Actuarial Weather Extremes
September 2019

Actuarial Weather Extremes: September 2019

Two Powerful Ocean-Borne Storms and a Heat/Dry Spell in the U.S. Southeast

Overview

This report is the sixth in a monthly series that was launched in April 2019. Each report covers extreme weather events that occurred in the month prior to the report's issuance. While the focus is upon weather events in North America, we periodically cover extreme weather events in other regions.

This report highlights three major weather events that occurred during September 2019:

- Hurricane Dorian, which struck the Bahamas with unprecedented force on September 1, and then marched slowly to the north, producing heavy rain and storm surge along the U.S. east coast and as far north as Nova Scotia and Prince Edward Island.
- Tropical Storm Imelda, which parked itself over southeastern Texas from September 17 to 21, exposing some areas to several consecutive days of extraordinarily heavy rainfall.
- A lengthy period of high heat in the southern and eastern United States (U.S.), resulting in the hottest September in the last six decades for many locations ranging from Texas to Ohio. In addition, most of the Southeast received little or no rain, resulting in monthly precipitation totals that were well below normal levels.

To evaluate the heat/dry spell in the U.S. Southeast, Global Historical Climatology Network ("GHCN") data[1] was used to rank temperature and precipitation observations for September 2019 against September observations from 1960 through 2018. The appendix provides a detailed description of our approach for ranking these observations.

For Dorian and Imelda, this report focuses on GHCN precipitation data. Of course, precipitation is only one dimension of these storms, particularly in the case of Dorian which produced both destructive wind speeds and dangerous storm surges[2]. However, we have chosen to focus on precipitation because we are still developing an understanding of the available databases for analyzing wind speed and storm surge. The GHCN data – the primary data source we have used thus far in this series of reports – is best suited for temperature and precipitation analyses.

Hurricane Dorian

On September 1, Dorian arrived at the Bahamas as a powerful Category 5 hurricane[3] with sustained wind speeds of 185 mph. Over the ensuing days, the storm weakened as it moved north along the U.S. coastline, declining to a Category 1 hurricane by the time it made landfall in Cape Hatteras, North Carolina on September 6. Thereafter, Dorian moved off the U.S. shore, traveling rapidly in a northeastern direction. During this period the storm regained some power, rebuilding itself into a Category 2 hurricane[4]. On September 7 and 8, Dorian hit the Canadian provinces of Nova Scotia, New Brunswick and Prince Edward Island, before finally heading east into the open ocean. Significant rainfall occurred from Florida to Virginia, as well as in southeastern Canada (Figure 1), with the heaviest precipitation falling in North and South Carolina (Table 1).

[1] The GHCN database contains daily weather observations from over 100,000 weather stations worldwide, covering over 180 countries. The GHCN database is hosted by the National Oceanic and Atmospheric Administration (NOAA) and is available for download from NOAA's website.

[2] https://www.nhc.noaa.gov/surge/

[3] "Category 5" is the maximum wind-speed rating as determined by the Saffir-Simpson Hurricane Wind Scale: https://www.nhc.noaa.gov/aboutsshws.php

[4] https://www.vox.com/energy-and-environment/2019/9/7/20854389/hurricane-dorian-death-category-canada-nova-scotia-bahamas-abaco-north-south-carolina

Table 1

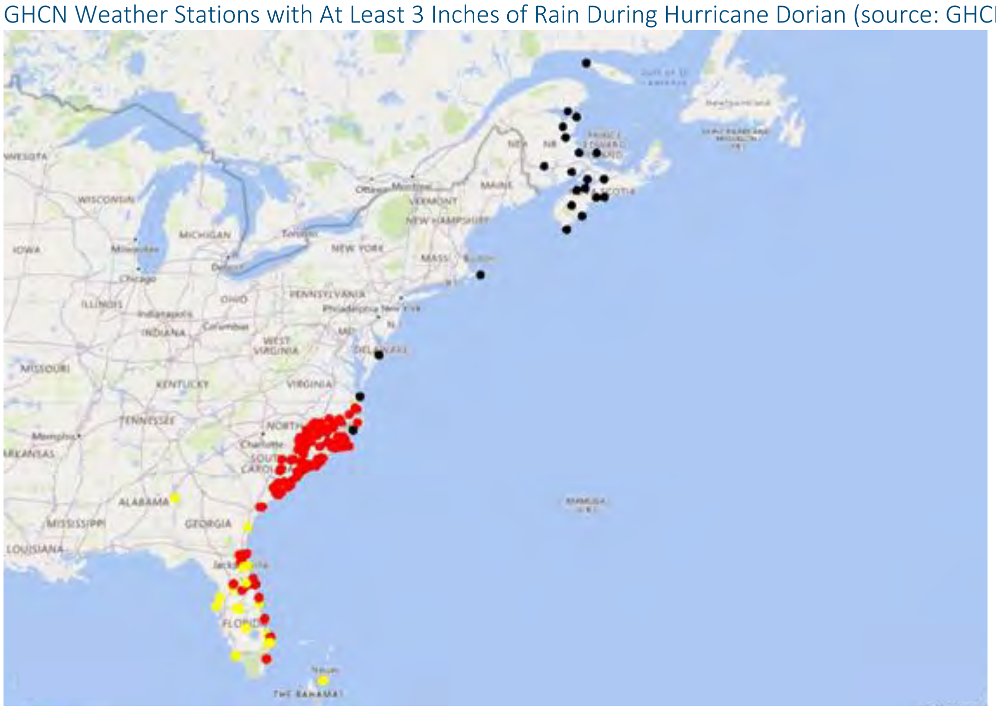
Top Ten Cumulative Rainfall Totals During Hurricane Dorian (source: GHCN data)

