morning and brought light rainfall. A complex of storms developed over southeast KS and moved into far northeast OK shortly after midnight on the 8th. These storms continued southeast across far northwest AR, ending by 3am. This activity brought only a few hundredths to around 0.50" of rain to the affected area.

Another complex of thunderstorms moved east across the OK/KS border and into northeast OK around sunrise on the 8th and continued through the morning. Additional scattered showers and thunderstorms continued north of I-40 through the early afternoon hours. By evening, convection renewed along the left over outflow boundary from the morning storms. Most of the activity was south of I-44, with the heaviest rain occurring across northwest and west central AR. Rainfall totals by 7am on the 9th ranged from around 0.10" to around 4", with widespread 1.5" to 3" over northwest and west central AR (Fig. 11). With a weak surface front, numerous convective outflow boundaries, and a weak upper-level disturbance, isolated to scattered showers and thunderstorms continued through the morning and afternoon hours of the 9th. This activity brought 0.25" to around 1.5" to the affected locations.

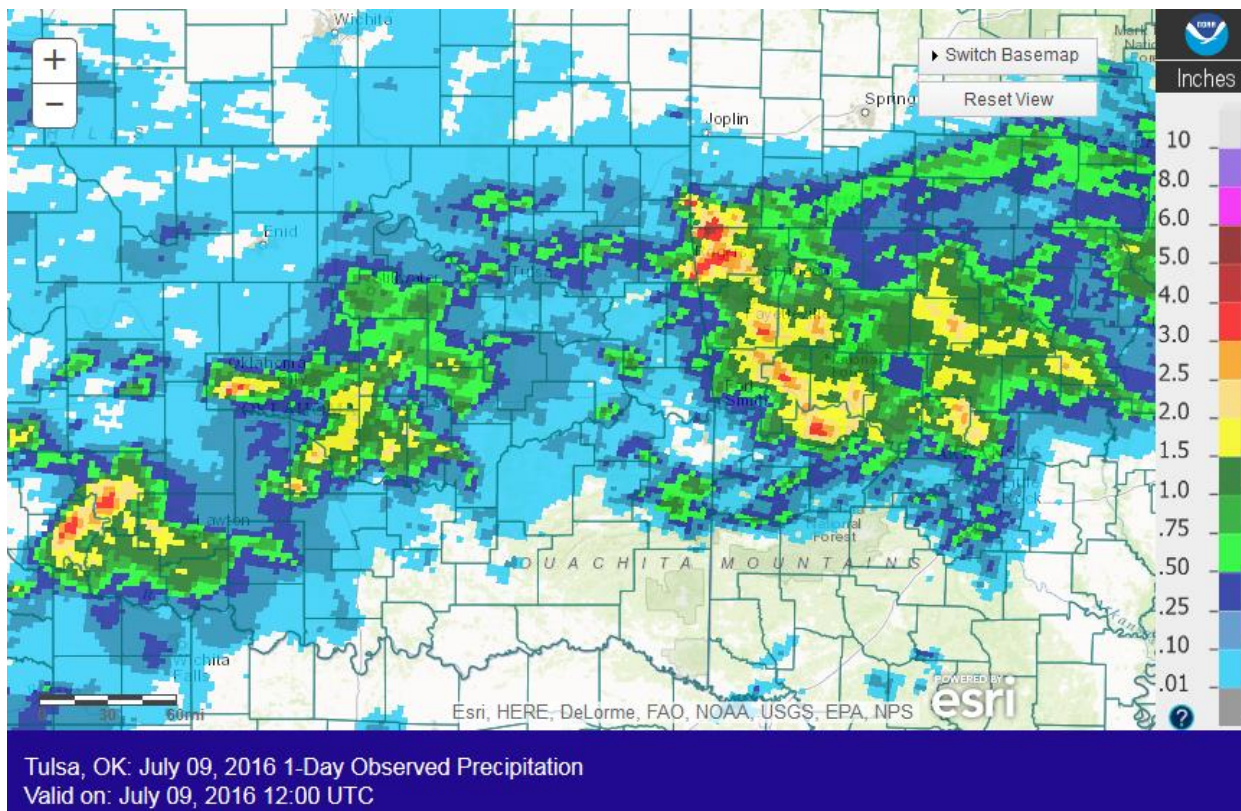


Fig. 11. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/09/2016.