City or Name of Weather Station	State	Total Rainfall (Inches)	Rainfall on Peak Day (Inches)	Peak Day	% Ranking of Peak-Day Rainfall
PAWLEYS ISLAND 5.6 NNE	SC	15.2	10.1	Sept 6	100.0%
PAWLEYS ISLAND 2.6 N	SC	14.8	9.3	Sept 6	99.9%
GEORGETOWN CO AP	SC	13.6	13.4	Sept 5	100.0%
WILMINGTON 8.0 ENE	NC	13.2	10.2	Sept 6	100.0%
MYRTLE BEACH 5.2 SW	SC	12.8	7.1	Sept 6	99.5%
SWANSBORO 1.4 N	NC	12.7	6.7	Sept 6	99.1%
WILMINGTON 7.3 NE	NC	12.6	10.1	Sept 6	99.8%
MCCLELLANVILLE 7 NE	SC	12.6	10.4	Sept 5	99.9%
GEORGETOWN 11.2 SW	SC	12.2	6.4	Sept 6	100.0%
MYRTLE BEACH 9.2 WSW	SC	11.6	6.1	Sept 6	99.5%

The column on the far right shows the percentile ranking of the peak day's rainfall. A ranking of 100% indicates a record relative to historical data from 1960 onwards, using a 10-day radius around the particular calendar day. A value of 99.5% indicates that the rainfall exceeded 99.5% of historical observations. The appendix provides a detailed description of the ranking methodology.

Figure 1

GHCN Weather Stations with At Least 3 Inches of Rain During Hurricane Dorian (source: GHCN data)



Color codes for day of peak rainfall:

Yellow = on or before September 3

Red = Sept 4, 5 or 6

Black = Sept 7 or 8

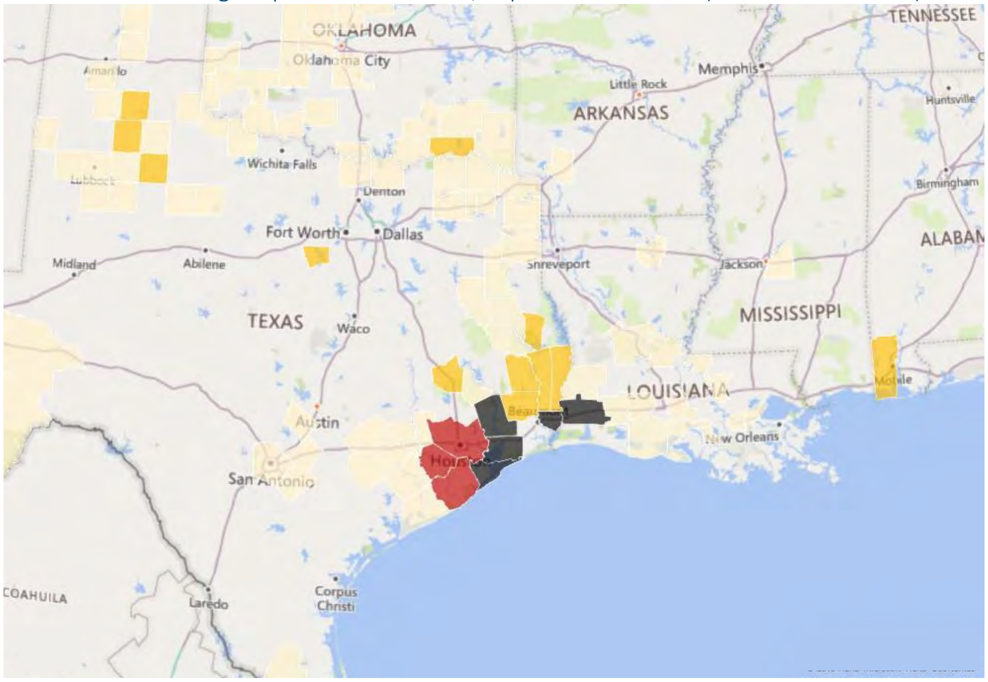
Tropical Storm Imelda

As its name indicates, Tropical Storm Imelda lacked the power of a hurricane. With a maximum sustained wind speed of 40 mph recorded at Freeport, Texas on September 17, the storm fell significantly short of the 74-mph threshold required to be classified as a Category 1 hurricane. Furthermore, about 9 hours after making landfall near Freeport, Imelda's wind speed declined below the 39-mph threshold required to be considered a tropical storm; as a result, the storm was reclassified as a "tropical depression."

While the storm lacked hurricane-force winds, it was nevertheless a potent producer of heavy rain, in part because it moved quite sluggishly across southern Texas, lingering over the region for several days. Across this period, cumulative rainfall was substantial (Table 2 and Figure 2). However, compared to Hurricane Harvey which struck Texas and Louisiana in 2017, Imedla affected a much smaller area and produced less rain (Table 3 and Figure 3).

Figure 2

Rainfall Totals During Tropical Storm Imelda, September 17 to 21 (source: GHCN data)



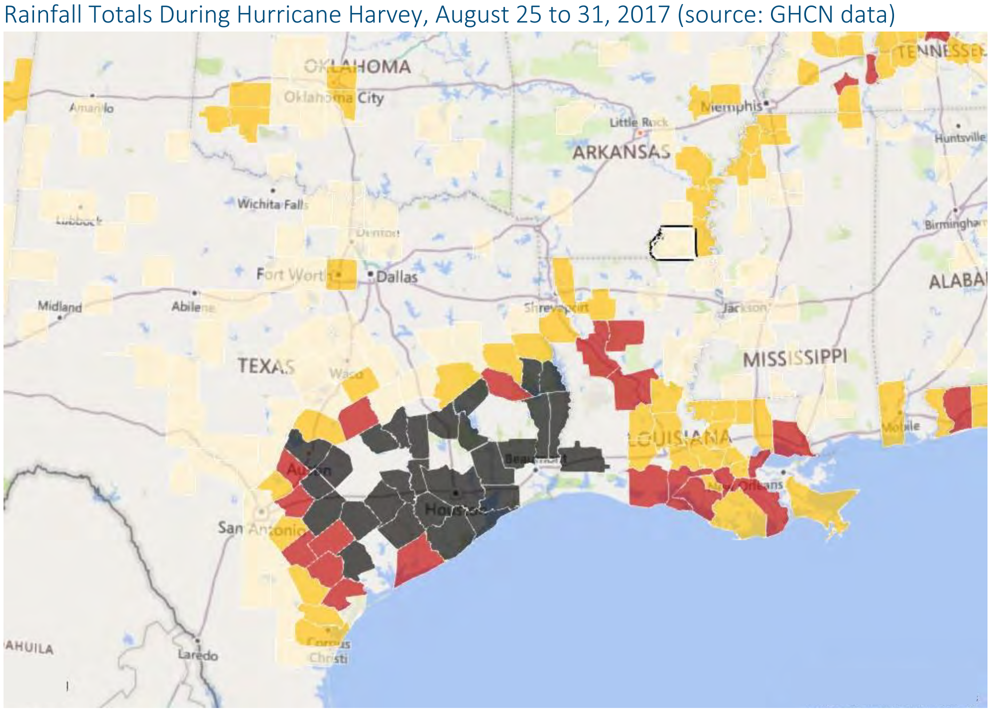
This map shows rainfall totals for the period from September 17 to 21, 2019. For those counties with more than one GHCN weather station, the station with the maximum rainfall was used. Note that not every county has a GHCN weather station and, as a consequence, the map may understate the geographic footprint of the storm.

The color codes for cumulative rainfall are as follows:

Black = 15+ inches
Red = 10 to 15 inches
Orange = 5 to 10 inches
Tan = 2 to 5 inches

Figure 3

Rainfall Totals During Hurricane Harvey, August 25 to 31, 2017 (source: GHCN data)



This map shows rainfall totals for August 25 to 31, 2017. For those counties with more than one GHCN weather station, the station with the maximum rainfall was used. Note that not every county has a GHCN weather station and, as a consequence, the map may understate the geographic footprint of the storm.

The color codes for cumulative rainfall are as follows:

Black = 15+ inches
Red = 10 to 15 inches
Orange = 5 to 10 inches
Tan = 2 to 5 inches

Table 2

Top Ten Cumulative Rainfall Totals During Tropical Storm Imelda (source: GHCN data)

City or Name of Weather Station	State	Total Rainfall (Inches)	Rainfall on Peak Day (Inches)	Peak Day	% Ranking of Peak-Day Rainfall
ROMAN FOREST 1.9 ENE	TX	33.0	16.9	Sept 19	100.0%
BEAUMONT 3.3 SW	TX	30.4	14.3	Sept 19	100.0%
BEAUMONT RSCH CTR	TX	27.6	19.4	Sept 19	100.0%
PORT ARTHUR SE TX AP	TX	22.8	11.6	Sept 19	99.9%
NEDERLAND 1.8 W	TX	21.5	11.0	Sept 19	100.0%
GALVESTON 6.4 NE	TX	20.6	7.3	Sept 18	99.8%
DAYTON 0.2 E	TX	19.9	9.0	Sept 19	100.0%
GALVESTON 8.3 NE	TX	19.2	8.6	Sept 18	100.0%
DAYTON 1.1 SE	TX	18.1	11.0	Sept 19	100.0%
GALVESTON 5.6 NE	TX	18.0	6.2	Sept 18	99.8%

Total rainfall is computed from Sept 17 to 21. The column on the far right is the percentile ranking of the peak day's rainfall. A ranking of 100% indicates a record relative to historical data from 1960 onwards, using a 10-day radius around the particular calendar day. A value of 99.8% indicates that the rainfall exceeded 99.8% of historical observations. The appendix provides a description of the ranking methodology.