Diurnal, terrain induced showers and thunderstorms affected primarily Le Flore, Sebastian, Franklin, and Carroll Counties on the 10th, bringing around 0.75" or less. An area of showers and thunderstorms moved south out of KS into northeast OK and northwest AR during the morning of the 12th, and dissipated by early afternoon before reaching I-40. This brought from a few hundredths of an inch to near 1.5" of rain north of I-40.

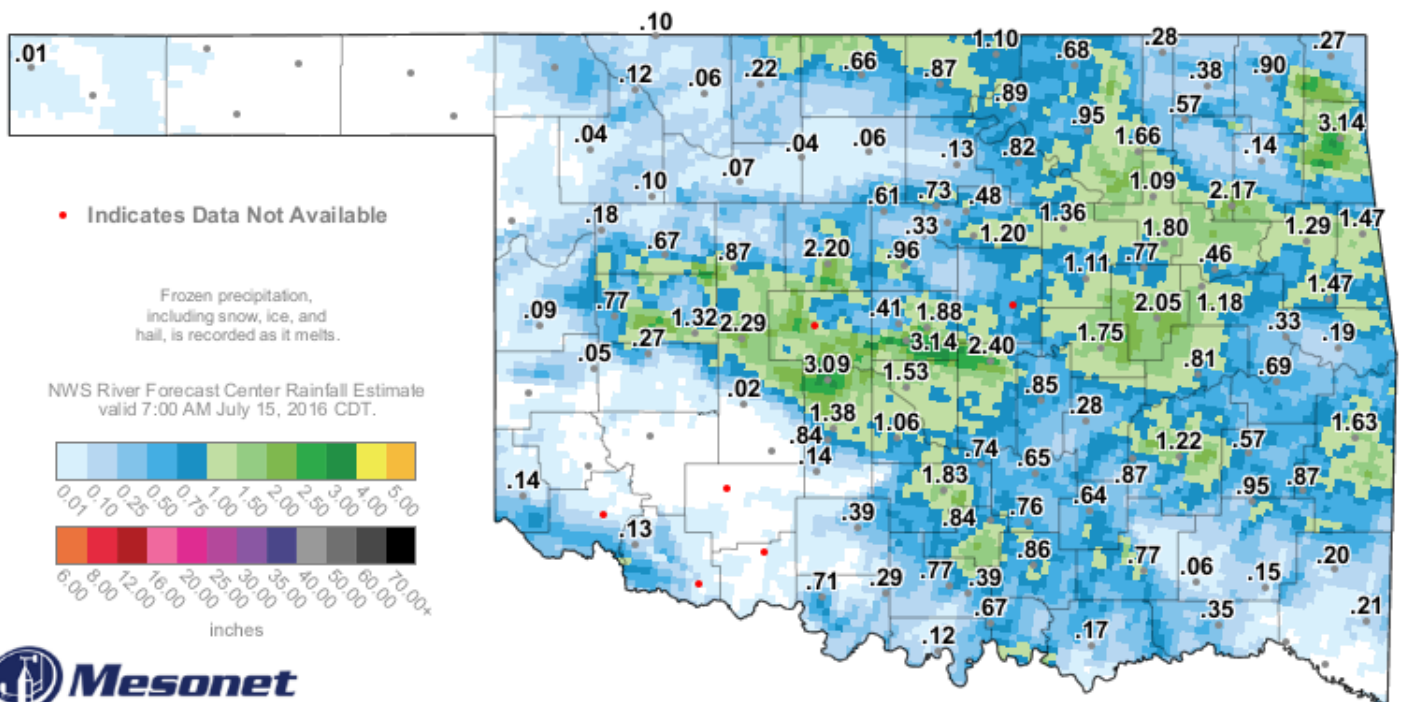
A short-lived line of showers and thunderstorms traversed northeast OK, primarily northwest of I-44 during the late morning through early afternoon hours of the 13th. These storms left an outflow boundary from southwest OK to north central OK into KS. More thunderstorms developed along this boundary during the late evening hours. These storms developed into another storm complex, moving southeast and affecting locations along and southwest of a Ponca City to Fort Smith line through the overnight and early morning hours of the 14th. Rainfall totals ranged from around 0.10" to around 1" of rain.

An MCS moved southeast out of KS and into the HSA a little before noon on the 14th. This complex intensified as it moved into the Tulsa metro area, producing damaging winds and very heavy rain. 1.5"-2" of rain fell in one hour in the most intense parts of the storm complex. Widespread damage occurred across eastern OK

and west central AR as the squall line produced straight-line winds of 60 to 80 mph. The Oklahoma Mesonet station in Haskell, OK measured an 80 mph wind gust (Fig. 14). Significant tree damage occurred, buildings were damaged, semis were overturned, and power lines were downed throughout the storm path. Over 100,000 customers were without power in just the Tulsa area alone. These storms continued to produce damaging winds all the way through northern Louisiana and west central Alabama. Additional information available at <http://arcg.is/1RNkyDs>. Additional thunderstorms developed across western and central OK later that night. These storms progressed east, moving into eastern OK during the early morning hours. More storms developed along an outflow boundary from far northeast OK down into northwest AR. This activity continued through the morning hours of the 15th, decreased through the late morning, and finally came to an end by late afternoon. The entire HSA received rainfall, ranging from around 0.25" to around 3" (Figs. 12, 13). Several locations in northeast and east central OK saw 1.5"-2.5" of rain, while far northeast OK and northwest AR had widespread 1"-3" by the time the storms ended.

Highest 24-hour rainfall totals ending at 7am CDT July 15, 2016 include:

Jay 3.3 NNE, OK	3.25	Vinita 8.6 ESE, OK	2.40	Morris 2.4SW, OK	2.36
Beggs 5S, OK	2.18	Inola 3SSE, OK	2.17	Jay 4N, OK	2.10
Oklmulgee 5SE, OK	2.05	Hartshorne 3.9NNE, OK	1.93	Tulsa 5SSW, OK	1.82



24-Hour Rainfall Accumulation (inches)

8:25 AM July 15, 2016 CDT

Created 8:30:29 AM July 15, 2016 CDT. © Copyright 2016

Fig. 12. 24-hour Estimated Observed Rainfall (image) and OK Mesonet measurements ending at 8:25am CDT 07/15/2016.