Table 3

A Comparison of Rainfall Totals for Tropical Storm Imelda versus Hurricane Harvey (source: GHCN data)

Total Multi-Day Rainfall	Number of GHCN Stations		Number of Counties		Square Miles (1000s)	
	Imelda	Harvey	Imelda	Harvey	Imelda	Harvey
Greater than 2 Inches	303	1353	84	198	77	164
Greater than 5 Inches	107	800	18	94	18	84
Greater than 10 Inches	59	430	9	56	10	51
Greater than 15 Inches	16	295	6	38	5	34
Greater than 20 Inches	6	193	3	25	3	24
Greater than 30 Inches	2	79	2	12	2	12
Greater than 40 Inches	0	21	0	6	0	6

The totals above are restricted to Texas, Louisiana, Mississippi, Oklahoma, Arkansas, Alabama and Tennessee. However, remnants of Hurricane Harvey had an impact beyond these states. Some counties have more than one GHCN station; in these cases, the station with the largest rainfall was used for the analysis. The "square miles" column is the total area of the affected counties.

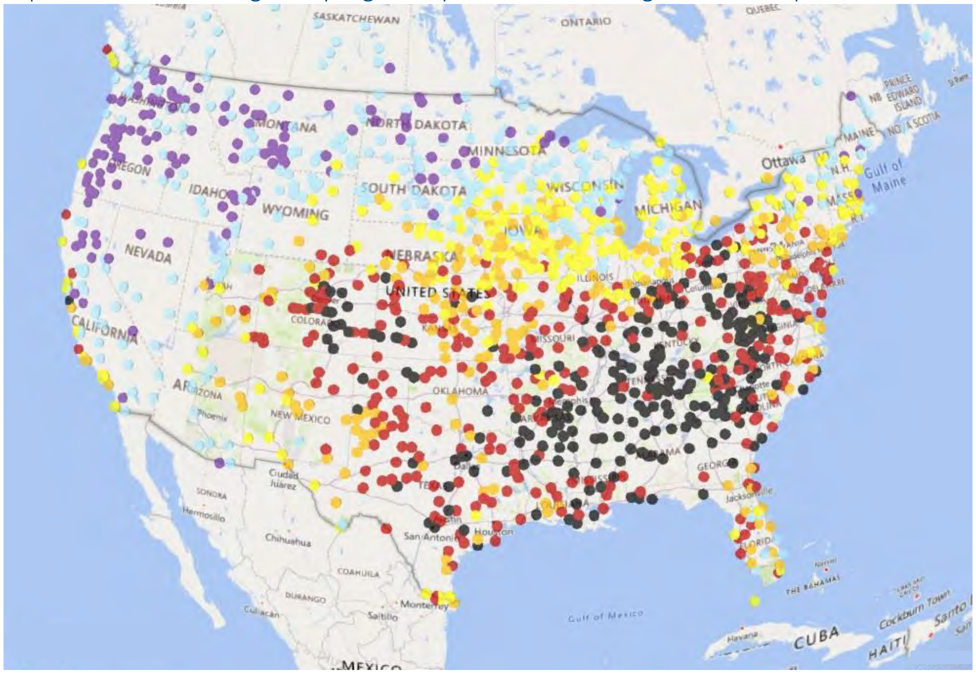
A Prolonged Period of High Heat and Low Precipitation in Southeastern U.S.

Across the southeastern U.S., temperatures were consistently well above normal for much of September. Indeed, ranked against the past 59 Septembers from 1960 through 2018, September of 2019 was the hottest month for many GHCN weather stations ranging from Texas to Ohio (Figures 4 and 5). In contrast, the western and northern portions of the U.S. experienced below-normal temperatures. The high heat in the Southeast was coupled with a lack of rain, with monthly precipitation totals well below normal levels (Figures 6, 7 and 8).

This contrast between the Northwest and Southeast is attributable, in part, to a jet stream that spent much of the month in an unusual pattern, with a trough close to the border of Mexico and New Mexico, and, downstream from this trough, a peak well to the north of the Great Lakes. Thus, the jet stream bisected the U.S., allowing cool weather to penetrate the Northwest, while encouraging unusual warmth and dryness to persist across the Southeast.

Figure 4

September 2019 Average Daily High Temperature Ranked Against Each September from 1960 to 2018



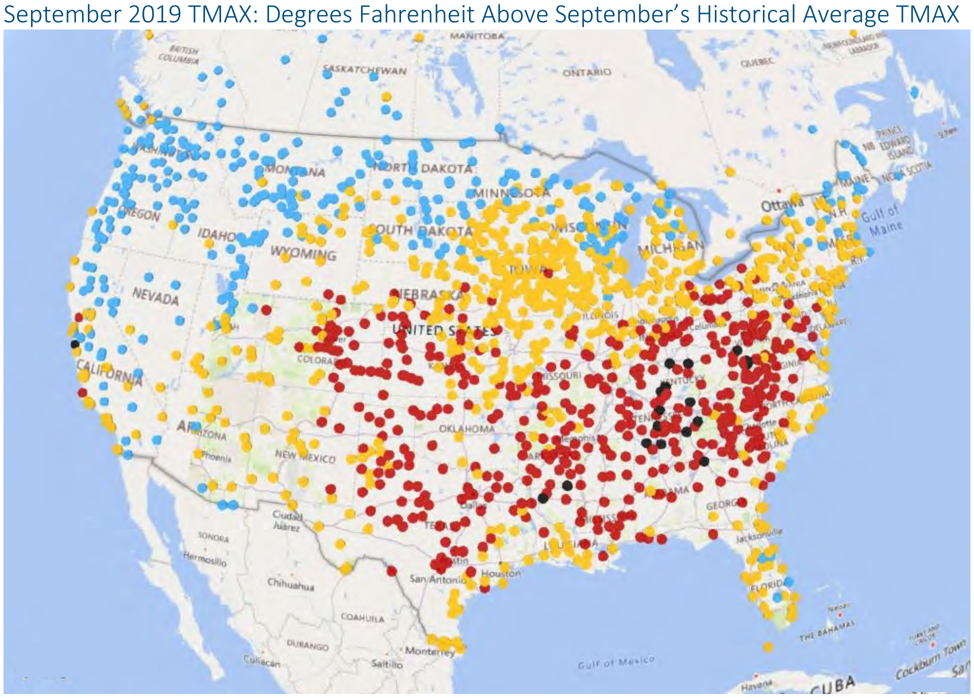
The average daily high temperature (TMAX) for September 2019 was compared to the corresponding value computed for each of the 59 Septembers from 1960 to 2018. A rank of "1" indicates that the September 2019 TMAX exceeds each of the 59 historical results.

The map's color codes are as follows:

Black = rank of 1
Red = rank between 2 to 5
Orange = rank btwn 6 to 10
Yellow = rank btwn 11 to 20
Light blue = rank 21 to 40
Dark blue = rank 41 to 60

Figure 5

September 2019 TMAX: Degrees Fahrenheit Above September's Historical Average TMAX



The average daily high temperature (TMAX) for September 2019 relative to the average TMAX computed across the 59 Septembers from 1960 to 2018.

The map's color codes for degrees above average are as follows:

Black = at least 10 degrees Fahrenheit above average

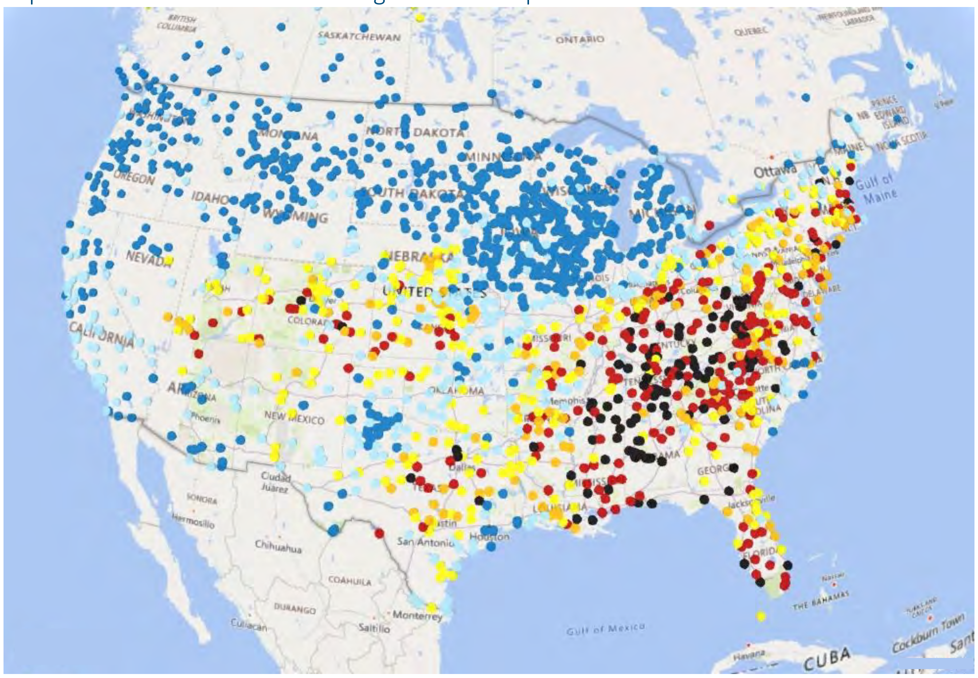
Red = 5 to 10 degrees Fahrenheit above average