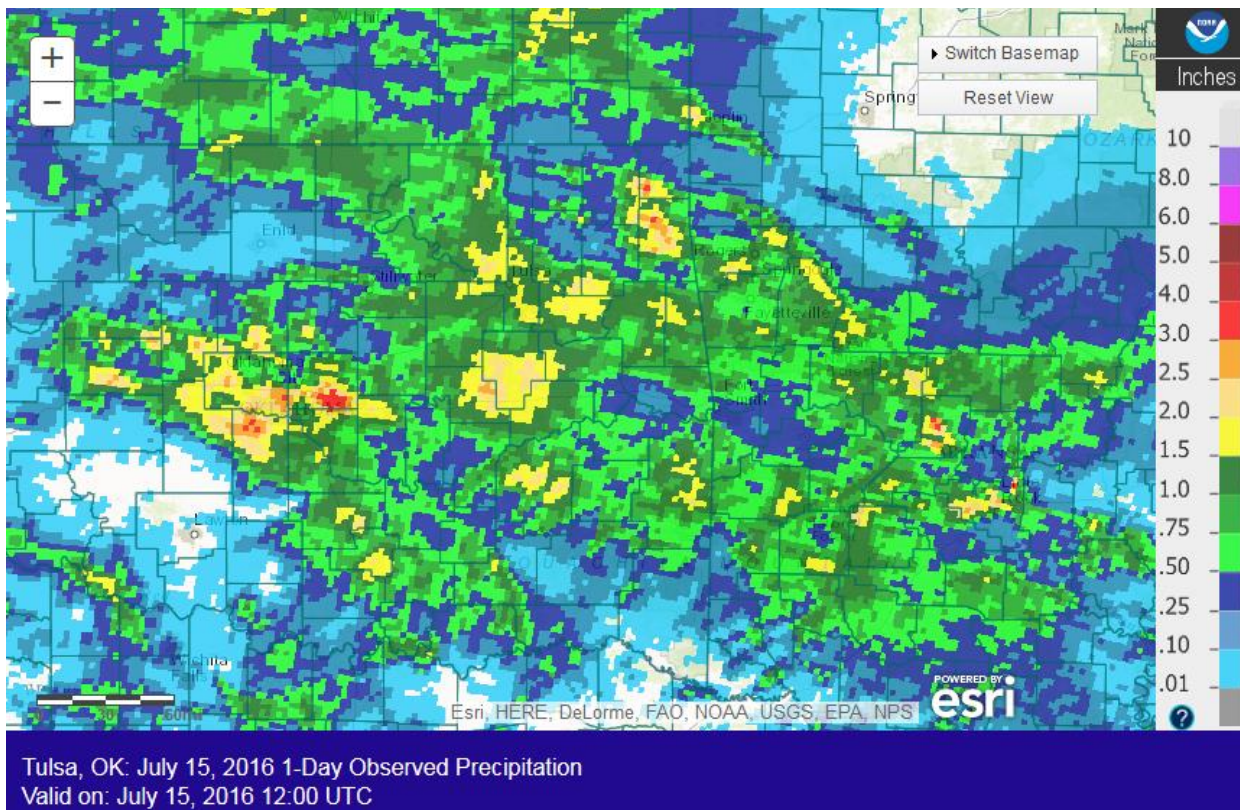


Fig. 13. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/15/2016.

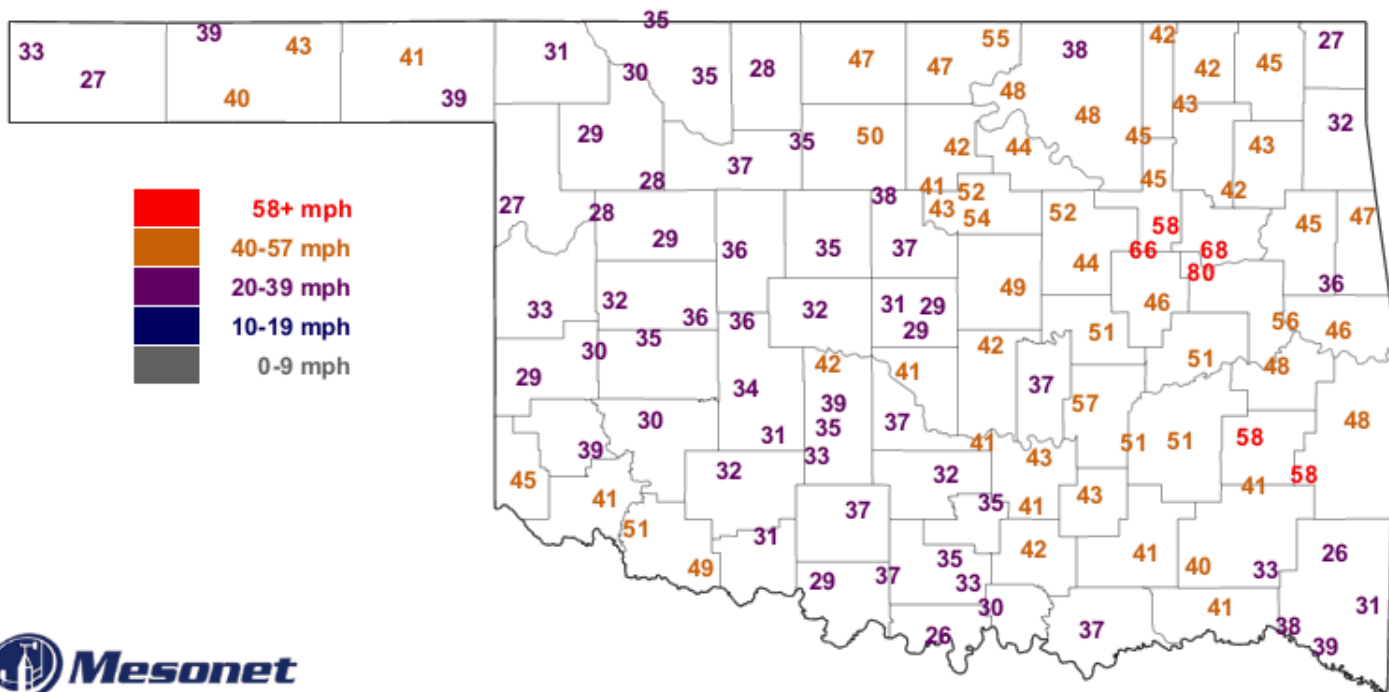


Fig. 14. OK Mesonet maximum wind gust measurements for 07/14/2016.

July 16-31

Isolated diurnal convection brought 0.10" to around 0.50" of rain to a few places in eastern OK and Sebastian Co. in west central AR on the 16th. Afternoon heating also resulted in widely scattered showers and thunderstorms across the HSA on the 19th, with localized rainfall totals around 1" or less.

Afternoon heating and terrain led to some scattered showers and thunderstorms for a few hours on the 23rd across southern Le Flore and the western portions of Choctaw, Pushmataha, Carrol, and Madison Counties. Rainfall amounts were around 1" or less. A similar story occurred on the 24th, with isolated activity east of a McAlester to Springdale line bringing around 1" of rain or less to the affected locations.

During the morning of the 25th, scattered showers and thunderstorms along the southern edge of a complex moving across KS affected northeast OK and northwest AR. Outflow from this activity sparked additional widely scattered showers and thunderstorms further south in west central AR and far southeast OK during the afternoon and evening. Then, new convection developed over central OK at mid-evening and affecting the west central portion of the HSA through the early morning hours. Rainfall totals for both rounds of storms ranged from 0.25" to around 3" in the affected areas (Fig. 15).