Orange = 0 to 5 degrees Fahrenheit above average

Blue = below average

Figure 6

September 2019 Rainfall Ranked Against Each September from 1960 to 2018

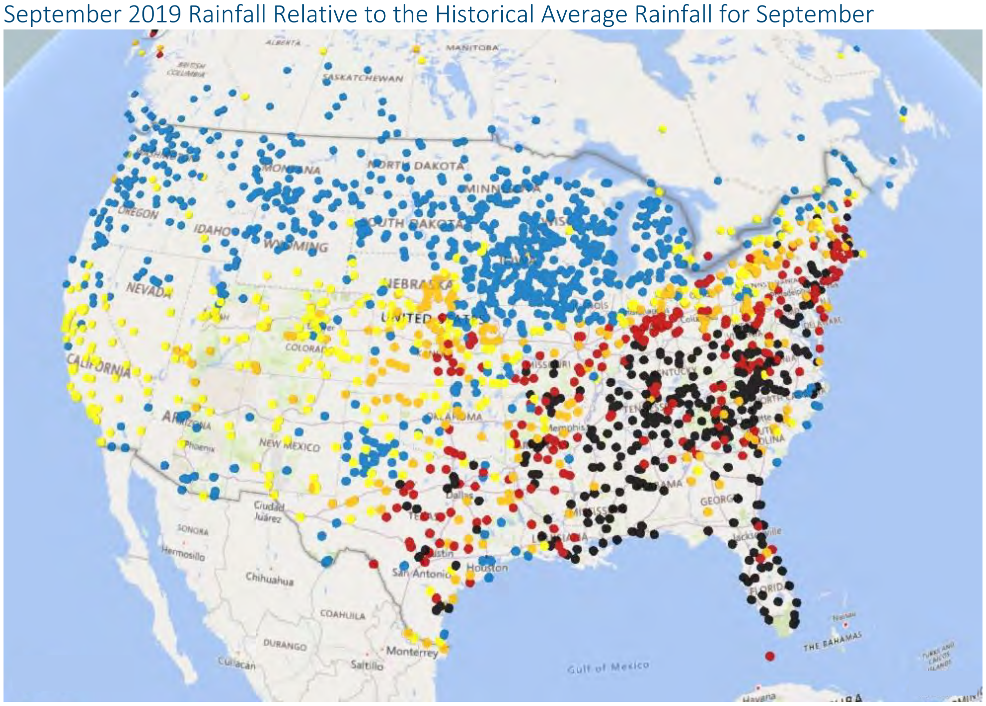


Total rainfall for September 2019 was compared to the corresponding value computed for each of the 59 Septembers from 1960 to 2018. A rank of "1" indicates that the September 2019 rainfall was the ***lowest*** on record. That is, the rank is a measure of dryness as opposed to wetness. The map's color codes are as follows:

Black = rank of 1
Red = rank between 2 to 5
Orange = rank btwn 6 to 10
Yellow = rank btwn 11 to 20
Light blue = rank 21 to 40
Dark blue = rank 41 to 60

Figure 7

September 2019 Rainfall Relative to the Historical Average Rainfall for September



Total rainfall for September 2019 was compared to the average rainfall computed across the 59 Septembers from 1960 to 2018.

The map's color codes are as follows:

Black = September 2019 rainfall 3+ inches below the historic average

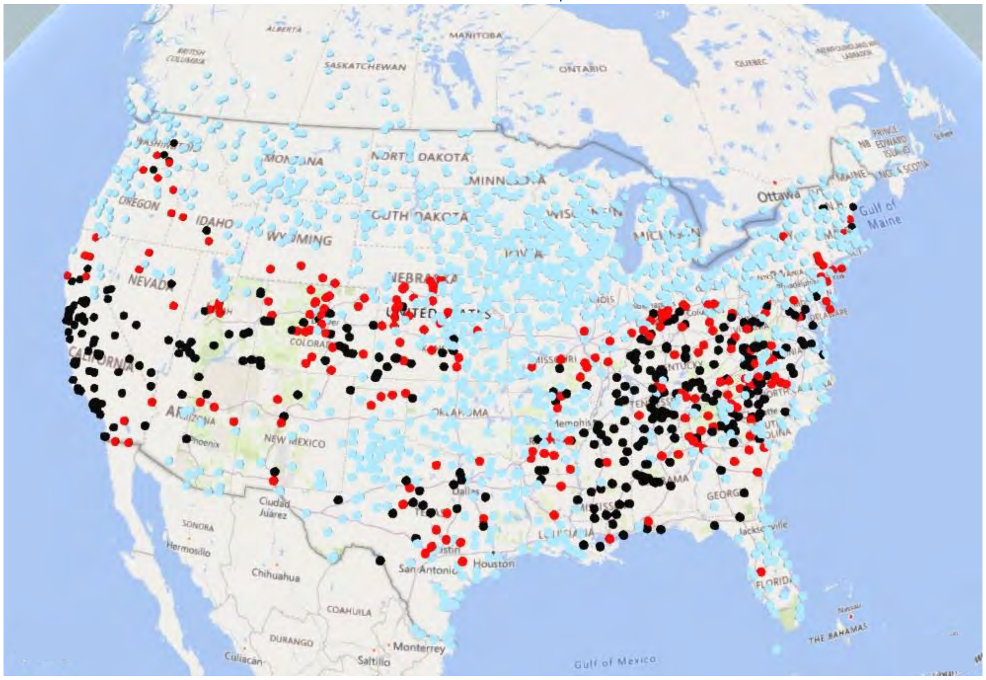
Red = 2 to 3 inches below average

Orange = 1 to 2 inches below average

Yellow = 0 to 1 inch below average

Blue = average or above average rainfall

Figure 8
Weather Stations with Less than 1 Inch of Rain in September 2019



The map's color codes are as follows:

Black = weather stations that received less than 0.5 inches of rain in September 2019

Red = 0.5 to 1.0 inches of rain in September 2019

Blue = More than 1 inch of rain in September 2019

Rough Assessment of the Losses Caused by Recent Extreme Weather

Economic and insured losses are often difficult to estimate in the immediate aftermath of an extreme weather event. With the passage of time, the extent of the losses gradually becomes clearer. Below, we offer a rough assessment of the cost of some of the weather events covered in our reports over the last few months:

September: Hurricane Dorian

While Dorian had an impact in the U.S. and Canada, losses are heavily concentrated in the Bahamas where the storm was at its greatest strength. According to the Wall Street Journal, as of September 22 the death count stood at 53, with over 1300 people still missing. Total property losses in the Bahamas are estimated at $7 billion[5].

September: Tropical Storm Imelda

According to the USA Today, the storm has been linked to five deaths[6], and AON estimates that economic losses will run into the hundreds of millions (of dollars)[7].

September: Heat/Dry Spell in the U.S. Southeast

According to the Wall Street Journal[8], the unusual heat and dryness in the U.S. Southeast is having negative effects on agriculture. Potential effects include damage to grass used to feed livestock and damage to the cotton crop. In addition, the dry soil makes it more challenging to harvest peanuts. The Baltimore Sun (a newspaper) indicates that the drought is affecting soybean crops and could even affect next year's wheat crop which must be planted this fall[9].

---

[5] https://www.wsj.com/articles/opening-the-door-to-hell-itself-bahamas-confronts-life-after-hurricane-dorian-11569176306
[6] https://www.usatoday.com/story/news/nation/2019/09/21/texas-flooding-tropical-storm-imelda-death-toll-increases-5/2402290001/
[7] https://www.reinsurancene.ws/storm-imelda-losses-will-reach-into-hundreds-of-millions-aon/
[8] https://www.wsj.com/articles/flash-drought-hits-south-as-record-heat-continues-into-fall-11570058348
[9] https://www.baltimoresun.com/weather/bs-md-drought-report-20190926-yooqxwbbuvcldise7a4oisugtm-story.html

August: Heavy Monsoon Rains in India

According to a Reuters' article published on August 14, heavy rains in the first half of August caused floods and landslides that displaced over one million persons in India and led to 270 deaths[10]. An article in Business Today[11] on August 16 indicates that coffee yields in the states of Karnataka, Kerala and Tamil Nadu are expected to decline by 30% to 40% due to August's rains and floods. Sugarcane, cotton and apple yields are also likely to be reduced[12].

Because India's monsoon season is volatile weather phenomenon with significant rainfall variation from year to year, month to month, and region to region, flood-induced fatalities and economic losses are not unusual in India. According to data from India's Central Water Commission, across the period from 1953 to 2017 an average of 1600 persons died each year due to heavy rains and floods, and across the 5-year period from 2013 to 2017, the average was 1953[13].

August: Heat Wave in Alaska

During August, large numbers of dead salmon were found in several Alaskan rivers[14]. According to observers, the fish died prior to spawning, whereas salmon typically die only after spawning. Some researchers are attributing these premature deaths to unusually high river temperatures caused by a combination of high air temperatures and lack of rain[15].

July: Heat Waves in the U.S. and Europe

Fortunately, few human lives were lost in these heat waves. In regard to economic costs, an assessment is difficult. Some examples of the impact of the heat waves are as follows: (1) in both Germany and France, a number of nuclear power plants had to be taken offline, thus temporarily reducing total power generation[16]; (2) in the United Kingdom, railway service was disrupted because the unusually high temperatures caused train tracks to expand or kink[17]; (3) in the United Kingdom, thousands of chickens died in a farmhouse that lacked a cooling system[18]; and (4) on a farm in the Netherlands, over 2000 pigs suffocated[19] after a ventilation system failed during the heat wave.

July 13-16: Hurricane and Tropical Storm "Barry"

Over $600 million in economic losses and nearly $300 million in insured losses, according to industry experts.

June 21-22: Derecho in Central and Eastern U.S.

An extreme wind event known as a "derecho" caused damage across a 1000-mile path from Nebraska to South Carolina. Thousands of structures affected, with economic losses estimated to be over $100 million by industry experts.

May: Severe Weather in U.S. Plains, Midwest and Southeast

Tornadoes, straight-line winds, hail, flooding: close to $3 billion of economic losses and $2 billion of insured losses, according to industry experts.

May to June: Flooding in U.S. Breadbasket

Flooding has had a significant impact on farmers' ability to plant crops this year. Economic and insured losses are estimated to be in excess of $4 billion by industry experts.

---

[10] https://www.reuters.com/article/us-southasia-floods/india-floods-kill-more-than-270-displace-one-million-idUSKCN1V413K

[11] https://www.businesstoday.in/current/economy-politics/karnataka-floods-landslides-brew-fresh-troubles-coffee-second-year-straight/story/372972.html

[12] https://economictimes.indiatimes.com/news/economy/agriculture/sugarcane-cotton-apple-crops-hit-by-late-rainfall-pan-india/articleshow/70744401.cms

[13] https://www.business-standard.com/article/current-affairs/at-107-487-india-accounts-for-1-5th-of-global-deaths-from-floods-in-64-yrs-118071900052_1.html

[14] https://time.com/5661024/alaska-high-temperatures-salmon-deaths/

[15] https://observers.france24.com/en/20190821-salmon-die-alaska

[16] https://www.reuters.com/article/us-france-electricity-heatwave/hot-weather-cuts-french-german-nuclear-power-output-idUSKCN1UK0HR

[17] https://www.telegraph.co.uk/news/2019/07/25/uk-heatwave-britain-bracing-hottest-day-record-temperature-could/

[18] https://www.independent.co.uk/news/uk/home-news/chicken-uk-heatwave-farm-deaths-lincolnshire-tesco-sainsbury-a9025516.html

[19] https://veganuary.com/blog/over-2000-pigs-suffocate-on-factory-farm-as-ventilation-system-fails/

Data

The temperature and precipitation data used in this report was obtained from the Global Historical Climatology Network ("GHCN") weather database, which provides daily weather observations from over 100,000 weather stations worldwide, covering over 180 countries. The database is publicly available through the National Oceanic and Atmospheric Administration (NOAA) via the following FTP site:

ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/daily/

Filename = ghcnd_all.tar.gz

Methods

To rank each daily rainfall observation for tables 1 and 2, we used GHCN data from 1960 to 2018 that falls within a 10-day radius of the particular day of interest. In addition, for weather stations that have short data histories, we pooled data from stations within a 10-mile radius, thereby creating a larger historical dataset against which to compare current or recent observations.

For example, consider a precipitation (PRCP) observation of 10.0 inches recorded on September 19, 2019 by a weather station in Vidor, Texas. To rank this observation, a PRCP distribution was compiled from the station's historical data, using observations from dates falling between September 9 and September 29 (a 10-day radius around September 19). Because this particular station has only 3 years of historical data, our ranking algorithm pooled data from nearby stations, resulting in a dataset with a total of 840 days of historical observations. Against this data, the September 19, 2019 measurement of 10.0 inches falls in the 99.8th percentile, which means that only 0.2% of historical observations were in excess of 10 inches.

To produce the temperature analysis shown in figures 4 and 5, we used GHCN's "TMAX" field which captures daily high temperature. Only weather stations with at least 55 years of September data from 1960 to the present were included in the analysis. For each station, the average TMAX across the 30 days of September was computed for each year from 1960 to 2019. The average TMAX for September 2019 was then ranked against the 1960 to 2018 data. An analogous approach was used for the precipitation analysis shown in Figures 6 through 8.

SOA Research Team for This Report

Patrick Wiese, ASA and Rob Montgomery, ASA, MAAA, FLMI

About the Society of Actuaries

With roots dating back to 1889, the Society of Actuaries (SOA) is the world's largest actuarial professional organization with more than 30,000 actuaries as members. Through education and research, the SOA advances actuaries as leaders in measuring and managing risk to improve financial outcomes for individuals, organizations, and the public.

As part of its work, the SOA seeks to inform public policy development and public understanding through research. The SOA aspires to be a trusted source of objective, data-driven research and analysis with an actuarial perspective for its members, industry, policymakers and the public. This distinct perspective comes from the SOA as an association of actuaries, who have a rigorous formal education and direct experience as practitioners as they perform applied research. The SOA also welcomes the opportunity to partner with other organizations in our work where appropriate.

Society of Actuaries
475 N. Martingale Road, Suite 600
Schaumburg, Illinois 60173
www.SOA.org