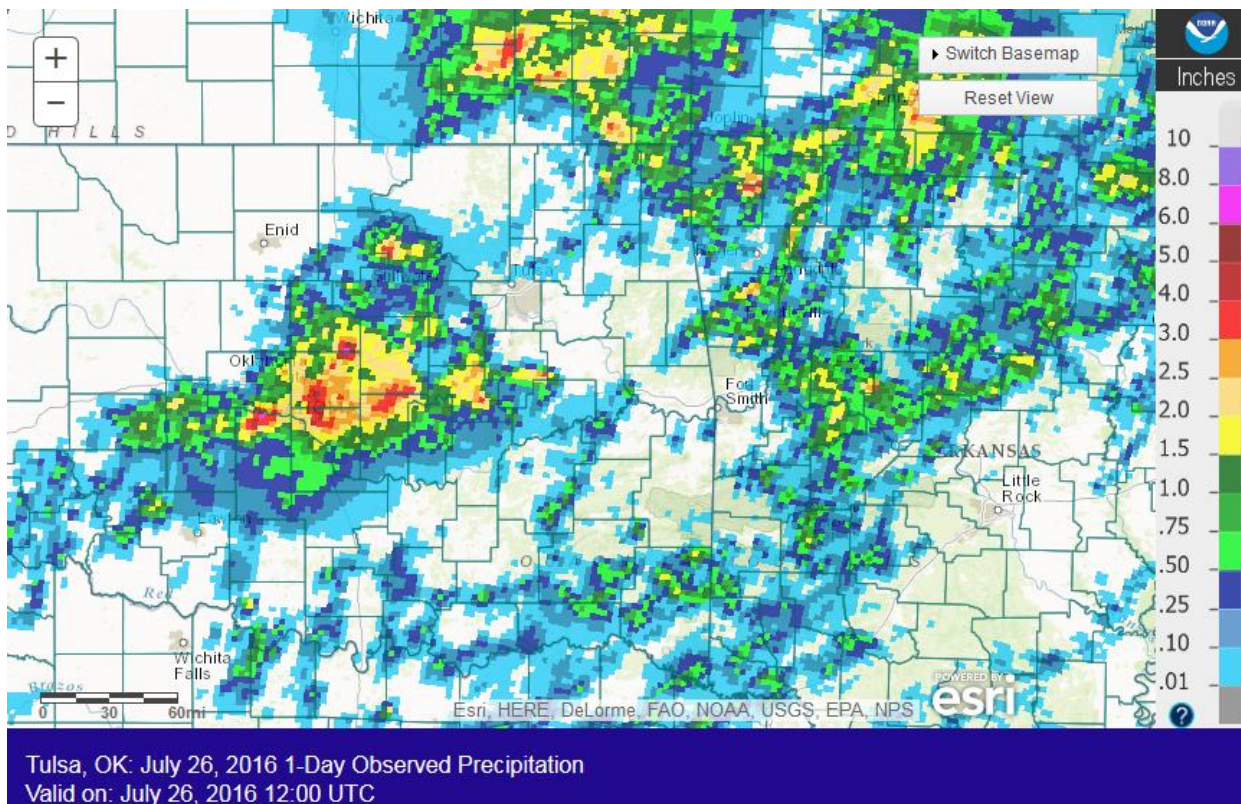


Fig. 15. 24-hour Estimated Observed Rainfall ending at 7am CDT 7/26/2016.

A moist and weakly capped airmass over the region allowed for scattered thunderstorm development the 26th-28th. Rainfall each of these days ranged from around 0.10" to 1.5", with 2"-3" in isolated spots.

In the pre-dawn hours of the 29th, a thunderstorm complex moved out of south central KS into north central OK. As it moved further south, it weakened and affected locations mainly west of Hwy 75. Rainfall was generally 0.50" to 2.5". However, these storms did spark additional thunderstorms over Creek County, which then moved east-southeast across east central OK and into west central AR before exiting the region mid-afternoon. These storms brought 0.25" to around 1.5" of rain, with around 3" in western Wagoner County. Late day heating and a left-over outflow boundary resulted in further storm initiation over far southeast OK. These storms produced 0.25" to near 1.5" of rain before moving south of the Red River around midnight.

Thunderstorms moved in from the west on the morning of the 30th, traversing northeast OK and northwest AR along and north of I-40. Additional storms developed along the terrain of far southeast OK during the afternoon. During the early morning hours, scattered storms developed over northwest AR. These storms moved east of the area by sunrise on the 31st. Rainfall totals ranged from 0.25" to near 2" in some spots. A few storms developed in east central OK during the afternoon, bringing some isolated areas of 0.25" to 1.5" of rain.

Written by:

Nicole McGavock
Service Hydrologist
WFO Tulsa

Products issued in July 2016:

*MLBA4 and OZGA4 transferred to NWS Tulsa HSA February 5, 2014

*Mixed case River Flood products began July 31, 2013

- 8 Flash Flood Warnings (FFW)
- 6 Flash Flood Statements (FFS)
- 1 Flash/Areal Flood Watches (FFA) (5 Watch FFA CON/EXT/EXA/EXB/CAN)
- 34 Urban and Small Stream Advisories (FLS)
- 1 Areal Flood Warnings (FLW)
- 0 Areal Flood Statements (FLS)
- 0 River Flood Warnings (FLW)
- 0 River Flood Statements (FLS)
- 1 River Flood Advisories (FLS) (2 Advisory FLS CON/EXT/CAN)
- 0 River Flood Watches (FFA) (0 Watch FFA CON/EXT/CAN)
- 0 River Statements (RVS)
- 0 Hydrologic Outlooks (ESF)
- 0 Drought Information Statements (DGT)

Preliminary Hydrographs:

