TEXAS CoCoRaHS OBSERVER

Fall 2018

Welcome to the Texas CoCoRaHS Observer newsletter.

The purpose of this newsletter is to keep observers informed of the latest news, events and happenings related to the CoCoRaHS program here in Texas, as well as news about the latest weather patterns affecting each region of Texas.

If you would like to have a presentation done for your group or organization about CoCoRaHS, please send an e-mailtoTexas@CoCoRaHS.org

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CoCoRaHS Data is Essential, and You Should See How

The following article by Greg Story published in the "Texas Weather Journal" illustrates the importance of CoCoRaHS observer's daily observations to river forecasting. This real-life example is just another reason why CoCoRaHS observer's make their walk outside every morning to read their gauge and to report at the usual reporting time of 7:00 A.M. This timely data is ingested into computer models which are run that morning along with other official data to produce various forecasts for the next 24 hours and beyond.

We hope you will enjoy reading and seeing how your data is used everyday. Think your observations aren't important? Think Again!

The following article was originally published in the Texas Water Journal (texaswaterjournal.org) in 2018, Volume 9, Number 1, September 21, 2018 and was first published in the Texas Weather Journal on that date. Published here with permission from the Texas Water Journal.

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Integration of the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) observations into the West Gulf River Forecast Center operations

Gregory J. Story[1*]

Abstract: This article will introduce the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network and illustrate its integration into the daily operations at the National Weather Service West Gulf River Forecast Center (WGRFC). An example will be shown on how the data were used during a specific flood event and will illustrate our extensive use of this data during Hurricane Harvey. The benefits of this network will be discussed. The network provides the WGRFC a source of rain gauge data where other sources of rainfall data are sparse and allows for verification of radar-based precipitation estimates. Members of CoCoRaHS provide observations that are vital in assisting the WGRFC with flood forecasting operations. Information on joining this important network is presented in this article.

Keywords: rainfall, observers, floods

Integration of CoCoRaHS observations

Terms used in paper

Acronyms	Descriptive name
CoCoRaHS	Community Collaborative Rain, Hail and Snow
HRAP	Hydrologic Rainfall Analysis Project
MPE	Multisensor Precipitation Estimate
NSF	National Science Foundation
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RFC	River Forecast Center
UTC	Coordinated Universal Time
USGS	U.S. Geological Survey
WSR	Weather Service Radar
WGRFC	West Gulf River Forecast Center

INTRODUCTION

In Story (2016), Texas Water Journal readers were introduced to the mission of the hydrologic program of the National Weather Service (NWS). The NWS West Gulf River Forecast Center (WGRFC), in cooperation with numerous federal, state, and local government entities, uses the latest science and technology to provide timely and accurate river forecasts for most of the river drainages in Texas in an effort to protect life and property. River response and flood potential often depend on the magnitude of each rainfall event. Prior to real-time weather tracking systems, the river forecast centers (RFCs) were faced with using daily rainfall totals from sparse sources, such as airport rain gauges, automated river rain gauges, and NWS co-operative observers. Due to the limited spatial distribution of the gauges, often the most intense rainfall amounts would be missed. This lack of information limited the RFCs' ability to provide real-time or near-real-time flood forecasts, often resulting in the river forecast crests being too low and the timing of those crests being late.

Since the advent of the Weather Service Radar-1988 Doppler (WSR-88D) radars in the mid-1990s, forecasters have been able to receive precipitation estimates each hour. While these estimates give much improved spatial and temporal resolution, the actual amounts of rainfall can be in considerable error. Therefore, dependable rainfall observations from gauges are still necessary. A rainfall network began 20 years ago that helps determine the accuracy of radar-based precipitation estimates. This is the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network.

WHAT IS COCORAHS?

CoCoRaHS is a non-profit, community-based network of volunteers of all ages and backgrounds who work together to measure and map precipitation (rain, hail and snow). CoCoRaHS is now in all 50 states, Puerto Rico and the U.S. Virgin Islands, the Bahamas, and Canada. The network originated with the Colorado Climate Center at Colorado State University in 1998, inspired in part by the Fort Collins flood the prior year (Reges et al. 2016). Since the beginning of this network, the WGRFC has seen the benefits of this precipitation data (as the WGRFC has river forecast responsibility in southern Colorado). In the years since, more than 6,100 Texans have joined CoCoRaHS, and more than 62,000 volunteers have joined nationwide (CoCoRaHS website 2018). While many of these observers have moved, passed on, or lost interest over time, the WGRFC receives around 1,000 CoCoRaHS observervations

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per day. Volunteers agree to take precipitation measurements and are asked to report even on days when no precipitation has occurred. We hope to receive rain reports from as many locations as possible. These precipitation reports are entered either through the CoCoRaHS website (www.cocorahs.org) or through an application on a mobile smart phone. The data are then recorded in a central archive at CoCoRaHS headquarters and made available to the public in near-real time on the CoCoRaHS website. The data are displayed and organized for many end users to analyze daily, with purposes ranging from water resource analysis and severe storm warnings to neighbors comparing how much rain fell in their backyards. CoCoRaHS is used by a wide variety of organizations and individuals. Aside from the NWS, meteorologists, hydrologists, and emergency managers routinely use this resource. Additionally, CoCoRaHS data benefit city utilities (for water supply, water conservation, or stormwater), insurance adjusters, agriculture, engineers, mosquito control personnel, ranchers and farmers, outdoor and recreation interests, teachers, students, and neighbors in the community.

CoCoRaHS has several goals: 1) to provide accurate high-quality precipitation data on a timely basis; 2) to increase the density of precipitation data available by encouraging volunteer weather observing; 3) to encourage citizens to have fun participating in meteorological science and heightening their awareness about weather; and 4) to provide enrichment activities in water and weather resources for teachers, educators and the community at-large. For its detailed mission statement, visit the link in the reference section (CoCoRaHS website 2018). Most importantly, this is a community project. The only requirements are that one have an enthusiasm for watching and reporting weather conditions, a desire to learn more about how weather can affect and impact our lives, and a good place to measure rainfall. By providing daily observations, one can help to fill in a piece of the weather puzzle that affects many across Texas. By using low-cost measurement tools, stressing training and education, and using an interactive website, the network's aim is to provide the highest quality data for natural resource, education and research applications, which can greatly aid flood forecasts and radar corrections. Both the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF) are primary sponsors of CoCoRaHS. Other organizations have contributed financially and/or with supplies and equipment. The list of sponsors continues to grow. Many other organizations and individuals have contributed time and resources to help keep the network running.

COCORAHS OBSERVATIONS AT WGRFC

Hydrometeorologists at WGRFC continuously monitor rainfall over their area of responsibility. As stated in Story (2016), the NWS uses rainfall estimates from multiple sources, but primarily from radars, in generating river forecasts. Precipitation estimates from the more than 24 WSR-88D radars with observations within the WGRFC area have allowed for better analysis of timing and areal distribution of precipitation. These rainfall estimates are adjusted based on comparisons to rain gauge data from all sources. These "best estimates" are used in NWS river forecasts models. Now, hundreds of 24-hour CoCoRaHS rainfall reports are available for post-analysis of this best estimate. Direct comparisons of the estimates and observer rainfall totals are made shortly after 1200 Coordinated Universal Time (UTC) (7 AM Central Daylight Time) each morning. These reports allow WGRFC's hydrometeorologists to determine areas where the radar-based estimates may be too low or too high. Forecasters can adjust estimates in specific hours to reproduce a 24-hour estimate that is more consistent with 24-hour gauge reports. The goal is to achieve a "general" level of acceptable error in the estimates. Computations are performed that show the correlation coefficient and percent bias of radar estimates, which vary by time and location. The goal is to modify the estimates to achieve minimum correlation coefficients (r) of 0.85 (an arbitrary in-house goal). Originally, most initial estimates are biased low (e.g. the 24-hour gauge reports are higher) and frequently have poor correlation. When initial radar-based estimates are linearly adjusted, which are spatially variable, the inherent error of most estimates is improved to the desired correlation ($r > 0.85$). Removal of this bias is crucial to improve flood forecasts. If these biases are not mitigated, a false identification of a flood wave that is too low might occur over time. An example of the WGRFC Gauge Check program is shown in Figure 1.

There are two types of CoCoRaHS reports used at the WGRFC. First, CoCoRaHS spotters can submit intense rainfall reports whenever the situation warrants. These reports are invaluable to forecasters, so much so that we have these reports trigger an "alarm" on our NWS workstations. Any observer can make a significant weather report. An example of the form an observer fills out on the CoCoRaHS website is shown in Figure 2.

An example of an intense rainfall report from Hurricane Harvey is shown in Figure 3.

Such reports are often a preemptive warning that rainfall may be occurring or even exceeding remotely sensed data from radar. It also allows WGRFC forecasters to adjust hourly estimates in near real time, improving flood forecasts.

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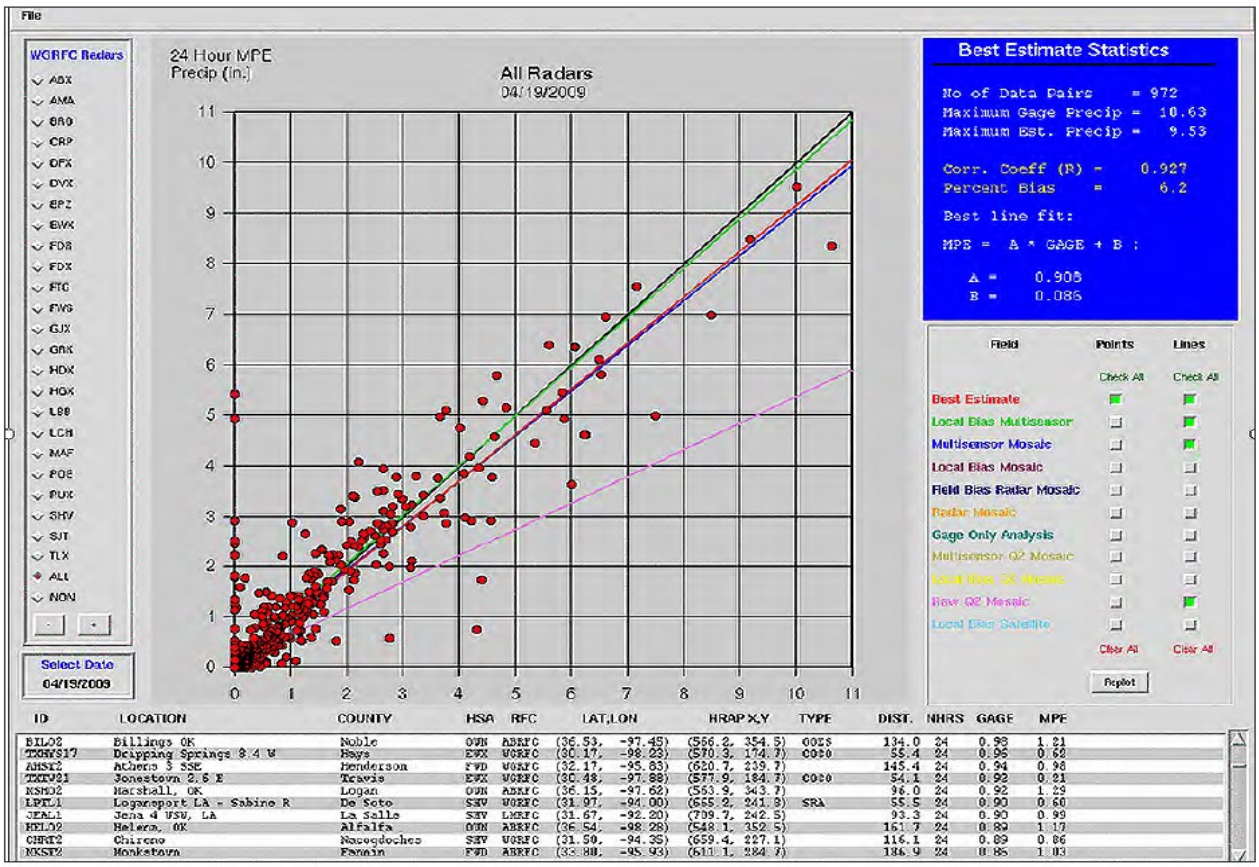

Figure 1. The Gauge Check Program used at WGRFC. Rain gauge values for the 24-hour period ending as 12 UTC (x-axis) are plotted against the associated Multisensor Precipitation Estimate (MPE) best estimate of precipitation (y-axis) at the location of that gauge. Values above the diagonal black line show an MPE overestimate, while values below indicate an underestimate. Colored lines show the calculation of MPE versus gauges for each radar-based field within MPE, with the red line being the final best estimate. The observations show a good correlation (R = 0.927) to radar estimates but is biased low by 6.2%. The MPE radar data are linearly adjusted to best match gauge data.

Second, the 24-hour CoCoRaHS rainfall measurements are ingested at the WGRFC through the morning, which are then compared to radar-based estimates (along with rain gauge observations from other sources). The CoCoRaHS rain gauge data are considered to be ground truth and one of the most readily available best data sources for radar corrections. Figure 4 shows an example from 2012 when CoCoRaHS reports from Ellis County helped improve a flood forecast:

In this example, the CoCoRaHS observer, who was located 0.6 of a mile west-southwest of Maypearl, gave us a rainfall reading of 4.51 inches. Our initial "best estimate" for that location was 2.60 inches, or about ½ the amount that fell. We went back to the hours it rained in this location and increased the radar-based estimates. This allowed us to match the CoCoRaHS amount in real time. This led to more runoff being calculated within our hydrologic model and produced a forecast hydrograph with higher runoff volumes than was originally produced. A small flood wave occurred on Chambers Creek that may have gone unforecasted had the CoCoRaHS gauge not shown the larger rainfall totals.

All 24-hour rainfall observations received from all sources, including the CoCoRaHS observations, are available each morning around 10 AM at: https://forecast.weather.gov/product.php?site=NWS&product=HYD&issuedby=FWR

This list can be used to compare all the rainfall readings in the WGRFC region.

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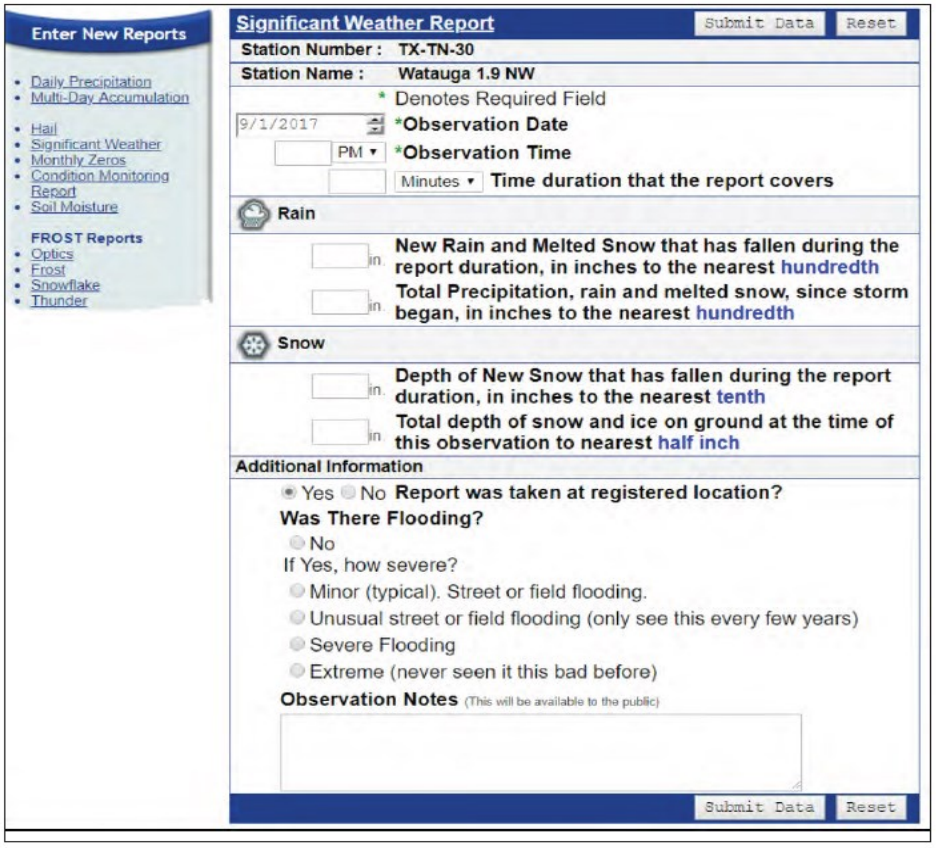

Figure 2. The significant weather report form for CoCoRaHS observers. This form can be used to report rainfall or snowfall of a short duration.

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intense rain report from CoCoRAHS spotter:

08/28/2017 12:00 AM local time
County: Brazos TX
College Station 1.6 S (number TX-BZS-92)
Latitude: 30.577365
Longitude: -96.31456
15.33 inches so far, with 0.28 inches in the past 60 mins
Flooding: Unusual
Comments: Hurricane Harvey rainfall from 2300-2359 on 8/27

Received NWS Boulder Sun Aug 27 23:09:31 2017 MDT
Sent to WFOs: HGX,FWD,FWR

All of today's CoCoRAHS observations are in WRKCCR (Boulder and Pueblo only)
Or at http://www.cocorahs.org (click on reports)
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Figure 3. An intense weather report from a CoCoRaHS observer during Hurricane Harvey reporting over 15 inches of precipitation and 0.28 inches in the last hour as received on a WGRFC text workstation.

Integration of CoCoRaHS observations

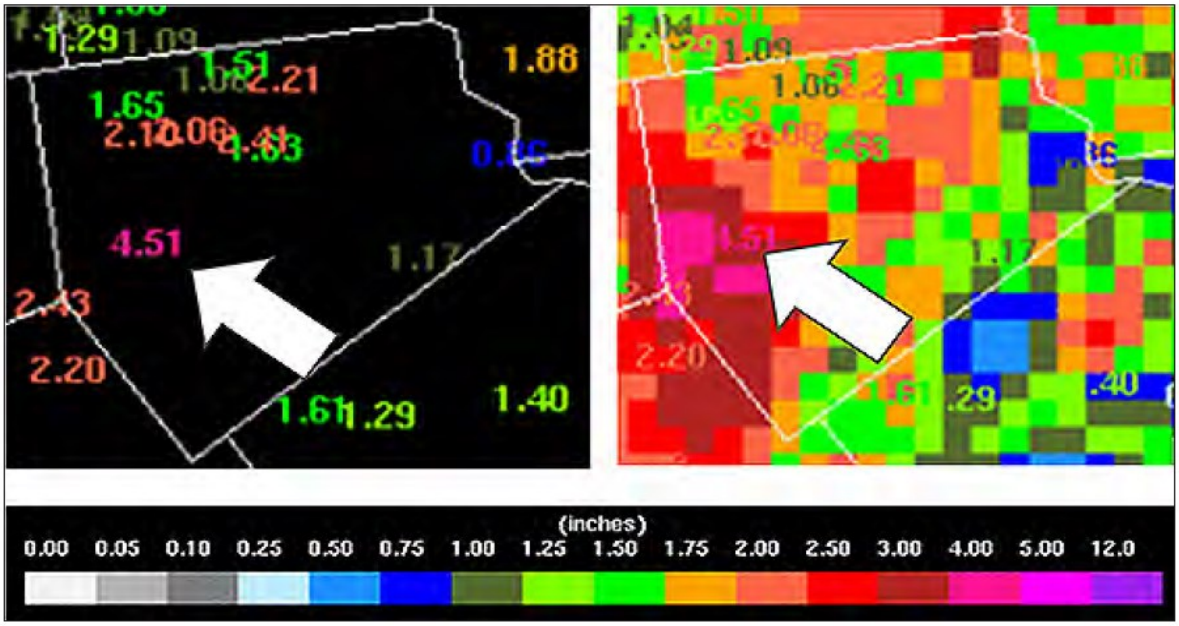

Figure 4. (Left) Location of CoCoRaHS gauge where initial underestimation was determined. Gauge values match the color scale. (Right) MPE final precipitation analysis with CoCoRaHS data overlaid after an adjustment was made to the 24-hour field. The arrow indicates where estimates were increased near Maypearl, Texas. The goal is to have the color of the MPE precipitation field match the color of the gauge reading.

EXAMPLES FROM HURRICANE HARVEY

Hurricane Harvey was the first major hurricane to make landfall in the United States since Wilma in 2005. The storm produced catastrophic impacts over southeast Texas and southwest Louisiana. Harvey made landfall near Rockport, Texas as a Category 4 hurricane. In a four-day period, many areas received more than 40 inches of rain as the cyclone meandered over southeast Texas and adjacent waters, with peak accumulations of over 60 inches (Blake and Zelinsky 2018). Hurricane Harvey produced the most rain on record for a tropical storm or other weather event in the contiguous United States. For more information, see the NWS Service Assessment on Harvey (NWS 2018), and see a scientific investigation report from the U.S. Geological Survey (USGS 2018).

Rainfall estimation from tropical systems is quite challenging. All sources of remote sensing have limitations during excessive rains and high winds. For an explanation of the reasons for these challenges, see Story (2012). Figure 5 shows Hurricane Harvey on the evening of August 25, 2017.

In the 24-hour period ending at 12 UTC on August 26, heavy rain from Harvey fell as it moved over parts of south central and southeast Texas. Figure 6 shows the CoCoRaHS reports, which were received just after 12 UTC.

The initial radar estimates ranged from 4 to 8 inches. However, the CoCoRaHS 24-hour readings had several contributors reporting 8.00 to 9.60 inches. The WGRFC initial estimates were too low, and these observations led us to increase final estimates. The final rainfall estimate from WGRFC software is shown in Figure 7:

The next day, for the 24-hour period ending at 12 UTC on August 27, we saw even larger underestimations. We initially estimated 8 to 13 inches of rain over southeast Texas, but the CoCoRaHS reports were much higher. The CoCoRaHS reports are shown in Figure 8 from day 2 of Hurricane Harvey and Figure 9 shows this graphically.

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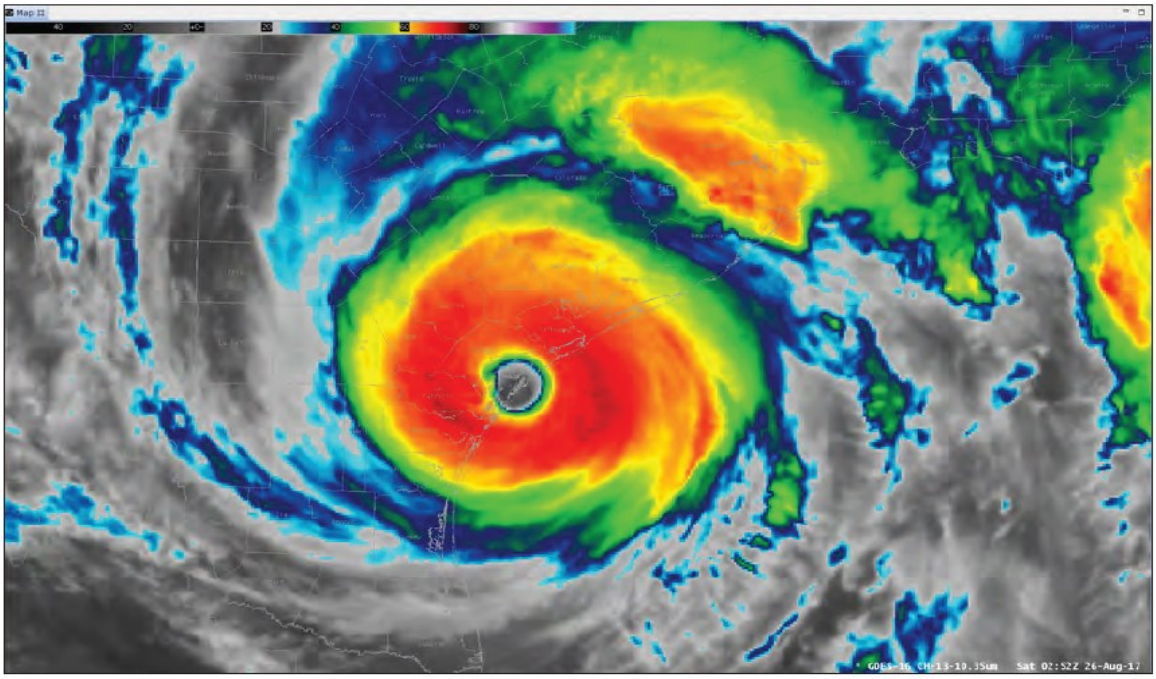

Figure 5. Hurricane Harvey at landfall as seen from GOES 16 satellite. The eye of Harvey is making landfall. The bright red colors around the eye indicate the eye wall and can be indicative of high rainfall rates.

LID		GAGE	MPE	LOCATION
TXFB17	:	9.60	8.63	Richmond 3.4 NE
TXGD15	:	8.92	5.35	Weser 1.9 NW
TXFB18	:	8.69	8.63	Richmond 2.9 NE
TXFB05	:	8.22	6.80	Sugar Land 3 SSE
TXFB12	:	7.61	6.74	Sugar Land 1 W
TXWH18	:	7.60	9.67	East Bernard 7.6 S
TXCLR10	:	7.50	4.99	New Ulm 5.1 S
TXCLR06	:	7.45	5.90	New Ulm 7.2 S
TXFB51	:	7.45	8.20	Richmond 4.4 NNE
TXDW19	:	7.41	5.31	Cuero 8.4 S

Figure 6. This table shows the ten highest August 26 CoCoRaHS reports. Alongside the gauge ID is the observed amount and our initial MPE estimate for that location.

Integration of CoCoRaHS observations

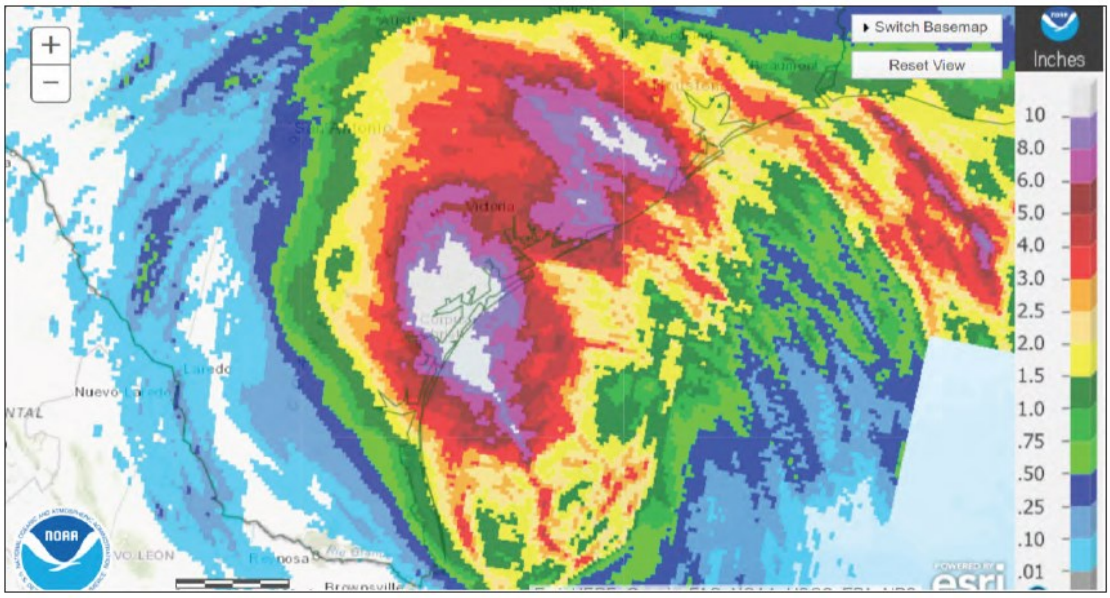

Figure 7. WGRFC best estimate of rainfall from the first day of Hurricane Harvey, 26 August 2017.

Again, since we were too low in our initial estimates, we increased them. This meant that increased flood volumes were forecasted. That resulted in many crest projections exceeding the major category (where extensive inundation of structures and roads occurs, with significant evacuations of people and property) or record category (where a river at a set forecast point had never been higher historically). Figure 10 shows our final estimate field from MPE after this increase.

LID		GAGE	MPE	LOCATION
TXGV44	:	21.62	12.90	Bacliff 0.5 SSE
TXHRR32	:	20.84	12.90	South Houston 4 SSW
TXHRR93	:	20.54	12.90	Pasadena 4.4 WNW
TXHRR31	:	19.41	12.90	Friendswood 2.5 NNE
TXGV60	:	19.38	12.90	Santa Fe 0.7 S
TXGV64	:	18.20	12.90	Hitchcock 1.6 NNW
TXHRR139	:	17.98	12.90	Cloverleaf 1.7 W
TXGV51	:	17.57	8.74	La Marque 1.8 E
TXHRR28	:	17.00	12.90	Webster 0.4 NW
TXGV63	:	16.59	12.90	Friendswood 1 SE

Figure 8. This table shows the 10 highest CoCoRaHS reports ending 12 UTC 27 August 2017. The data indicate five readings in excess of 19.25 inches that correspond to initial MPE estimates of just under 13 inches over parts of Harris and Galveston counties in southeast Texas.[1]

[1]The reason for the 12.90" matching so many gauges is two-fold. All have to do with the multisensor approach in MPE itself. MPE uses the Hydrologic Rainfall Analysis Project (HRAP) grid array. One HRAP grid is roughly 4 square kilometers. MPE arrives at just one value for an entire grid. You can have multiple CoCoRaHS gauge readings located in the same HRAP grid. That happens to be the case with a few of the gauges in Figure 8. Also, the HRAP grid value is derived from an hourly rain gauge if there is an hourly gauge located in that grid. Gauge values in the multisensor analyses actually have a sphere of influence, which is larger than one grid size, thus gauge readings can bleed over into other surrounding grids. Therefore, multiple grids can have the same value in a general location.

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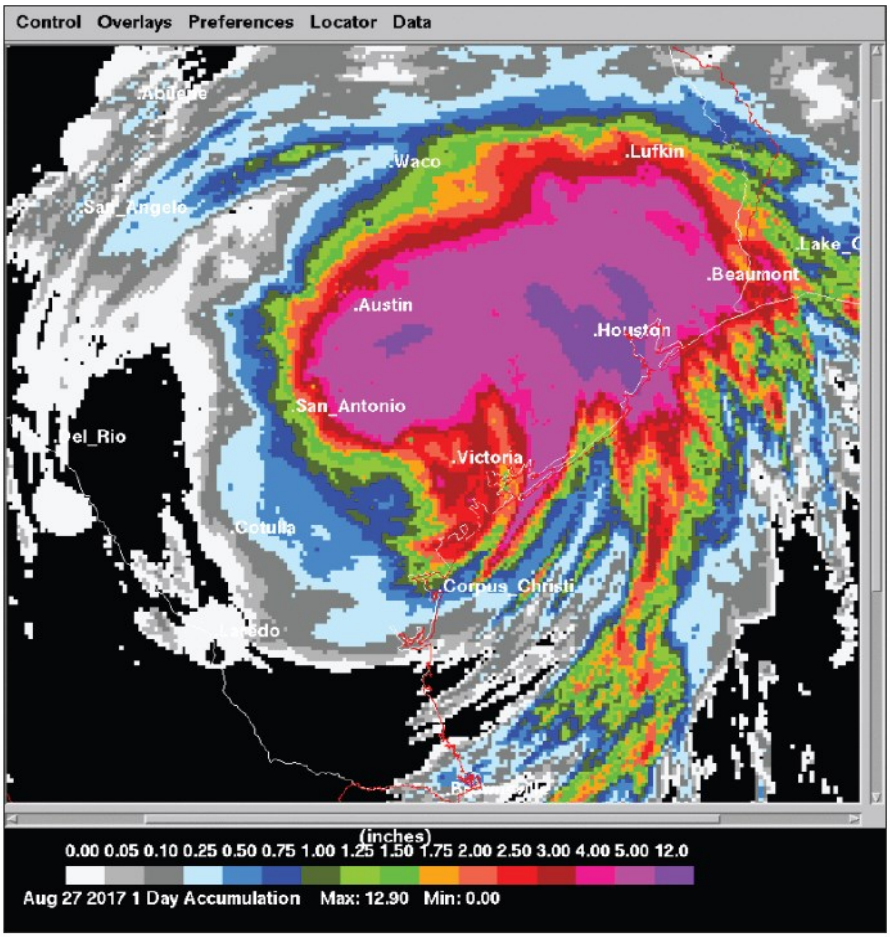

Figure 9. This was the initial estimate of rainfall from day two of Hurricane Harvey from WGRFC multisensor software.

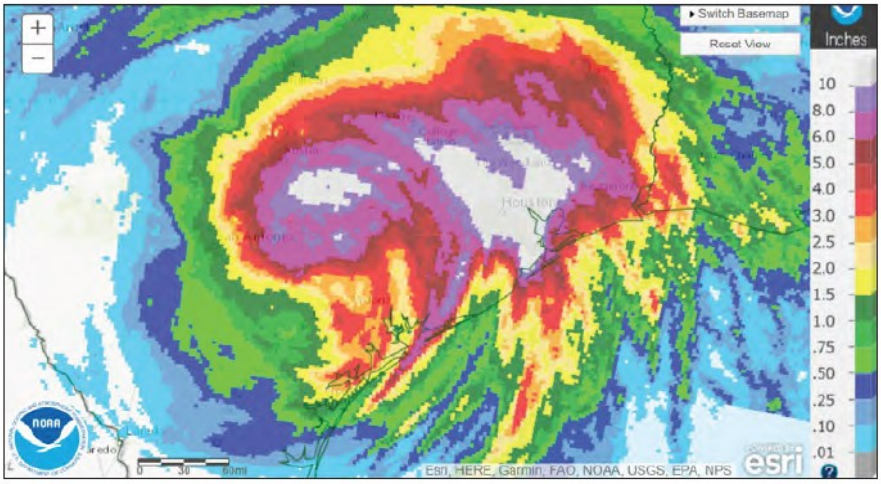

Figure 10. The final best estimate field from 12 UTC 27 August 2017. Note the sizable increase in the areal coverage of the heaviest rainfall over the initial estimates in Figure 9.

Integration of CoCoRaHS observations

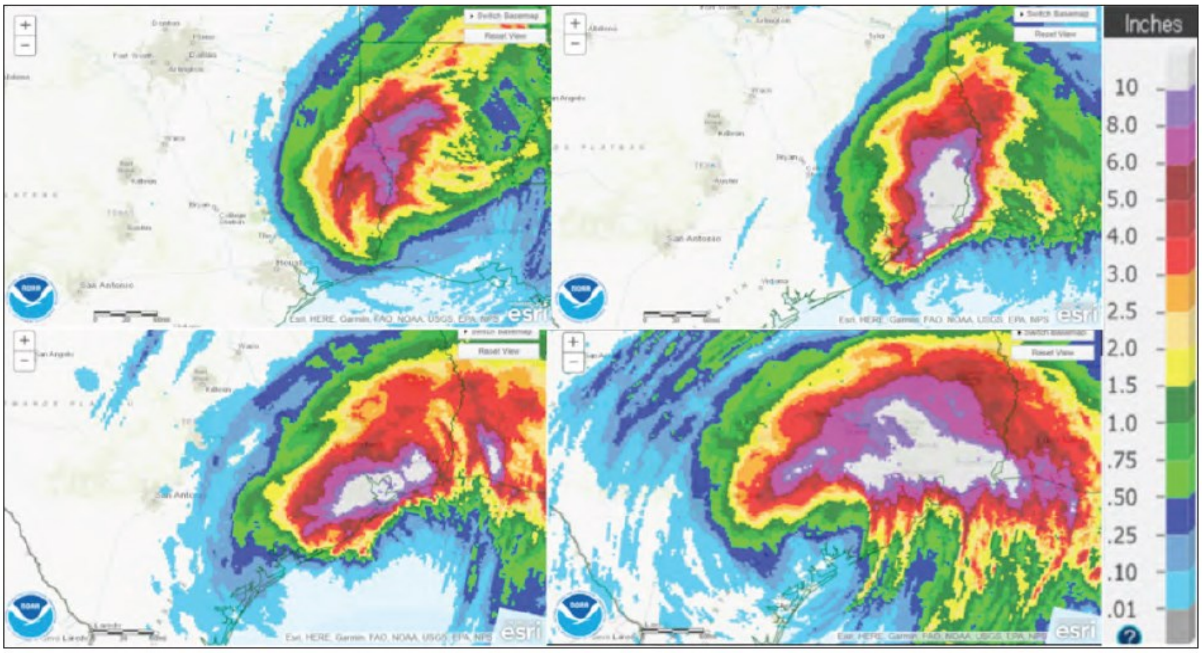

Figure 11. Final rainfall estimates. (Lower Right) August 28. The CoCoRaHS rain gauge data showed a maximum of 18.35 inches near Katy and a dozen observations in excess of 13.25 inches. The initial maximum MPE estimate was 12.90 inches, thus MPE showed severe underestimation and was adjusted higher. (Lower Left) August 29. CoCoRaHS rainfall readings showed a maximum rainfall of nearly 15 inches northeast of Friendswood, with ten observations in excess of 13 inches. Initial MPE rainfall estimates were in excess of 12 inches from south of Houston to near Beaumont/Port Arthur, showing the underestimation from radar-based MPE was not quite as severe. (Upper Right) August 30. CoCoRaHS rainfall readings indicated a maximum rainfall of over 15 inches about 5 miles south of Beaumont, with six observations in excess of 10.50 inches. The initial MPE estimates around 12 inches over extreme southeast Texas centered on Beaumont were too low and were adjusted upward for the final analysis. (Upper Left) August 31. CoCoRaHS rainfall readings confirmed the heaviest rainfall in excess of 7 inches had shifted into Sabine Parish, Louisiana. The initial MPE estimates were much closer as the rain rates decreased and shifted into western Louisiana, thus only limited adjustment upward was necessary for the final analysis.

Based on the CoCoRaHS observations, the initial MPE estimates were too low for the remainder of the Harvey rain event. The final daily rainfall for Harvey from August 28–31 are shown in Figure 11.

In the end, approximately 90% (60 out of the 67) of NWS river forecast locations in southeast Texas reached flood stage. Approximately 69% (46 out of the 67) reached major flood stage and approximately 46% (31 out of the 67) set flood records. The NWS issued more than 300 flood-related warnings at official river forecast points where USGS stream gauges measure flow volumes, out of 330 in the WGRFC area of responsibility (NWS 2018). The CoCoRaHS observations helped improve the NWS lead time on the magnitude of flooding. With initial estimates biased low, adjustments were made in real time to radar precipitation totals. These CoCoRaHS readings contribute greatly to the NWS WGRFC's mission of saving lives and property from floods here in Texas. Quite often the majority of the highest ten rainfall readings in the state on any given day come from CoCoRaHS observers. Figure 12 shows the gauge-corrected totals using CoCoRaHS and other data sources that gave the WGRFC its best estimate of rainfall from Hurricane Harvey.

CONCLUSION

CoCoRaHS is a volunteer, community-based organization that always needs more observers. The more reporting observers, the better the chances that the WGRFC can match the magnitude of rainfall. Even a daily report of no rainfall is useful information, as the final precipitation estimates that are computed also go into the state and national Drought Monitor maps each week (see http://droughtmonitor.unl.edu/CurrentMap.aspx).

To become a volunteer, you may follow these simple steps:

1. Read through the website and see what the project is about (https://www.cocorahs.org/).The website has information on "How To Measure Precipitation," "How To Measure Snow,"

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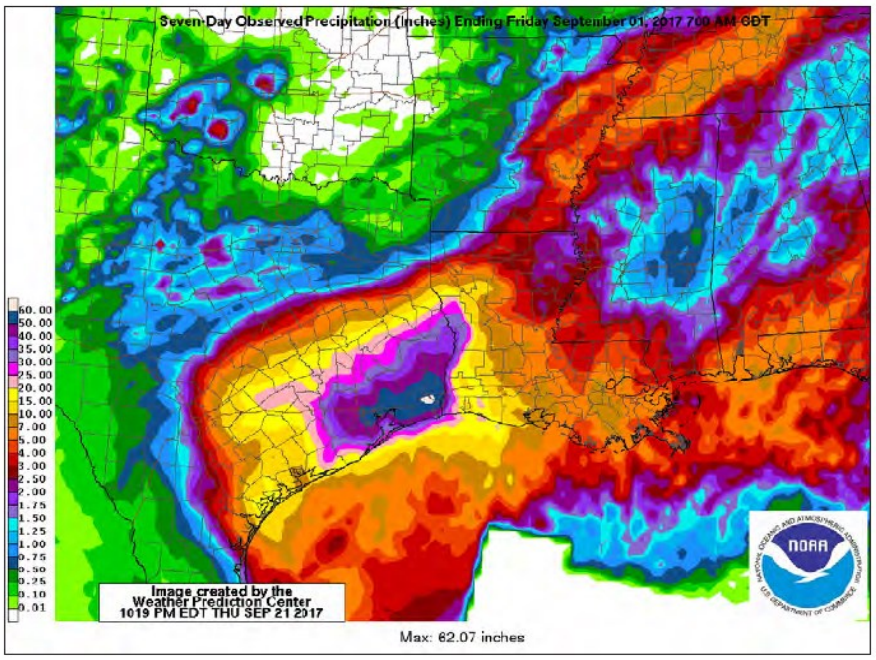


Figure 12. Total accumulated rainfall from Tropical System Harvey. Note the 62-inch final maximum total near Beaumont/Port Arthur.

and "How To Measure Hail" as well as information on the equipment used.

2. Make sure you have a rain gauge. You may purchase an official rain gauge from the link on the CoCoRaHS website for approximately $31.50 (see www.weatheryourway.com/cocorahs). They are excellent gauges that measure in hundredths of an inch. It is asked that your rain gauge be a 4" diameter all-weather gauge or better.

3. Go to our "Join CoCoRaHS" web page and sign up (https://www.cocorahs.org/application.aspx).

4. Either attend a training session for volunteers in person, or view the "Training Slide Show" found on the CoCoRaHS home page. It is very beneficial to read through the website on-line training materials completely. It is important to know how CoCoRaHS observers make and report their measurements. Good training along with careful observing and reporting are very important to the network and the users of the data.

5. Contact CoCoRaHS with any questions that you may have. Coordinators are available at the state and regional levels as a resource to assist you in getting started. Texas coordinator contact information can be found at: https://www.cocorahs.org/Content.aspx?page=coord_tx

6. Report your data daily on the website (www.cocorahs.org/Login.aspx) or use the CoCoRaHS smart phone application (Apple or Android). If you are unable to report on the internet, you may obtain CoCoRaHS Precipitation measurement forms from CoCoRaHS headquarters (or you may print your own from the website) and mail them.

We look forward to receiving many new observers in the future.

REFERENCES

Blake E, Zelinsky D. 2018. Hurricane Harvey (AL092017) 17 August–1 September 2017.

National Hurricane Center Tropical Cyclone Report. https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf

CoCoRaHS website. 2018. Fort Collins (Colorado): Colorado State University; [accessed August 21, 2018]. https://www.cocorahs.org/

CoCoRaHS Mission Statement. 2018. Fort Collins (Colorado): Colorado State University; [accessed August 21, 2018]. https://www.cocorahs.org/Content.aspx?page=mission

(NWS) National Weather Service. 2018. Service Assessment: August/September 2017 Hurricane Harvey. Silver Spring (Maryland) National Oceanic and Atmospheric Administration, National Weather Service. https://www.weather.gov/media/publications/assessments/harvey6-18.pdf

Reges H, Doesken N, Turner J, Newman N, Bergantino A, Schwalbe Z. 2016. CoCoRaHS: The evolution and accomplishments of a volunteer rain gauge network. Bulletin of

Integration of CoCoRaHS observations

the American Meteorological Society. 97:1831-1846.

Story G. 2016. An introduction to the NWS West Gulf River Forecast Center. Texas Water Journal. 7(1):56-63. https://journals.tdl.org/twj/index.php/twj/article/view/7036

Story G. 2012. Chapter 12: Estimating precipitation from WSR-88D observations and rain gauge data. In: Verdin JP, Wardlow BD, Anderson MC, editors. Remote sensing of drought: innovative monitoring approaches. Boca Raton (Florida): CRC Press Taylor and Francis Group. p. 281-306.

Watson KM, Harwell GR, Wallace DS, Welborn TL, Stengel VG, McDowell JS. 2018. Characterization of peak streamflows and flood inundation of selected areas in southeastern Texas and southwestern Louisiana from the August and September 2017 flood resulting from Hurricane Harvey. Reston (Virginia): U.S. Geological Survey. 44 p. U.S. Geological Survey Scientific Investigations Report 2018–5070. https://doi.org/10.3133/sir20185070.

Wichita Falls Regional Climate Summary

By Charles Kuster
CIMMS/NSSL

September and October 2018 brought abundant and much-needed rainfall to the Wichita Falls region. Wet days (at least one CoCoRaHS station reported 0.05 inches or more) were relatively common and by the end of October, the area had seen 32 wet days and only 30 dry days (all CoCoRaHS stations reported less than 0.05 inches). The largest single-day rainfall event ended on September 22nd. During this event, almost every CoCoRaHS station reported over 2.30" of rain with the maximum occurring in Wilbarger County. Weather radar estimates indicate that many locations in Wilbarger and Baylor County saw at least 3" of rain with a couple areas potentially seeing 6–8" of rain (Fig. 1)! Conditions changed, however, once November arrived. Very little precipitation fell in November as 27 out of 30 days were dry days. Once again all CoCoRaHS stations reported less than 0.05 inches in November.

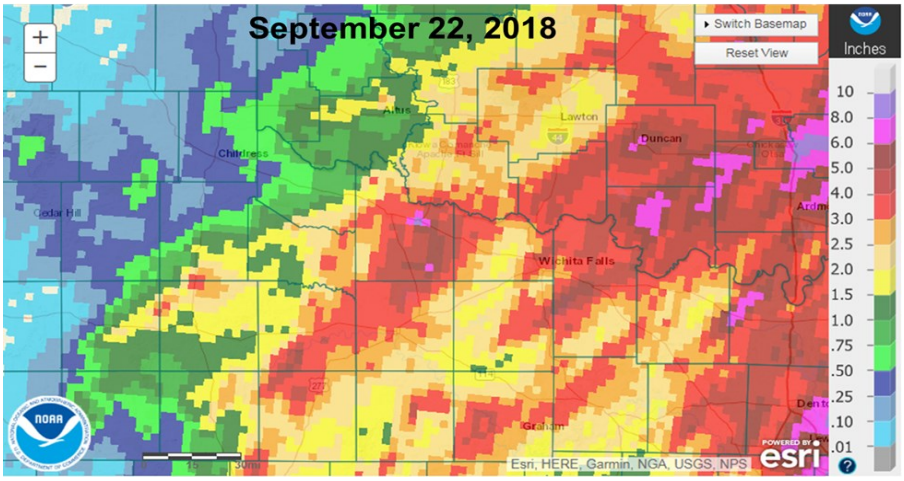


Figure 1: 24-hour rainfall estimates ending on the morning of September 22, 2018.

As a whole, the fall of 2018 was quite wet in the Wichita Falls region. Many locations received at least 8" of rain during the season and many locations saw between 150–300% of normal precipitation (Fig. 2). In total, there were 57 dry days (63%) and 34 wet days (37%). For comparison, last fall had 69 dry days and only 22 wet days. The plentiful rain has also resulted in all parts of the region no longer being under any drought category according to the U.S. Drought Monitor (https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?TX). We will have to watch out for drought returning especially if the dry November pattern continues deep into the winter.

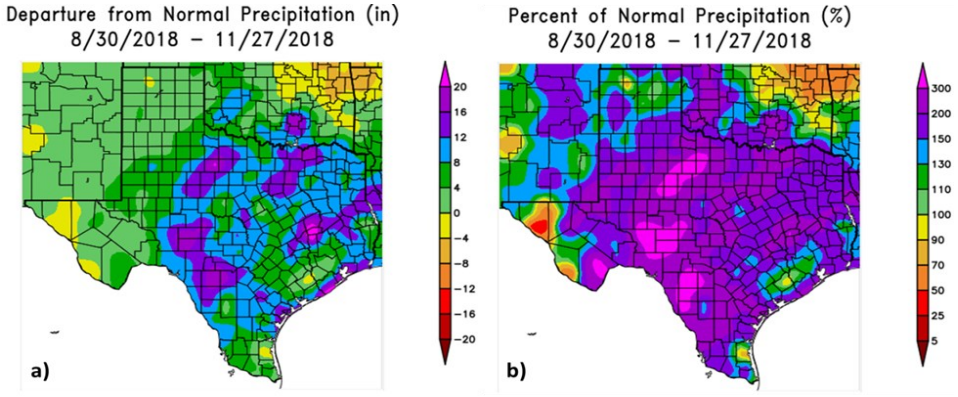


Figure 2: Map showing a) departure from normal precipitation and b) percent of normal precipitation. In both maps, cool colors indicate above normal precipitation and warm colors indicate below normal precipitation.

Climate Summary for West Texas/ SE New Mexico

Fall 2018 Climate Summary for West Texas and Southeast New Mexico

By James DeBerry
Midland NWS

West Texas and Southeast New Mexico saw a very wet fall, with most locations surpassing their annual precipitation averages early.

September

September was a wet month, as abundant moisture in West Texas and Southeast New Mexico began colliding with the first few fall cold fronts.

On September 6th, showers and thunderstorms developed in a tropical airmass in Pecos County. Several roads west and south of Fort Stockton were flooded, and at least one high-water rescue was performed.

These showers and storms carried over into the 7th, further north near Coyanosa. Roads near there, especially FM 1776, were inundated with up to 2' of runoff. In Midland in Midland County, as well as Odessa in Ector County, over 4" of rain fell in some parts of the cities, with Midland being hit the hardest. Numerous roads were flooded or closed, stalling many vehicles and necessitating high water rescues. Water even got inside a few homes. Elsewhere, road closures were reported near Imperial in Pecos County, as well as the vicinity of Lenorah in Martin County.

On September 21st, thunderstorms flooded roadways and stalled vehicles near Big Lake in Reagan County.

Several other events took place throughout September, but these were in more rural areas, where verification is difficult to come by. The Rio Grande was elevated most of the month, rising in and out of flood.

Monthly radar rainfall estimates ranged from as little as 1/2" near the Guadalupe Mountains to 10-15" in the southeast Permian Basin. However, the highest observed rainfall was just of 9" in the Chisos Mountains in the Big Bend. The average of rainfall reported across West Texas and Southeast New Mexico was almost 3 ¼".

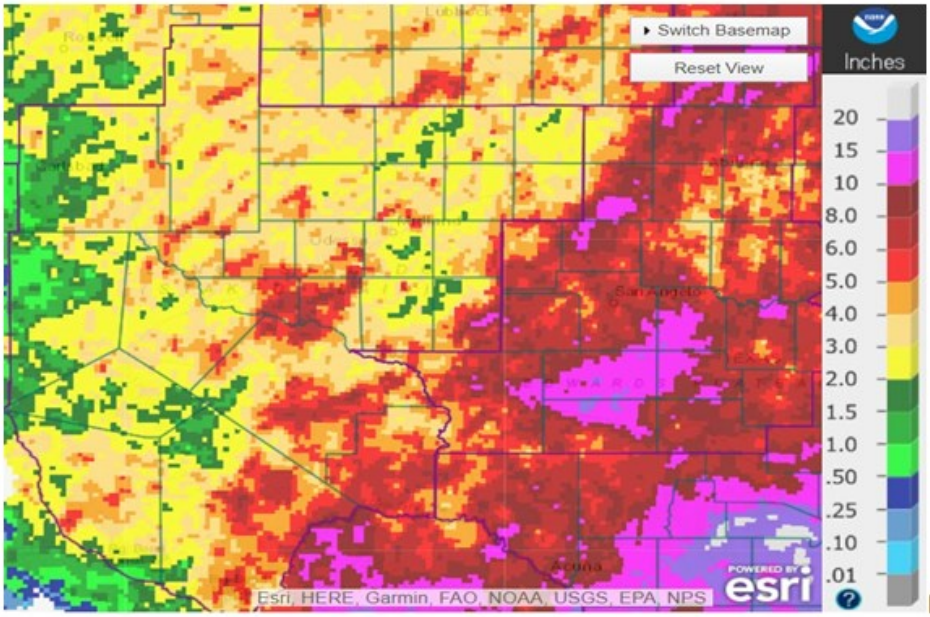


Figure 1: September rain in West Texas.

October

October was another wet month for West Texas and New Mexico, with many locations exceeding their annual averages. In general, most events were of a wetting rain nature, but a few convective episodes resulted in flash flooding.

On October 5th, thunderstorms developed near Seagraves in Gaines County, and a few high water rescues occurred just north of town. A more widespread event happened on the 8th-9th, when thunderstorms rolled through the Permian Basin and areas east. Flash flooding put many roadways underwater, some of which were later barricaded, from Midland in Midland County to Westbrook in Mitchell County. Many high water rescues were reported. Glasscock County was hit hardest, where radar estimates up to 10" of rain fell from training thunderstorms. Texas State Highway 158, connecting Midland to Sterling City, was washed out. On October 13th, thunderstorms developed in the vicinity of Midland, and several roadways were barricaded due to high water.

"Climate Summary for West Texas/ SE New Mexico (continued)"

Monthly radar rainfall estimates ranged from as little as 1/2" in northwest Eddy County and the Presidio Valley to 10-15" in the upper Colorado River Valley and Permian Basin. The highest observed rainfall was almost 11 ½" in Snyder in Scurry County. The average of rainfall reported across West Texas and Southeast New Mexico was over 4 ¼".

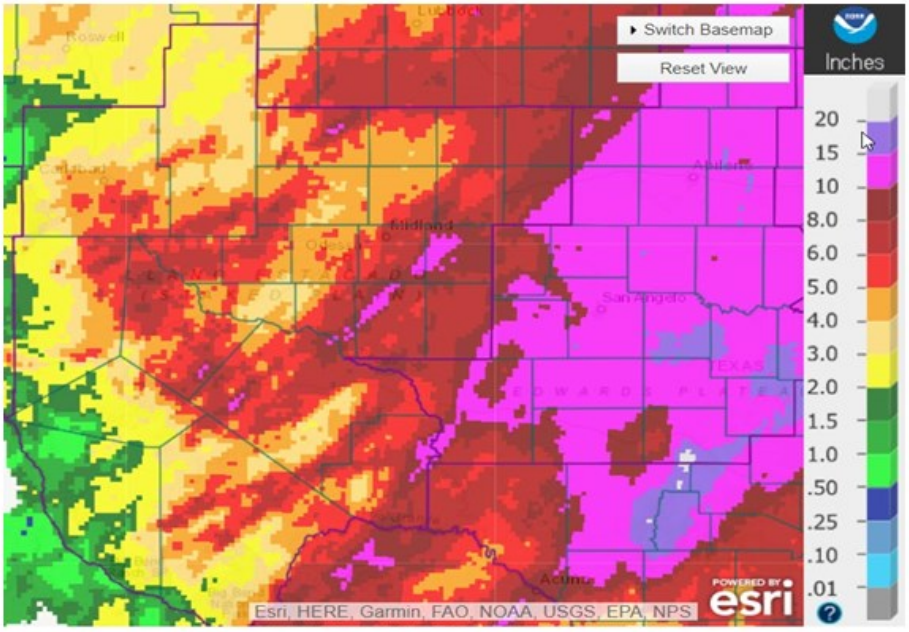


Figure 2: October rain in West Texas.

November

The well ran dry in November, with no significant hydrologic events or rainfall. Monthly radar rainfall estimates ranged from nothing in parts of Southeast New Mexico to up to 3" in the upper Colorado River Valley.

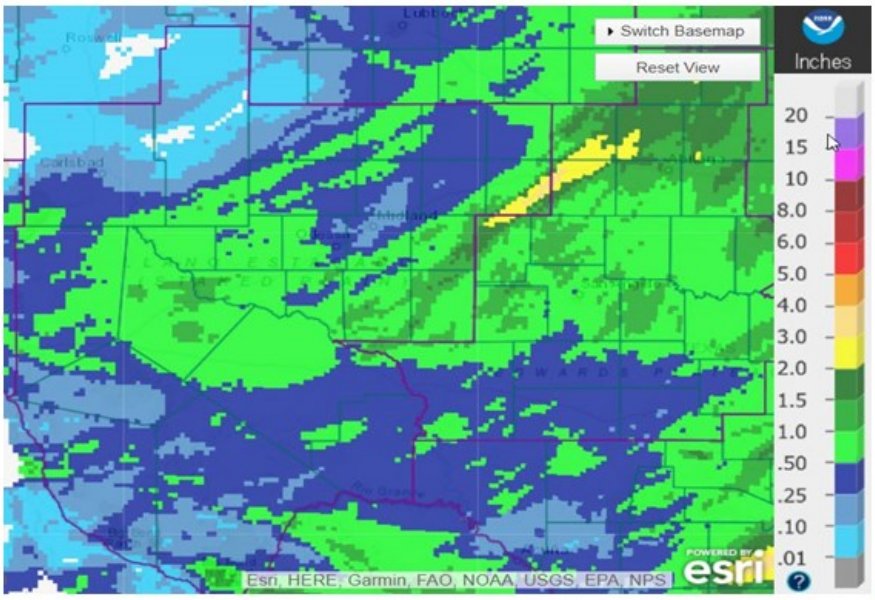


Figure 3: November rain in West Texas.

As a result of abundant rainfall this fall, all of West Texas is out of drought. In Southeast New Mexico, western Eddy County is in severe or moderate drought. The rest of Southeast New Mexico is out of drought. Reservoir levels across the HSA averaged 49.6% of conservation capacity as of November 30th.

North Texas Regional Fall Climate Summary

By Greg Story NWS WGRFC

Greetings from North Texas! We really have been on a rainfall roller coaster in north Texas the past several months. Just to review, January 2018 was dry. February started off dry but then most of north Texas got drenched. We had the wettest February on record. March was slightly below normal for rain. In April we had below normal rainfall in north Texas. We had the 7th driest April of record. In May most locations saw below normal rainfall especially over extreme northeast Texas. The below normal rainfall regime continued through June and July then the pattern started to change in August. Above normal rainfall occurred over north Texas except for the southeast portions. A most historic autumn season followed.

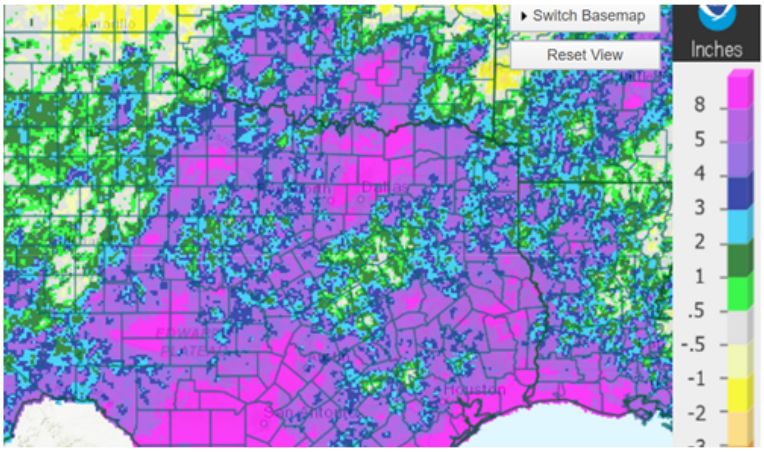


Figure 1: Departure from normal rainfall for September 2018. The green and beige colors indicate near normal precipitation, while the blue and purple colors indicate above normal. Note how many north Texas locations had more than 5 inches of rain above normal.

In September a vast majority of Texas, including north Texas, saw much above normal precipitation, especially in the area southwest of the DFW metroplex. At DFW airport they got 12.69 inches in September. The normal amount is 2.55 inches so they were above normal by 10.14 inches for the month. This was the wettest month since May 2015 when DFW had 16.96 inches. The 24-hour precipitation total (September 21-22) at DFW Airport was 7.48 inches. This amount ranks as the 3rd highest 24-hour rainfall total on record and the highest such total since 1932. Additionally, September 2018 was the wettest September ever. In Waco they received 4.90 inches, thus they missed out on the heaviest rain but were still above normal.

The largest storm of the month to affect north Texas started on September 21. A slow moving upper low moved across Texas. Also, a cold front moved across the region. Tropical moisture still lingered over the state, and this led to heavy rain over many areas. While rainfall events earlier in the month tended to favor central and south Texas, this upper low brought the heaviest rain to north Texas through September 23. As I mentioned, the 24-hour precipitation total (September 21-22) at DFW Airport was 7.48 inches. This was the most rain seen in a single 24-hour period in 86 years.

The Greatest 24-Hour Precipitation Totals for DFW:

Rank	Precipitation	Date
1	9.57	Sep 4-5, 1932
2	8.81	Apr 24-25, 1922
3	8.11	Sep 21-22, 2018*
4	7.44	Sep 20-21, 1900
5	6.99	May 23-24, 1908
6	6.03	May 16-17, 1949
7	5.91	Sep 30-Oct 1, 1959
8	5.85	Sep 3-4, 1943
9	5.75	Sep 7-8, 2010
10	5.40	Aug 17-18, 1915

On September 22, Bonham 4.0 NE (Fannin County) received 10.62 inches, Hutto 0.8 WNW (Williamson County) got 9.88" and McKinney 3.1 SW (Collin County) picked up 9.88". In Dallas County a flood of record was experienced on White Rock Creek. The rain let up a bit September 24 – 25 before the next cold front moved across Texas September 26 – 27. Some locally heavy rain again occurred along and ahead of the front. On September 26 Cottonwood 1.3 NE (Kaufman County) got 4.70 inches.

"North Texas Regional Fall Climate Summary (continued)"

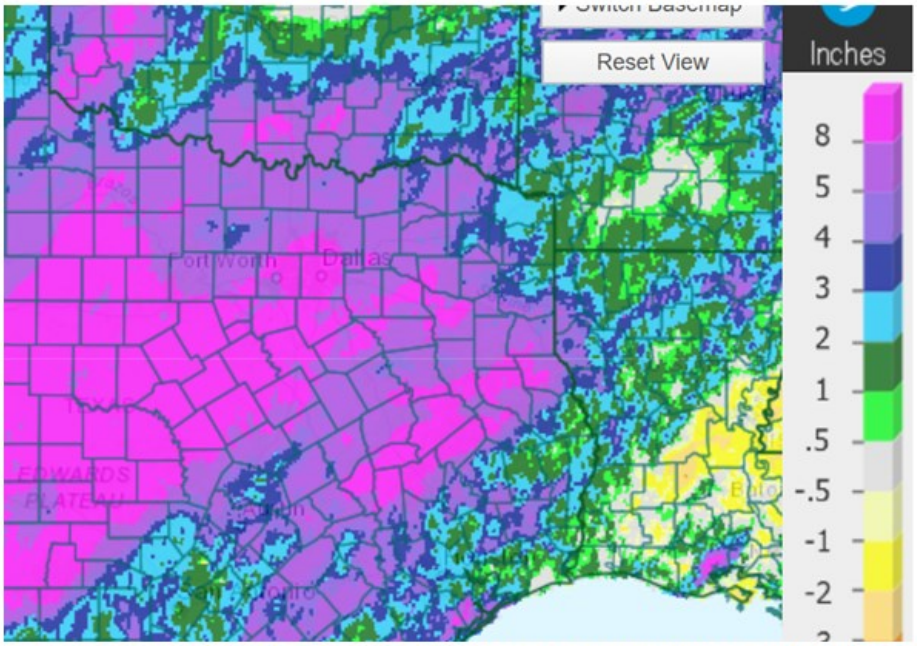


Figure 2: This is the October 2018 departure from normal rainfall map. The brown and yellow colors indicate below normal precipitation, while the green, blue and purple indicate above normal rain.

All of north Texas saw much above normal rainfall in October. In Waco they received 12.56 inches. Waco normally gets 3.90 inches so they were 8.66 inches above normal. At DFW airport they got 15.66 inches. The normal amount is 4.22 inches so they were above normal by 11.44 inches for the month. With the 15.66 inches of rain recorded at DFW, it makes it the wettest October on record, breaking 1981's record of 14.18 inches. We had two consecutive months with a record rainfall - September and October - in Dallas/Fort Worth. These are the first back-to-back months with record precipitation totals since February and March of 1945. And here is the list of highest monthly precipitation ever recorded in DFW. Note that October was the fourth highest and the previous month (September) was seventh highest ever.

Rank	Month	Precipitation Total
1	Apr 1922	17.64
2	Apr 1942	16.97
3	May 2015	16.96
4	Oct 2018*	15.66
5	Oct 1981	14.18
6	May 1982	13.66
7	Sep 2018*	12.69
8	May 1957	12.64
9	Apr 1957	12.19
10	May 1946	12.09

I will simply highlight the largest storms of the month.

October 7 through 11:

A large upper low formed over the southwest U.S. The initial heavy rain was over the western parts of north Texas which produced large flows on the Brazos River upstream of Possum Kingdom Lake. Then a "rain bomb" occurred over the Texas Hill Country. On October 9 a daily record rainfall occurred at the Dallas/Fort Worth Airport of 2.27 inches, besting the previous record of 1.92 in 1968. Dallas Love Field picked up 4.72 inches and Covington (Hill County) had 4.37 inches for the most in North Central Texas.

October 13 – 14

The remnants of eastern Pacific hurricane Sergio came across north and west Texas into southern Oklahoma. Heavy rain fell in north Texas. A daily record rainfall of 2.20 inches was set at DFW airport October 13. This broke the old record of 1.47 inches set in 1960.

"North Texas Regional Fall Climate Summary (continued)"

October 15 through 20

A strong arctic cold front moved through Texas. Meanwhile a persistent closed low pressure system hung over the southwestern U.S. which pushed upper disturbances over the front. The upper low finally moved out on the 19th, but a remnant low continued along the southern Texas Gulf coast for an additional day or so. On October 15 a record precipitation total of 2.93 inches was set at DFW airport. This broke the old record of 1.93 inches set in 2007.

October 23 – 25

A long wave trough moved out of the southwestern U.S. and moved across Texas. In addition, we had the remnants of eastern Pacific hurricane Willa move across south Texas. Rainfall amounts of around 1.00 inch were common, with the heaviest amounts being 2.07 inches in the Grand Prairie portion of the Metroplex.

October 31- November 1

A cold front moved across the state, along with a vigorous upper level trough. Widespread rainfall occurred, with the heaviest at Kountze (Southeast Texas) of around 6.00 inches. The speed of the storm prevented this from being a widespread heavy rain event.

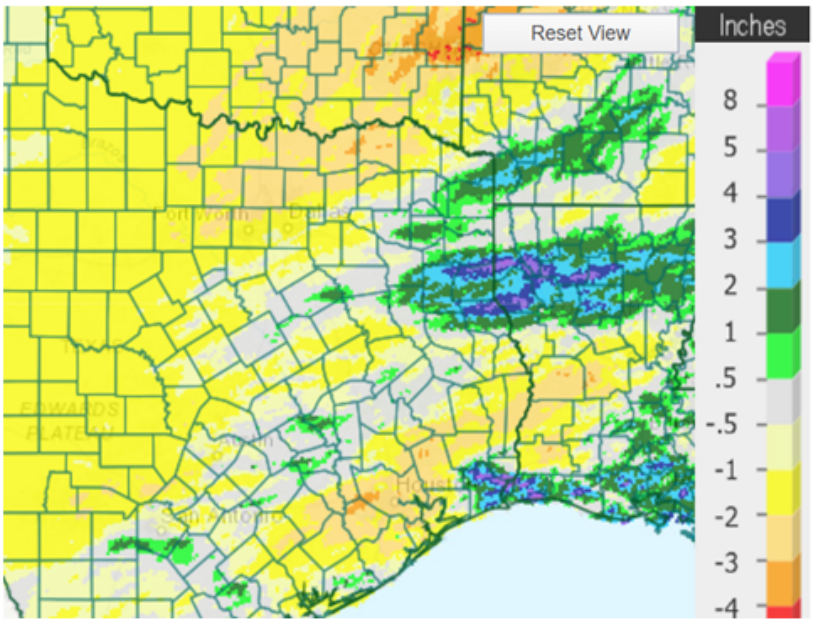


Figure 3: Departure from normal rainfall for November 2018. The brown and yellow colors indicate below normal precipitation, while the green, blue and purple colors indicate above normal rain.

In November, the weather pattern changed from extremely wet to a more normal autumn regime. Above normal rainfall was limited to portions of northeast Texas, while the remainder of north Texas was near to below normal. In Waco they received 3.19 inches, which was just slightly above normal by 0.37 of an inch. At the DFW airport they got 0.86 of an inch in November (compared to 15.66 inches in October). The normal amount for November is 2.71 inches so they were below normal by 1.85 inches for the month. Adding up the totals for 2018 through November, DFW has received 51.42 inches. The normal amount is 33.59 inches so they are 17.83 inches above normal for the year.

The largest storm of the month to affect north Texas was on November 1. The storm actually began October 31. A strong short wave trough moved across Texas along with a cold front. Around 1.50 inches was observed in east Texas toward the Toledo Bend Lake, while around 1" fell in the DFW metroplex.

"North Texas Regional Fall Climate Summary (continued)"

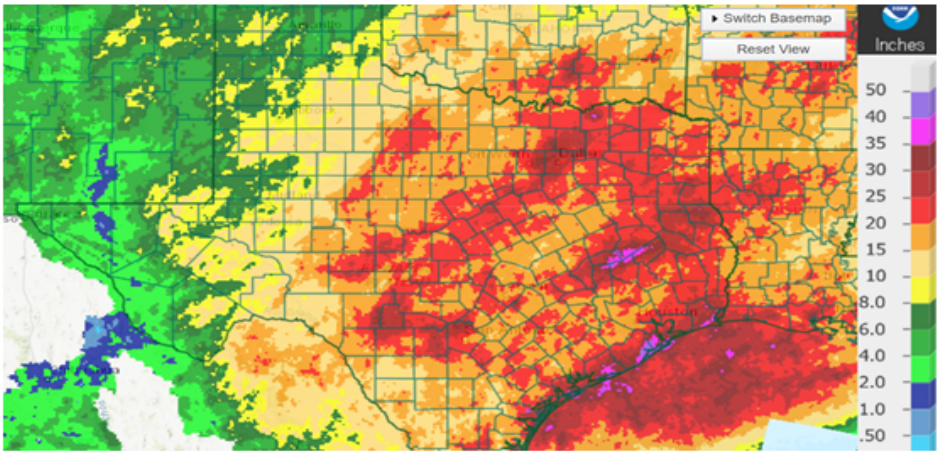


Figure 4: Autumn precipitation 2018

All of north Texas saw heavy rain during the fall. This autumn season concluded as the wettest season in 120 years of recordkeeping since 1898 in Dallas/Fort Worth.

Fall – Wettest Years in Inches (September through November)

Rank	Precipitation	Year
1	29.20	2018*
2	21.82	2015
3	18.11	1981
4	16.88	1919
5	16.37	1964

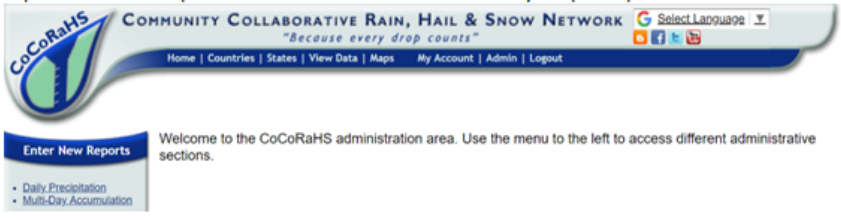
For 2018 at DFW Airport, the rainfall has moved up to number 3 on the wettest year's list. Here's an updated look at those years. Also noted is the ENSO climate cycle during the wettest years (if known).

Annual – Wettest in Inches

Rank	Precipitation	Year	
1	62.61	2015	El Niño
2	53.54	1991	El Niño
3	51.42	2018*	Started with La Niña/ENSO-Neutral/Heading toward El Niño
4	51.03	1932	
5	50.62	1973	La Niña
6	50.49	1957	El Niño
7	50.05	2007	La Niña
8	47.47	2004	El Niño
9	46.64	1914	
10	45.74	1919	

I want to thank you for submitting your rainfall readings to CoCoRaHS during this excessively wet season. They continue to be extremely valuable to us at the National Weather Service. It is critical that we see the magnitude of rainfall events in order to adjust the amounts of rainfall going into our hydrologic flood model. This certainly was the case in September and October. Please continue making your daily weather observations, even when the weather at your site had a low amount of rainfall (or no rainfall). A report of zero rainfall is just as important as a non-zero one!

In conclusion, one of my responsibilities at the National Weather Service is to quality control all rainfall observations from every available data source. One problem I see on a semi-frequent basis is when a CoCoRaHS multi-day rainfall observation is entered in as a daily (24-hour) report. We cannot make as effective use of your report when that occurs and it gets flagged as an error. What I encourage you to do is this: when you get ready to enter your CoCoRaHS report, ask yourself the following question. Did the rain I just measured fall in the past 24 hours, or did it fall over the past couple days? If it fell in the past 24 hours, enter the report as you normally would as a daily precipitation report. If not, use the link below it and enter your report as a multi-day accumulation rainfall report. That will help us out a lot. Thank YOU so much for your participation in CoCoRaHS. Have a great Holiday season!



East Texas Regional Fall Climate Summary

By: Davyon Hill (Meteorologist-National Weather Service-Shreveport)

It was a very active weather pattern for the autumn months across East Texas. As a result, most of East Texas ended the fall with above normal rainfall and free of drought conditions.

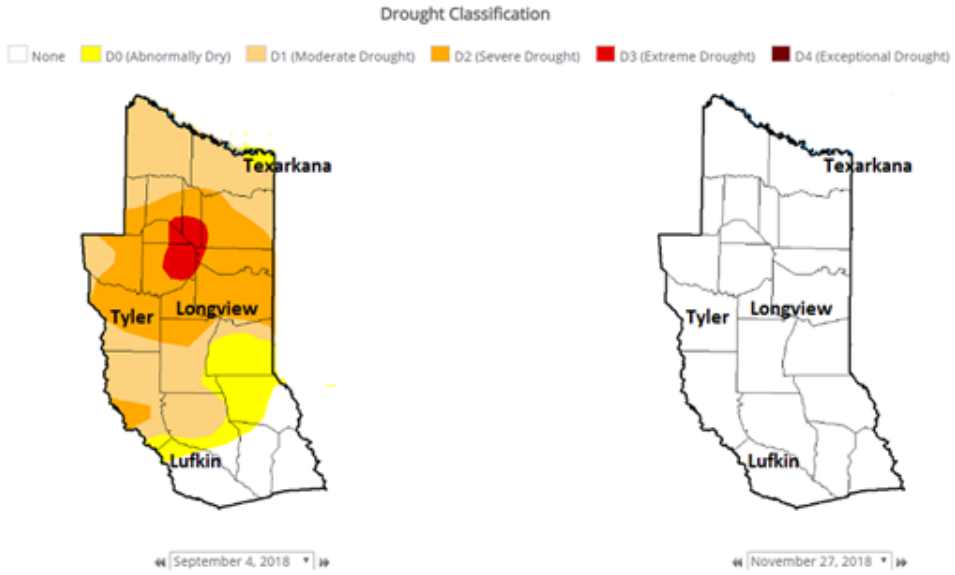


Fig. 1: Drought Comparison Map for East Texas on September 4, 2018 and November 27, 2018-Courtesy of the National Drought Mitigation Center

An active sea breeze pattern begins to take shape across the Texas/Louisiana Gulf Coast by early September. This active pattern continued through the entire month, bringing much needed rain to East Texas. In addition to the active sea breeze pattern, several cold fronts moved across the region, enhancing the rainfall totals. One of those fronts moved through on Sept. 22-23, bringing several CoCoRaHS sites two plus inches of rain. Detroit 14.9 N received 3.65 inches on the 22nd and another 2.27 on the 23rd. Almost all of the drought conditions across the region were erased with just September's rainfall. Lufkin's Angelina County Airport received 10.25 inches of rain for the month, which was the 4th highest in its recorded history for the month of September.

The month of October started out fairly quiet. However, strong southerly flow continued to pump gulf moisture into the region daily which resulted in isolated to widely scattered showers and thunderstorms during the afternoon hours during the first portion of the month. By the 9th, a cold front swept through the region, bringing 1-2 inches of rain across many of the CoCoRaHS sites. Another frontal system moved across the region on the 14/15th of the month. This front was very shallow, and warm southwest flow aloft behind the front created an overrunning situation which resulted in heavy rain from the 14th thru 16th. Tyler Pounds Field Airport recorded 4.12 inches on the 14th which broke the previous daily record for the 14th of 2.35 inches set in 1911. Lufkin's Angelina County Airport also set a daily record rainfall on the 15th of 4.75 inches which broke the previous daily record rainfall for the 15th of 1.71 inches set in 1957. Several roads in the Lufkin area were closed due to Flash Flooding as many of the CoCoRaHS sites in Angelina County report over 5 inches of rain from the 14th thru 16th. Lufkin 3.0 SW and Lufkin 0.9 SSE reported 6.13 and 5.29 respectively just on the 16th alone. Several more frontal passages occurred during the remainder of the month which resulted in additional heavy rainfall across the region. Tyler Pounds Field Airport recorded its wettest October on record with 13.09 inches, beating the previous record of 12.87 inches set in 1985. Lufkin's Angelina County Airport recorded 14.40 inches, which was its 3rd wettest October of all-time.

"East Texas Regional Fall Climate Summary (continued)"

The month of November was the driest out of the autumn months. However, a strong cold front moved across the region on Nov.12 bringing severe weather and flash flooding to the region. Longview East Texas Airport observed a daily record rainfall of 2.50 inches which beat the previous November 12th record of 1.70 in set in 2000. Behind this cold front, very cold arctic air moved into the region along with a weak upper level disturbance. Several of the CoCoRaHS sites reported light snow, especially south of Interstate 20. Zavalla 2.0 ESE recorded 0.2 inches and Broaddus 15.3 SE recorded a Dusting/Trace of accumulation.

Fig. 2: Snow Flurries observed on Highway 64 in Tyler, TX just after midnight on November 13, 2018. - Courtesy of KLTV viewer Laurel Jones

Fortunately, the periods of heavy rain during the fall months was enough to completely lift the region out of drought conditions. With a weak El Nino expected this winter, there is a good chance that East Texas will see above average precipitation and remain drought free over the next several months

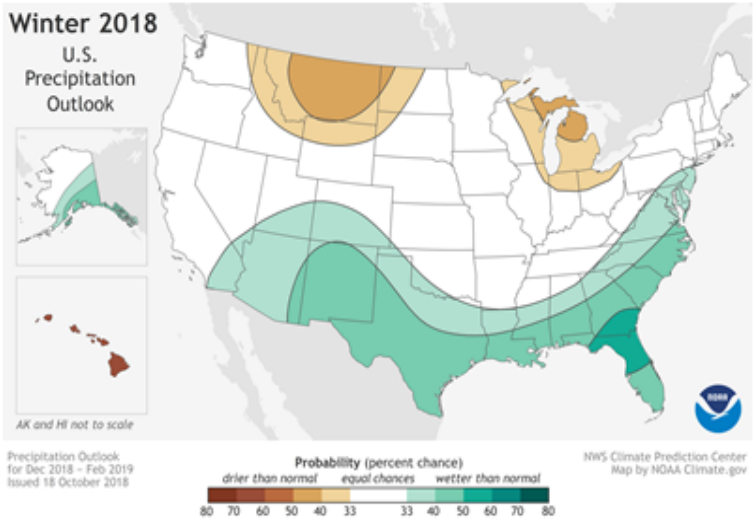


Fig. 3: US Precipitation Outlook for 2018-2019 Winter- Courtesy of NOAA Climate Prediction Center

Lower Rio Grande Valley Regional Fall Summary

Autumn (September – November) 2018 Summary

Lower Rio Grande Valley, Texas

By Barry Goldsmith

Several weather events defined a highly changeable autumn in the Rio Grande Valley. Both September and October would begin with searing and record heat before changes doused the scorching air. November would also begin very warm but would soon be followed by a long and strong taste of winter. The increasingly frequent cooling trends in October and November pushed the seasonal average to or just below the 1981-2010 normal – a welcome change from yet another searing hot summer (June-August).

September began on a record (hot) temperature pace for the first week of the month, before a weak tropical disturbance in the western Gulf shipped waves of deep atmospheric moisture through much of south Texas. Rainfall from September 9th through 17th ranged from 2 to 8 inches in the Cameron/Willacy portion of the Valley, to 6 to 16+ inches along and west of U.S. 281/IH 69C in Hidalgo and Brooks County. Local flooding occurred in the Valley in Harlingen, Donna, and Mission, with more widespread high standing water on grazing land from northern Hidalgo through Brooks, parts of Jim Hogg, and Kenedy County. For the month, rainfall totals of 8 to 20+ inches were common across the Deep South Texas and Rio Grande Valley ranch country, with 3 to 10 inches across the highly populated US 83/US 77 corridor in the Lower Valley. These rains eradicated pockets of moderate to severe drought, which had redeveloped following the Great Flood of June 2018 during another near-record hot July and August. The rainfall would mark the wettest September since 2014 and one of the wettest this century. The rainfall would temper the early month temperatures but only a shade; values ended up 2 to 4˚F above normal, with warm sultry nights a key reason for the departure.

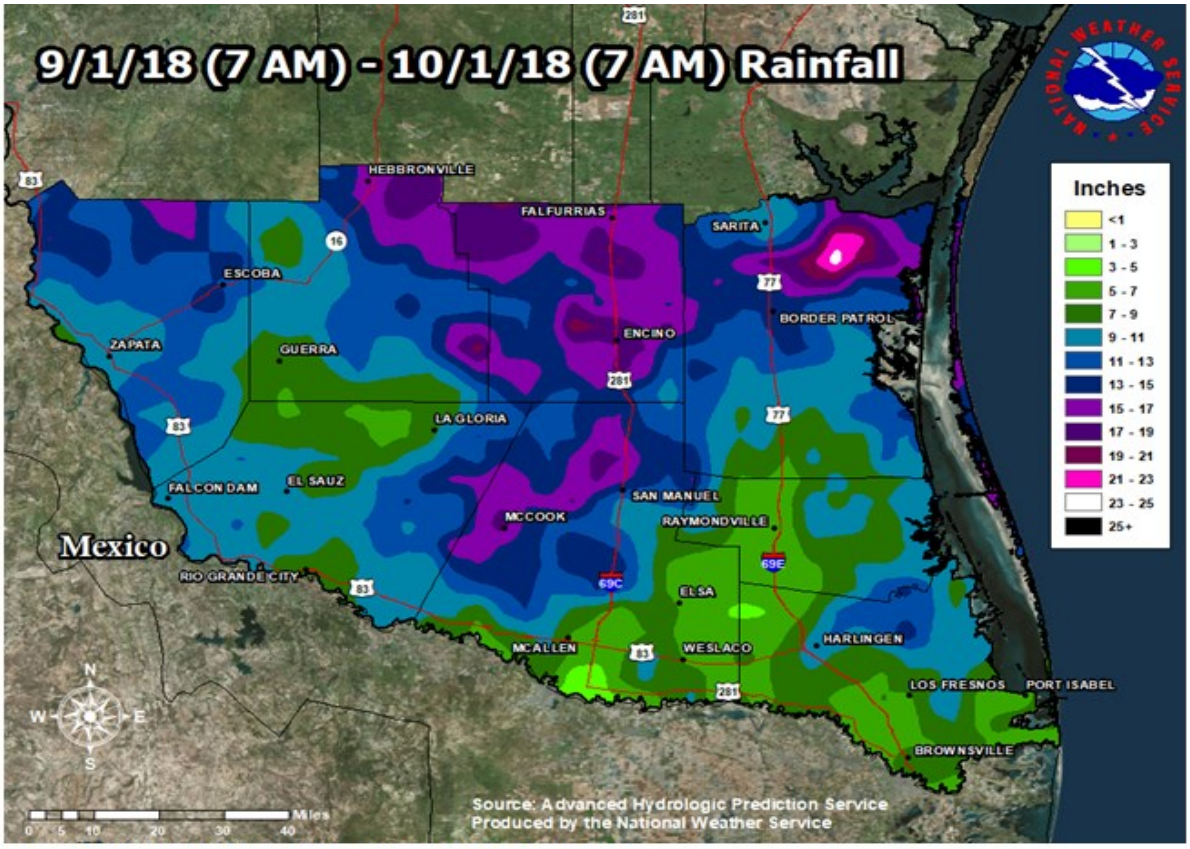
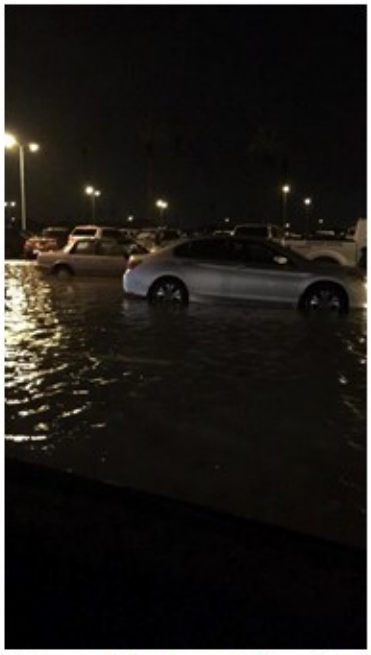


Figure 1: September rainfall for Lower Rio Grande Valley

"Lower Rio Grande Valley Regional Fall Summary (continued)"



Pictures 1-3 above: Urban flooding in the Rio Grande Valley between September 9 and 14, 2018


Pictures 4 and 5 above: Rural flooding in northern Hidalgo County (left) and near Encino (Brooks County, right), September 15-16, 2018

October began as a redux of September: Record heat for the first eleven days of the month, as a broad and strong subtropical upper level ridge dominated the southern U.S. from the Atlantic coast westward through Texas. The west side of the ridge would break down as a deep trough of atmospheric low pressure moved into the southern Rockies; meanwhile, the Atlantic ridge would elongate along the east coast from north to south by the 9th, and allow a channel of flow to direct rapidly intensifying Hurricane Michael into the Florida Panhandle early on the 10th. The Rockies trough would weaken as it slid into the central Plains; a weak front would briefly lower temperatures before the subtropical ridge would return for the weekend of the 13th and 14th. A much stronger upper level trough with a Polar connection would dive into the northern Rockies and northern Plains soon after. Unseasonably strong surface high pressure would dive down the front range of the Rockies on the 14th and 15th and surge into northern Mexico by the 16th. Chilly air followed with temperatures crashing from the lower 90s into the lower 60s during the afternoon of the 15th, with morning temperatures in the 40s and 50s and afternoon temperatures in the upper 50s to mid-60s – more than 20°F below average – holding through the 18th. After a brief warmup (but still below average), another cool snap arrived between the 22nd and 25th. Seasonably warm temperatures would close the month, but the prolonged stretch (10 or

"Lower Rio Grande Valley Regional Fall Summary (continued)"

more days below 80 degrees, from the 16th through 25th) set a new October record for persistent coolness. Summer was definitely a memory.

The cold fronts with limited moisture on either side of them kept rainfall totals at around 50% of the 1981-2010 average, with a few exceptions including Harlingen which had a single day dump of nearly 4 inches on the 11th.

November picked up where October left off, with yet another record to near-record start for the first week (Nov. 1 to 8) with temperature ranking a few degrees behind the prior records set in 2016 and 2017. It would all come crashing down on November 9th, as temperatures crashed into the 50s to lower 60s by day (40s and 50s by night) through the 12th. A reinforcing shot of polar-sourced air arrived on the 13th, with unusually early reports of ice pellets in 45 to 50˚F (but with low wet bulb temperature) air. This would be followed by record cold and biting wind chill temperatures early on the 14th. The earliest Valley-wide freeze in twenty-five years (October 31, 1993) sent lows into the upper 20s to lower 30s across the region, with "feels-like" temperatures in the 20s to start the day. Sunshine would warm temperatures back into the upper 50s and 60s, but low humidity and calm winds overnight would bring the season's first 'wet' frost early on the 15th. Air temperatures that morning were in the mid to upper 30s, but ground temperatures fell to or just below freezing in sheltered locations.

Seasonable temperatures would make a brief appearance following the cold snap, but would disappear again – this time following a more typical "gray" 'norther on November 18th. The week of Thanksgiving was brisk and chilly with many locations away from the coast struggling to reach 60˚F; 40s and 50s were locked in across the ranchlands through Thanksgiving Day away from the coast before moderation begin on Black Friday. Quick moving systems followed, with a welcome warmup Thanksgiving weekend before a "blue" 'norther arrived to close the weekend. Despite sunshine, daytime temperatures only reached the 60s to lower 70s with mornings in the 30s to around 50 on the 26th and 27th. November would end up generally between 3 and 5 degrees below the 1981-2010 average and rank among the twenty-five coldest on record across the Valley.

Periodic light precipitation along and behind the "gray" 'northers on the 10th and again the week of Thanksgiving provided just enough precipitation for a near average month in selected locations like McAllen, Harlingen, and Brownsville – but the Deep South Texas region as a whole was much drier than the already dry average, with many locations receiving little to no rainfall (10 to 25 percent of the ~1 inch average).

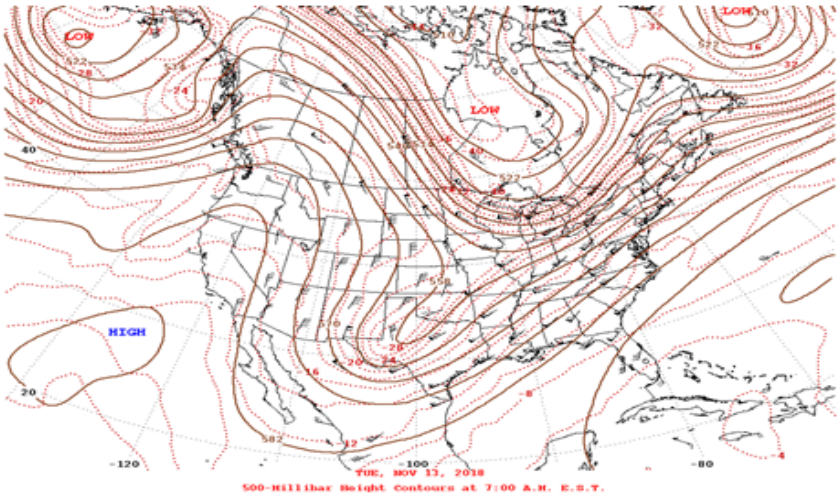


Figure 2 above: 500 mb (steering) pattern on November 13, 2018. Note the cross-polar flow diving across the Canadian Prairie Provinces, then splitting into a dip of the circumpolar vortex near Hudson Bay and a second mid latitude trough into north Texas. This setup is a modified "McFarland" pattern, which has been favorable for polar-sourced air masses to be overrun with moisture that can lead to wintry precipitation in the Valley. Even though it was November, light sleet was reported on the 13th during the morning in Edinburg with no impact.

"Lower Rio Grande Valley Regional Fall Summary (continued)"

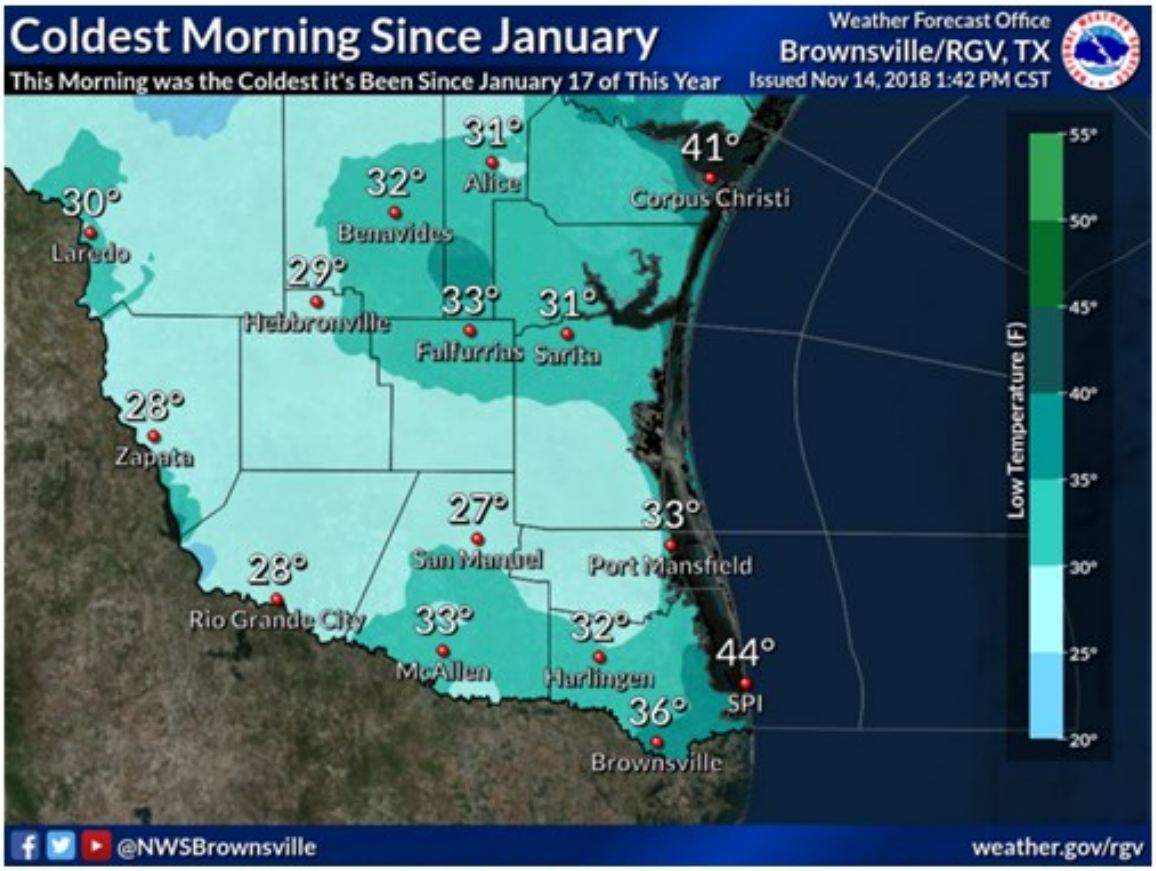


Figure 3: Observed and interpolated minimum temperatures for November 14th, 2018.

Pictures 6-9 above: Light 'wet' frost observed at sunrise in north Brownsville on November 15th, 2018.

Texas State Fall Climate Summary

Texas State Summary

By: John Nielsen-Gammon, Texas State Climatologist, Texas A&M University

Are weather records made to be broken?

Probably, if you wait long enough, any weather record will be broken. Sometimes that's an awfully long wait, though: if it wasn't for climate change, you'd have to wait 10,000 years to have a decent chance of seeing some of Hurricane Harvey's rainfall records broken.

On the other hand, the weather records might change. We think of weather records as the equivalent of documents, maybe not written in stone but at least recorded, with some particular value. The daily weather records that you make and submit to CoCoRaHS has that sort of permanent, unchangeable quality, especially since those records are now being archived in the United States' official climate data archive. Those don't change.

You hear sometimes about people "manipulating" climate data records. Usually, those are computer programs designed to go through all of the climate data and flag suspicious occasions in which one station's temperature went in one direction while all surrounding temperatures went in a different direction. A simple way this can happen is if a station used to record its daily temperatures at 5PM switches to recording them at 8AM.

To see this, suppose there's a really strange place whose 5PM temperature is always 80 °F and whose 8AM temperature is always 60 °F. Except one bizarre Monday the 5PM temperature is 90°F and the 8AM temperature is 40 °F. An observer taking daily observations at 5PM would record two days with a high of 90 °F (since it was 90 °F at the end of Monday's 24-hour period and at the beginning of Tuesday's 24-hour period) and one day with a low of 40 °F. Conversely, an observer taking daily observations at 8AM would record one day with a high of 90 °F and two days with a low of 40 °F, for the same reason. In almost all cases, an 8AM observer will double-count cold temperatures and a 5PM observer will double-count high temperatures. So when a station switches observing time from 5PM to 8AM, its average temperature goes down!

This gets corrected in data that's used for measuring long-term climate trends, but it doesn't get changed in the record values for a particular day. If 90 °F got recorded on two days, then that's the official record, and 90 °F is the number to beat on both days, even if the daily observations switch to 8 AM.

There's another problem when we talk about statewide records, such as the amount of precipitation received by Texas in September and October. When I checked a few weeks ago, Texas had just experienced its third wettest month ever (September 2018) and its fourth wettest month ever (October 2018). Now, according to the data available in early December, October was the third wettest month and September the fourth wettest month.

What changed? The National Centers for Environmental Information received more climate data. It actually takes a few months for all the data to trickle in. If late-arriving data features lots of rain that couldn't have been estimated from surrounding stations, the statewide average will go up. If the new data is drier than expected, the statewide average will go down. We won't know the final statewide precipitation totals for another couple of months. And if they find some more data buried under a rock somewhere, it could still change even afterwards.

As things stand right now, Texas picked up an average of 6.93" in October. That trails only May 2015's 9.05" and August 2017's Harvey-assisted 7.00". And September now stands at 6.67", a bare hundredth over what's now the fifth-place total.

This is actually a remarkable fact. Statewide rainfall numbers date from 1895. But the four wettest months in Texas history have all occurred in the past three and a half years, and two of them were in the past three months. If you thought you were unusually busy this fall emptying your rain gauges, you're right.

I don't know how long that remarkable fact will survive. Maybe next month the September 2018 total will drop down into fifth place when some late data trickles in. So let's just marvel over it while it lasts.

Brazos Valley Regional Fall Climate Summary

Fall 2018 Precipitation Summary

Bryan-College Station/Brazos Valley Region, Texas

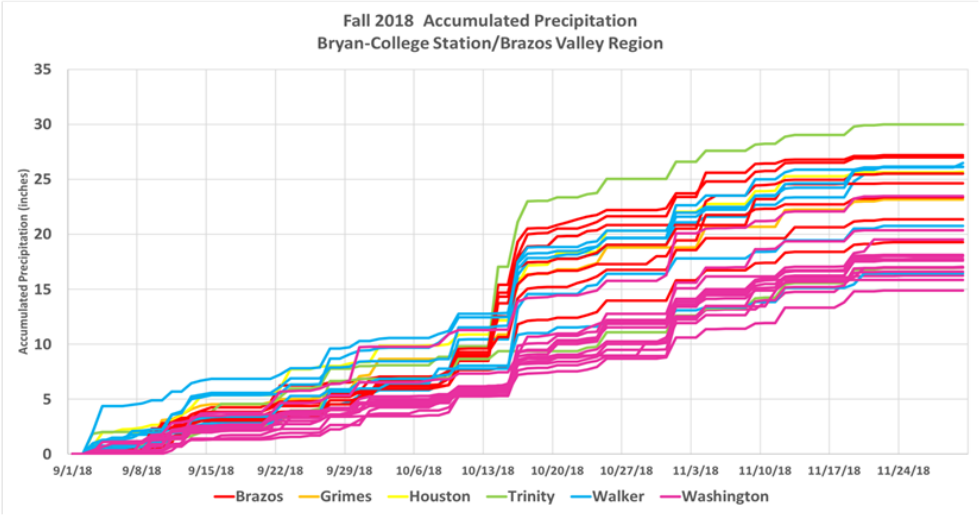
By: John Nielsen-Gammon, Texas A&M University, Texas State Climatologist, and Regional CoCoRaHS Coordinator
Jeramy Dedrick, Graduate Assistant for the Office of the State Climatologist

Summary:

The season's observing period included two of the wettest months on record for the state of Texas. Bryan-College Station and the rest of the Brazos Valley Region was not spared by these substantial accumulations during the past three months. Accumulations in September and October were of particular distinction this fall as the two-month period surpassed April-May 2015 as the wettest two-month period on record for the state. During these months, departures from normal accumulation were consistently 150-300+ percent above normal in the region. Brazos, Trinity, and Walker counties observed these record-breaking conditions most distinctly as represented in their high seasonal totals.

Observer Statistics:

There were **47** active CoCoRaHS observers during the fall season, an increase of two observers from the summer. **9** observers reported for the full 91 days of the season. Not including these stations that covered the entire seasonal period, **21** others reported for at least 75% of the period, providing a total of **30** active observers with reliable measurements across 6 (Brazos, Grimes, Houston, Trinity, Walker, and Washington) of the region's 8 counties.



Accumulated Precipitation:

Starting the season, rain accumulations were nearly an inch a week for each observer. By the end of September, most stations had accumulated upwards of 5 inches. Walker County sites surpassed the 5-inch mark by September's halfway point and were pushing nearly double this amount before the end of the month. The weekly trend of rain accumulation for the other 5 counties continued through the first part of October before several heavy rain events occurred from October 14 to 17. Observers in all but Washington County measured gains in accumulation within a range of 4 to greater than 6 inches in these 4 days alone. Moderate accumulations were observed for the rest of the month before Halloween storms increased totals across the region. November rain totals were a bit more average for the month with a few daily totals that helped to increase the overall season's accumulation. Trinity, Walker, Houston, and Brazos county observers provided measurements that show these counties were by far the wettest of the season.

Season Statistics:

Wettest Day: **7.22"**, October 14 (Trinity County)
Wettest seasonal total: **29.99"** (Trinity County)
Longest spell of days without measurable rain: **10**; November 21 – November 30 (Washington County)
Longest spell of days with measurable rain: **14** (Houston County)
Regional Season Average: **21.26"** ± 4.35"

Austin/San Antonio Regional Fall Climate Summary

Historically Wet Fall across South Central Texas

By Brett Williams - NWS Austin/San Antonio

Fall 2018 was very wet and a bit chilly across South Central Texas. After a hot and dry summer created widespread drought conditions across the region, multiple heavy rain events impacted the area beginning in early September and continuing through mid-October. By late October, all of South Central Texas was removed from drought conditions. Furthermore, the National Weather Service Forecast Office in Austin/San Antonio issued a total of 48 flash flood warnings this fall due to the multiple heavy rain events. San Antonio recorded its wettest fall on record, with 25.11 inches of rain falling. Del Rio was next in line, recording their 2nd wettest fall on record. Austin Camp Mabry and Austin Bergstrom International Airport came in at their 12th and 17th wettest falls on record, respectively. In regards to temperatures, it was generally cooler than normal across the region. San Antonio recorded its 16th coldest fall on record. Del Rio checked in at 18th coldest on record, while Austin Camp Mabry and Austin Bergstrom experienced their 40th and 17th coldest falls on record.

September began wet across South Central Texas. Labor Day Weekend saw heavy rains across the region. In the evening hours of Labor Day, a stationary thunderstorm dropped up to 12 inches of rain across northern portions of San Antonio and Bexar County in a matter of 4 hours, causing flash flooding. About a week later on September 9th, another heavy rain event impacted the region. Then on September 21st and 22nd, another round of heavy rain caused flash flooding across much of South Central Texas. San Antonio experienced their wettest September on record, with 16.86" of rain falling. It was the 3rd wettest month on record at San Antonio, trailing only to October 1998 and July 2002. Del Rio came in at their 5th wettest September on record, while Austin Camp Mabry and Austin Bergstrom saw their 6th and 12th wettest Septembers on record. Temperatures for the month of September were generally near normal.

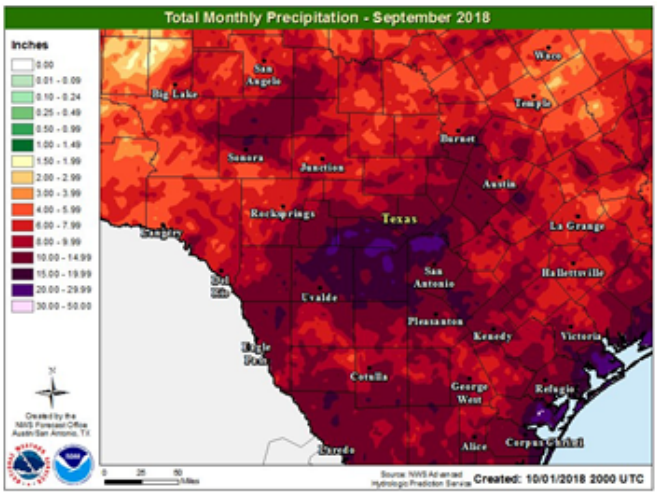
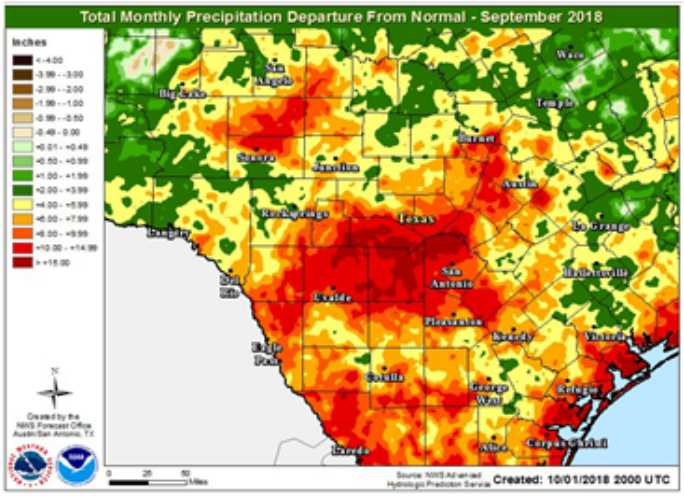


Fig. 1: September Total Rainfall across SC Texas



Fig, 2: September Precipitation Departure across SC Texas

The rainy trend continued into the month of October. The evening hours of October 7th and into the early morning hours of October 8th saw heavy rain and flash flooding across portions of the Hill Country and southern Edwards Plateau. The most impactful rain event of the season occurred on October 15th and 16th, when 6 to 12 inches of rain fell across a large area of the Texas Hill Country. Much of this rain fell directly into the Llano River Basin. On the early morning hours of Tuesday, October 16th, a massive flood wave travelled down the Llano River from south of Mason toward the town of Llano. The Llano River at Llano crested at 40.17 feet, only 1.3 feet shy of the all-time highest historic crest (which occurred on June 14, 1935). This flood wave continued down the Llano River toward Kingsland, and came overtop the Ranch Road 2900 bridge in Kingsland, eventually destroying it. The floodwaters continued into the Highland Lakes northwest of Austin. Lake Travis rose to 704.39 feet, which was the 5th highest crest on record. A massive influx of silt and other debris from the flooding inundated Austin Water treatment plants, and a Boil Water Notice was in effect from October 22nd through October 28th.

The weather was much calmer for the month of November, as it was generally drier than normal across the region. However, November brought much cooler than normal temperatures. The region received its first hard freeze on the morning of November 14th, where temperatures dropped into the low 20s across the area. San Antonio recorded their 10th coldest November on record while Austin Bergstrom recorded their 9th coldest November on record. Del Rio and Austin Mabry came in at their 26th and 29th coldest Novembers on record, respectively.

"Austin/San Antonio Regional Fall Summary (continued)"

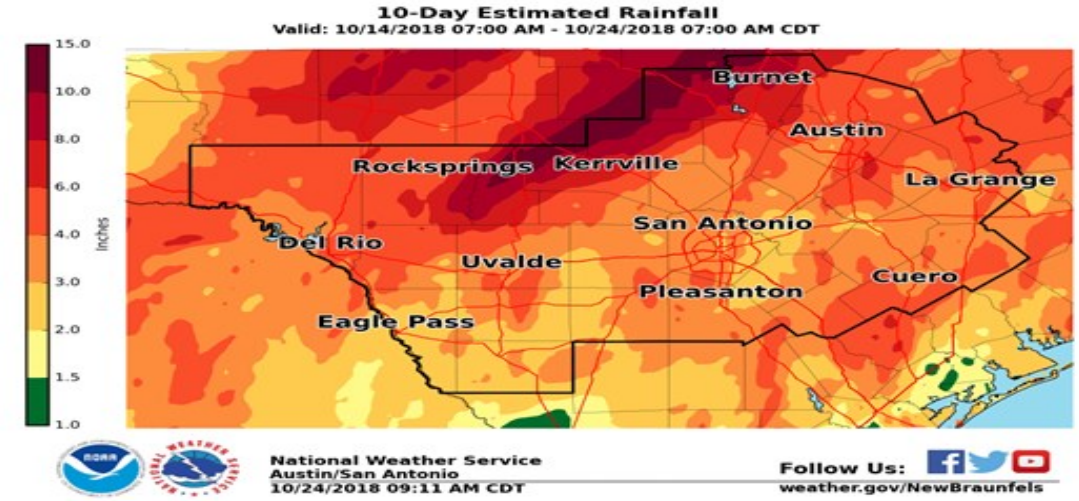


Fig. 3 Ten Day Rainfall Ending October 24th across South Central Texas

Fig. 4: The Llano River Bridge in Llano on morning of October 16th (photo credit: Will Leverett)

Fig. 5: Llano River at Llano Hydrograph showing crest just below record flood stage

Houston/Galveston Regional Fall Climate Summary

Houston/Galveston Regional Fall Climate Summary

By: Ron Havran, Houston/Galveston Regional CoCoRaHS Coordinator

September Climate Summary:

Monthly precipitation values were well above normal for the month of September across the region. Temperatures throughout the month of September were near to only slightly above normal. Most of the month remained on the rainy side with only the third week of the month being a touch drier due to the influence of high pressure. During the first week of September, Gulf moisture and a tight pressure gradient across the region allowed for decent rainfall and cloud cover which helped to keep temperatures 3 to 5 degrees below normal. A stalled frontal boundary acted as a region of shower and thunderstorm development in the second week of the month resulting in mostly cloudy conditions. Most of the precipitation was enhanced due to a lingering mesoscale boundary such as a stalled front, diurnally driven precipitation with ample gulf moisture, or an area of weak surface low pressure coupled with an upper level disturbance. Coastal areas had over 20" of rain in many places. See Fig.1 Galveston and Brazoria counties had the highest CoCoRaHS rainfall averages. Waller and Colorado counties had the lowest CoCoRaHS rainfall averages. See Fig.2 The second half of the month was warmer, which helped to keep the mean monthly temperature near normal. The third week of the month was dominated by high pressure which kept conditions both drier and warmer. A stalled frontal boundary with a region of low pressure towards the end of the month added more rain to a very wet month across most of the region.

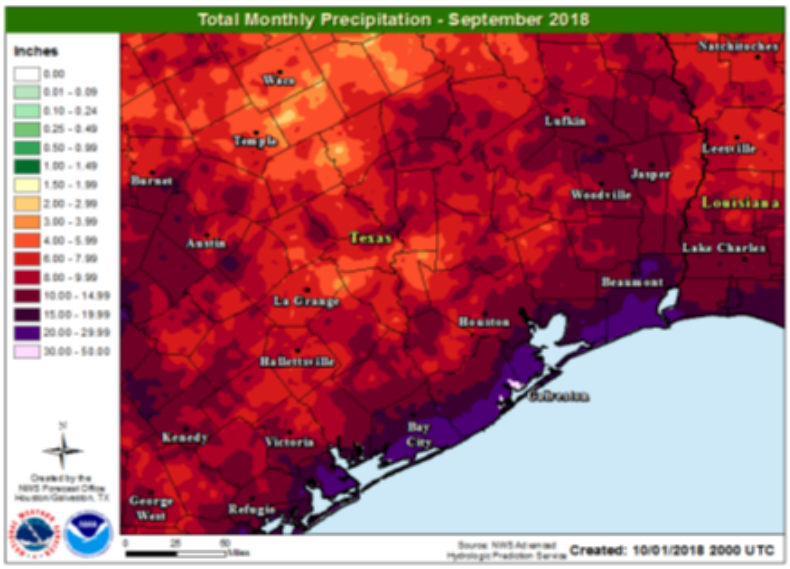


Figure 1: Total September Precipitation

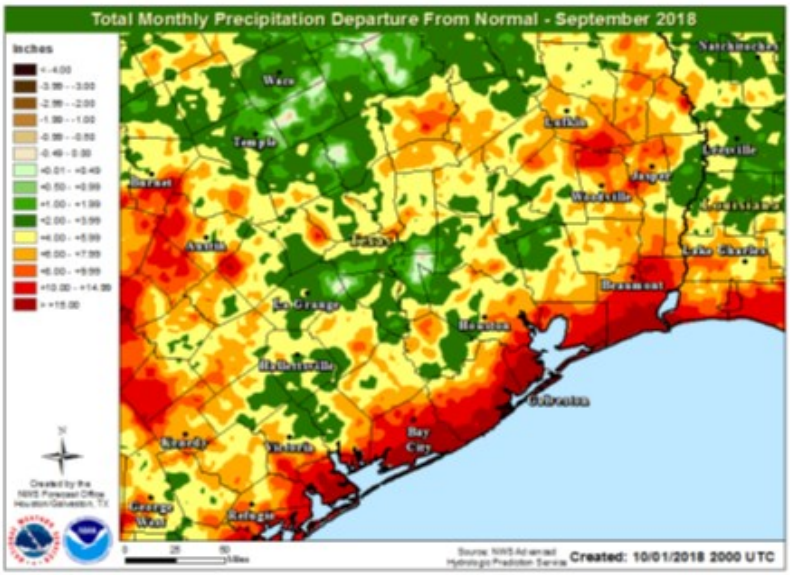


Figure 2: September Precipitation Departure from Normal

"Houston/Galveston Regional Fall Summary (continued)"

October Climate Summary:

In October across Southeast Texas, climate sites were mostly above normal, with departures ranging from a little under one inch to nearly seven inches above normal. The first week of October was warm with temperatures 5 to 10 degrees F above normal. October brought the first strong cold front of the season with temperatures falling well-below normal during the end of the first and into the second week of the month. The trend of below normal temperatures continued through the third week with the passage of multiple weak cold fronts. The last week of the month was above normal as a few warm fronts pushed north from the Northwestern Gulf of Mexico across Southeast Texas. The mean of the monthly temperatures was therefore only slightly above normal by 1 to 2 degrees F for most of the region. The highest average CoCoRaHS station rainfall counties were San Jacinto and Galveston counties. The lowest average CoCoRaHS station rainfall counties were Chambers and Jackson counties.

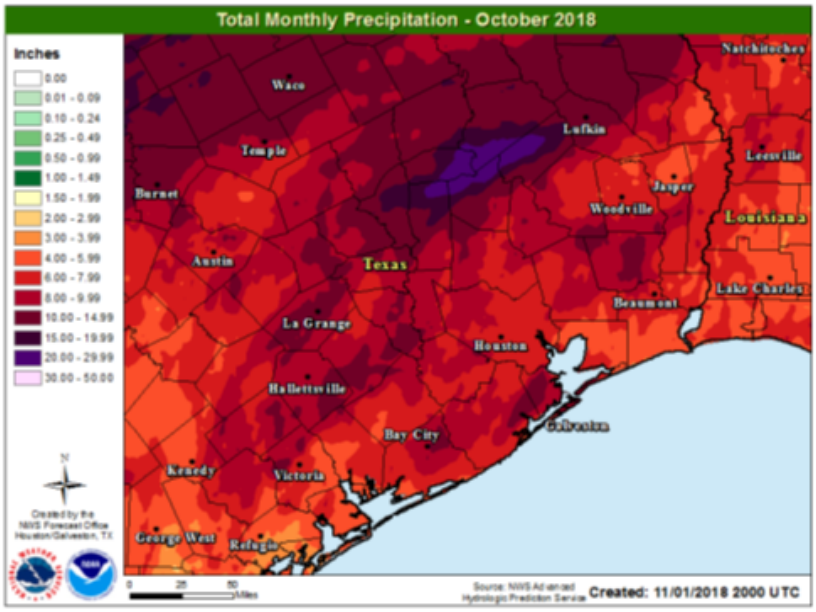


Figure 1: Total October Precipitation

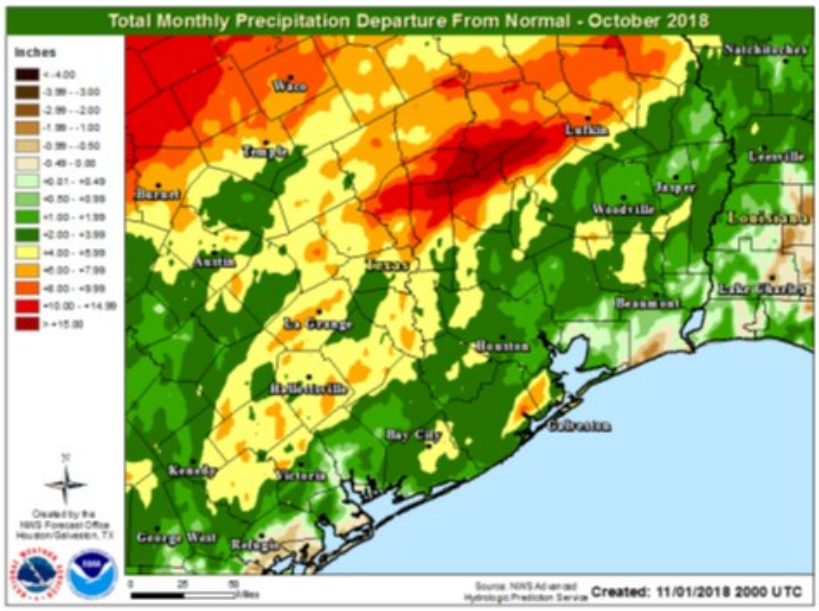


Figure 2: October Precipitation Departure from Normal

"Houston/Galveston Regional Fall Summary (continued)"

November Climate Summary:

The first few days of November brought dry weather as an area of high pressure was overhead. By November 4th, rainfall returned to the forecast as a cold front passed through the area. The second week of the month brought the most rain associated with a few coastal low pressure systems which pushed warm fronts north along the coast and at times further inland. This also helped to bring precipitation in small quantities across the region. Multiple cold fronts continued to push through SE TX and wintry precipitation was even seen on November 13th as the freezing line dipped southward across the state of Texas, Louisiana and even southern portions of Mississippi. Behind most of these cold fronts were regions of high pressure which helped to keep conditions drier than normal. The second half of the month was definitely drier than the first, with mostly high pressure overhead and the progression of a few dry cold fronts. Temperatures fluctuated drastically throughout the month of November with daily departures from normal swinging from fifteen to twenty degrees below normal to ten to fifteen degrees above normal at times. Overall, monthly average temperatures were below normal by three to five degrees. Multiple strong cold fronts helped to bring in these colder than seasonal normal temperatures. The dry cold fronts resulted in most of the climate sites ending the month of November with a rainfall deficit between one to three inches. Harris and San Jacinto counties had the highest CoCoRaHS station average rainfall while Wharton and Waller counties had the lowest CoCoRaHS station average rainfall totals. See figures below.

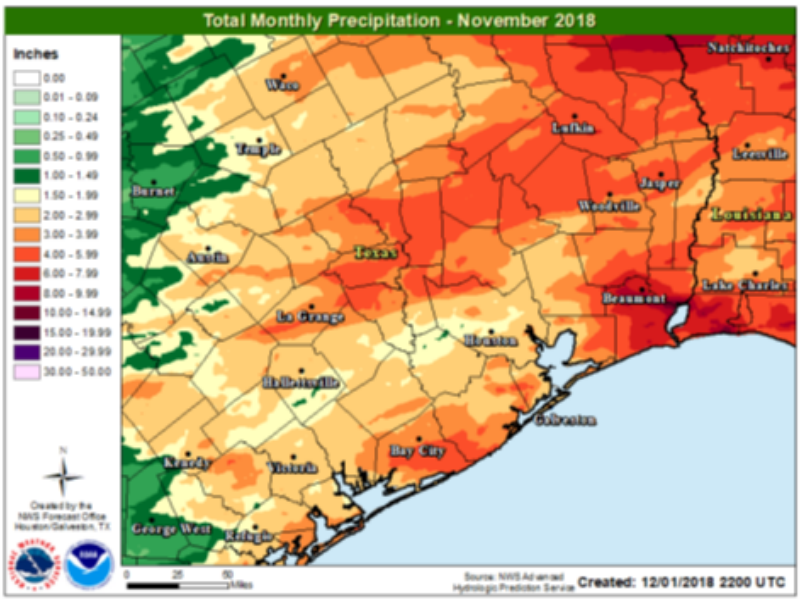


Figure 1: Total November Precipitation

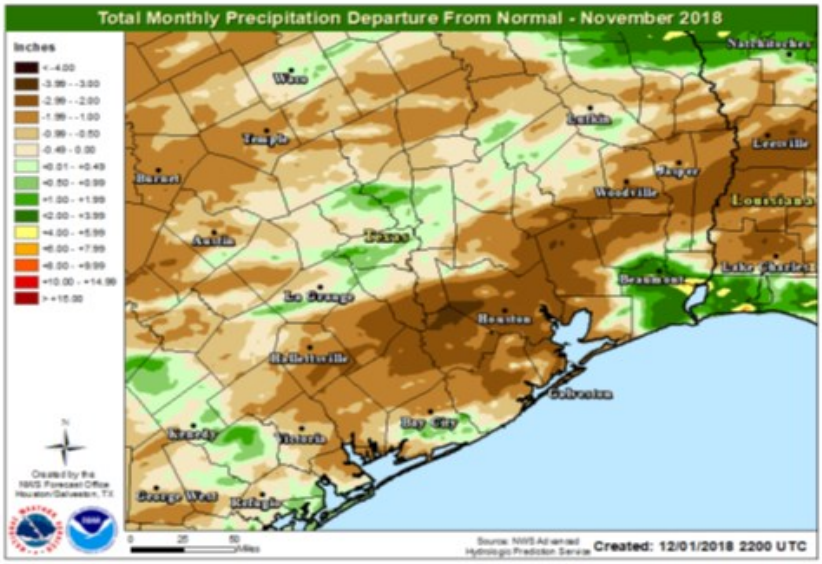


Figure 2: November Precipitation Departure from Normal

"Houston/Galveston Regional Fall Summary (continued)"

Fall 2018 CoCoRaHS Houston/Galveston Region Rainfall

County Rainfall Average and County Station Rainfall Maximum Total in inches per month

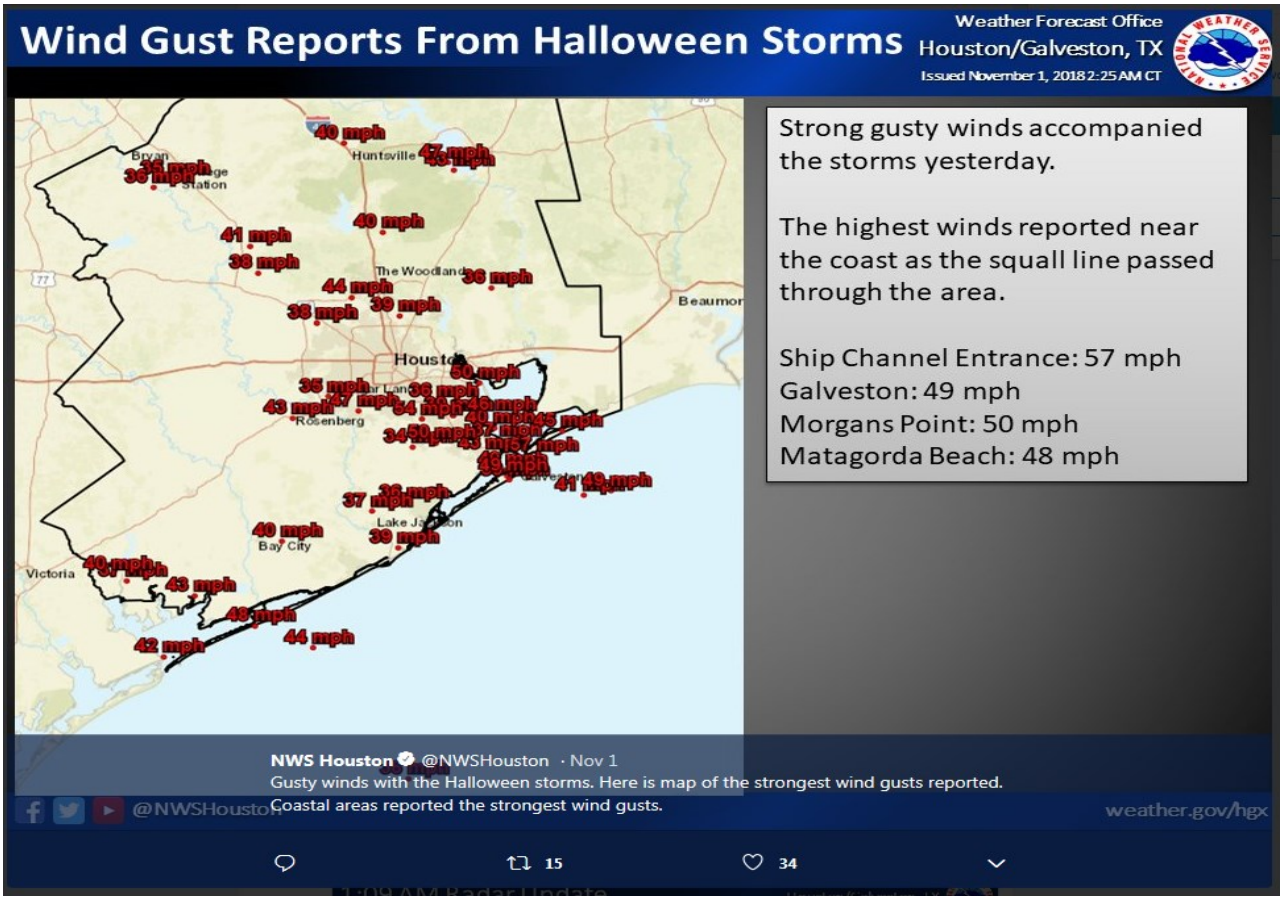
County	September		October		November		Fall Total
	AVG.	MAX.	AVG.	MAX.	AVG.	MAX.	3-Month Rain Total
Austin	5.94	7.49	8.51	10.67	2.82	3.58	17.27
Brazoria	17.94	23.88	7.40	9.62	2.11	3.63	27.45
Chambers	N/A	12.89	5.22	6.79	2.50	2.92	N/A
Colorado	5.53	5.88	6.82	7.74	2.06	2.40	14.41
Fort Bend	6.97	9.12	6.76	8.16	1.39	1.96	15.12
Galveston	23.92	31.43	9.31	10.91	2.49	3.45	35.72
Harris	9.88	21.11	7.22	9.29	7.07	9.02	24.17
Jackson	N/A	13.87	N/A	5.27	N/A	1.31	N/A
Liberty	7.78	8.66	8.37	10.97	2.47	3.06	18.62
Matagorda	N/A	13.61	N/A	10.55	N/A	4.91	N/A
Montgomery	7.97	11.81	7.65	10.23	3.56	4.50	19.18
Polk	5.86	7.46	7.89	9.36	3.55	4.44	17.30
San Jacinto	6.87	10.00	9.68	10.82	4.46	5.13	21.01
Waller	N/A	4.94	N/A	9.25	N/A	0.80	N/A
Wharton	7.37	9.32	5.66	6.91	1.85	2.33	14.88
Region Totals	9.64	31.43	7.75	10.97	3.08	9.02	20.47

Denotes wettest month for a category

Denotes driest month for a category

Note: Months with a N/A for avg. county rainfall had only one station reporting in that county.

Note: All data taken from the cocorahs website by using the Total Precipitation Summary Report for each county by month.



2018-2019 Winter Weather Outlook

By: Bob Rose
Lower Colorado River Authority

This Winter's Weather Factors

- A weak to moderate Modoki El Niño is forecast early winter through spring.
- El Niño's tend to focus the coldest air over the central and eastern US.
- Warm water temperatures in the northeast Pacific and north Atlantic should help cold air flow south through the central US. (-NAO).
- El Niño's often produce above normal rainfall across Texas in the winter months.

The 2018-2019 Forecast Summary

- Temperatures averaging 1-2 degrees below normal December through February.
- Some cold periods may last more than a couple of days.
- Above normal rainfall expected into spring.
- At least a couple of periods of ice or snow flurries will be possible.

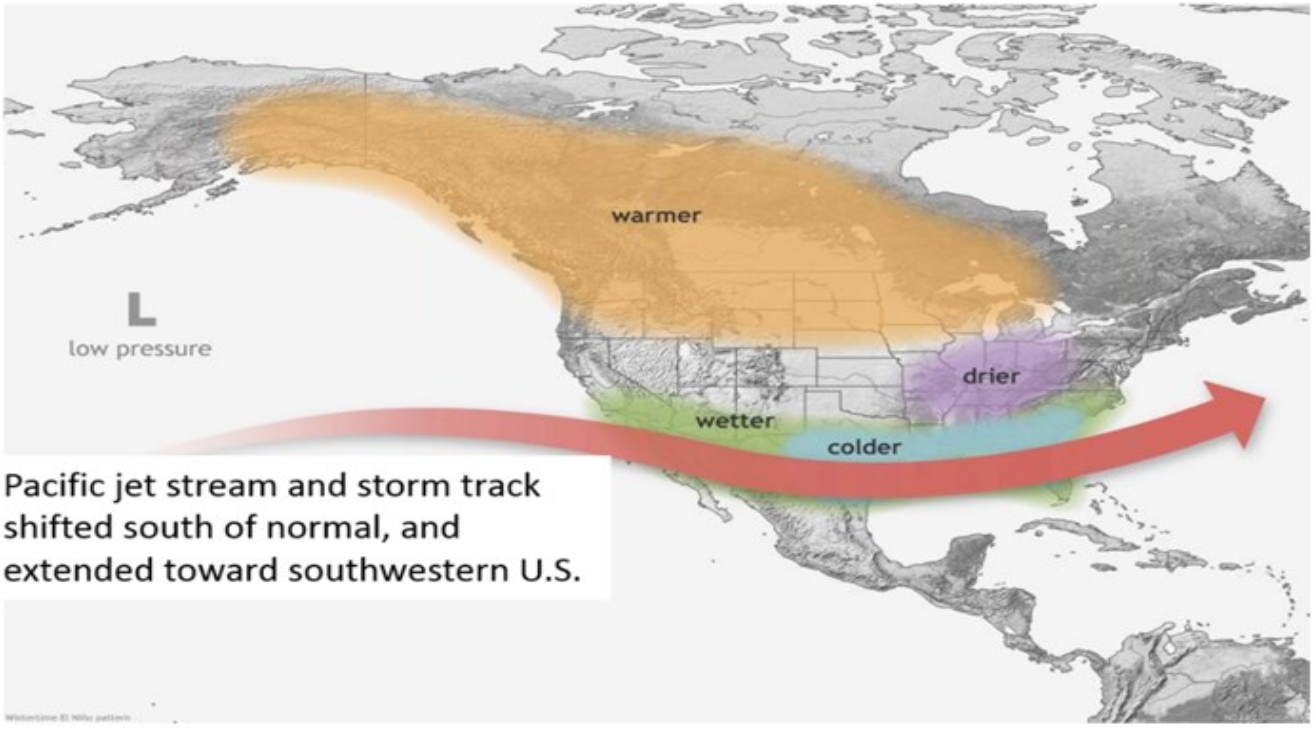


Fig 1: Typical jet stream pattern across North America during El Niño years.

"2018-2019 Winter Weather Outlook (continued)"

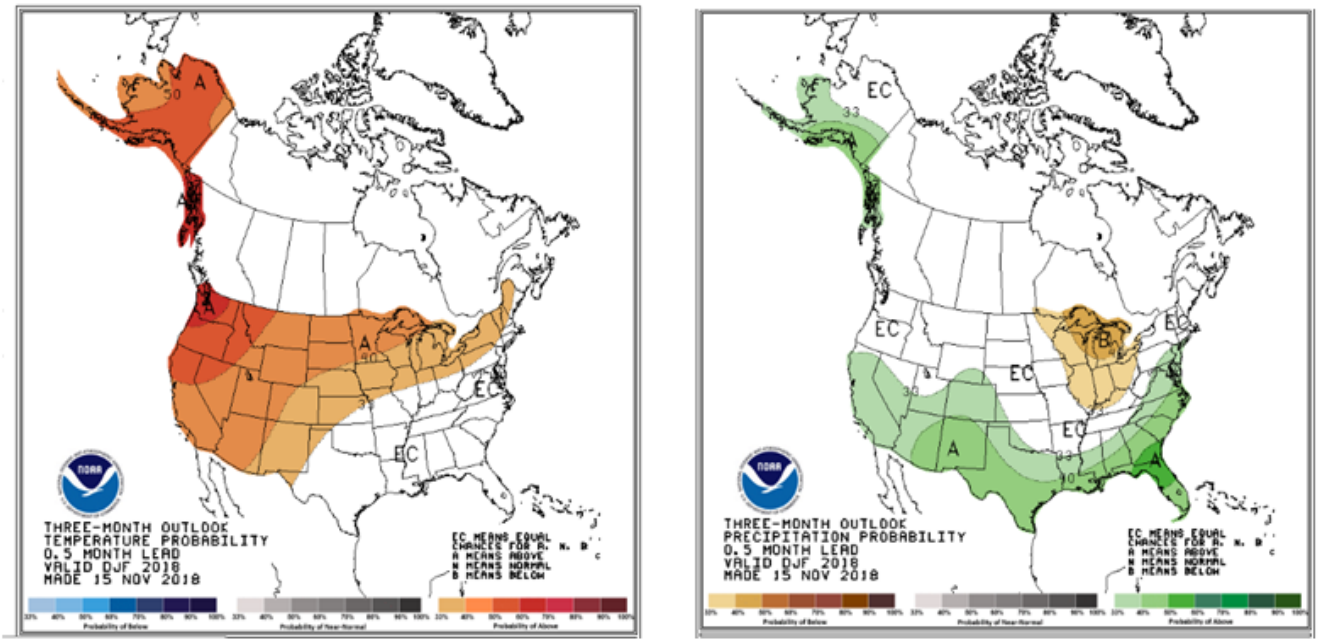


Fig2: NOAA Winter Temperature and Precipitation Outlooks for the lower 48 states December – February

National Weather Service Rainfall Outlook

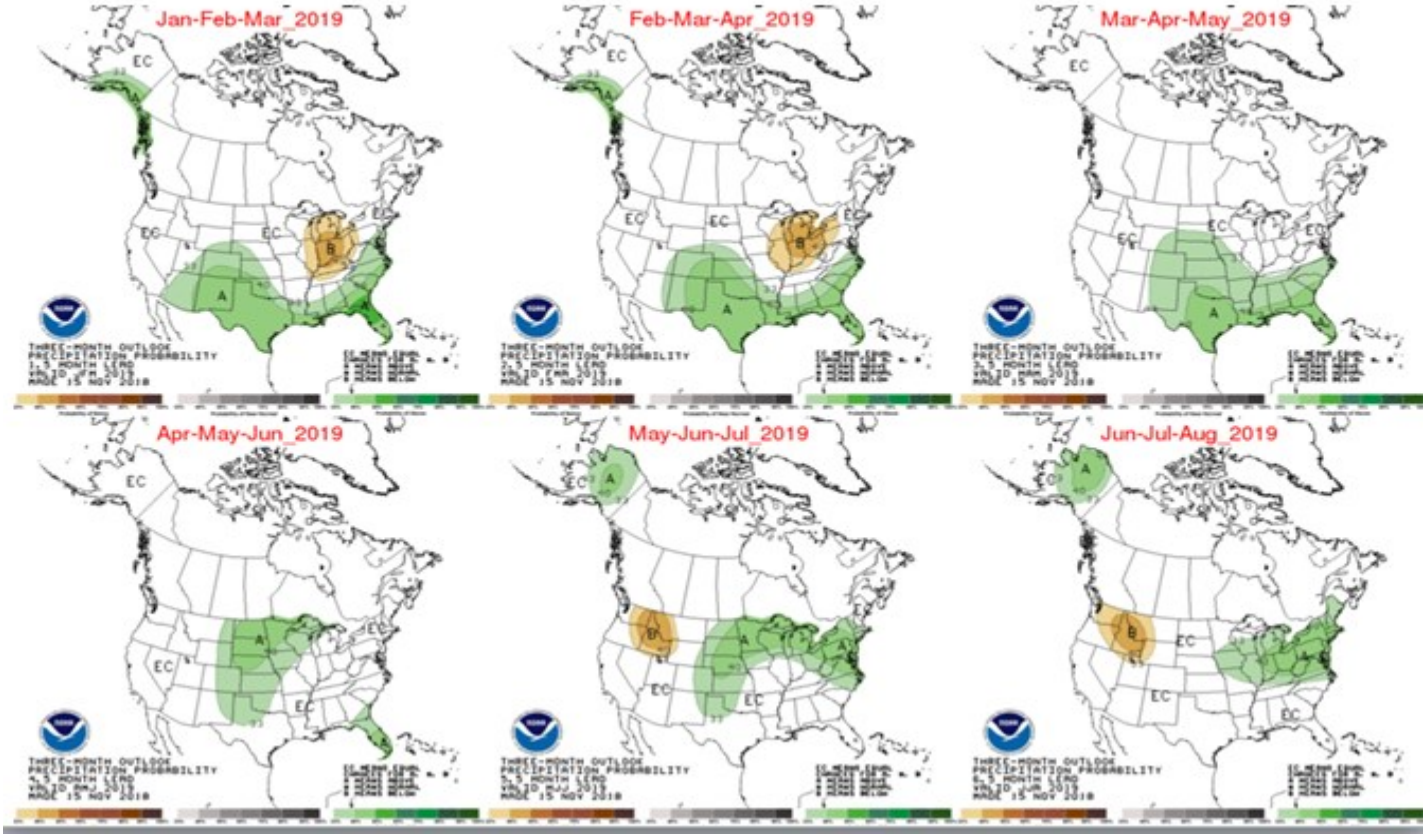
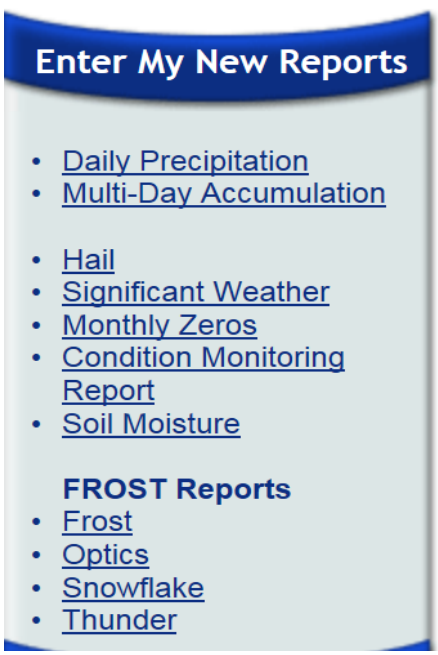
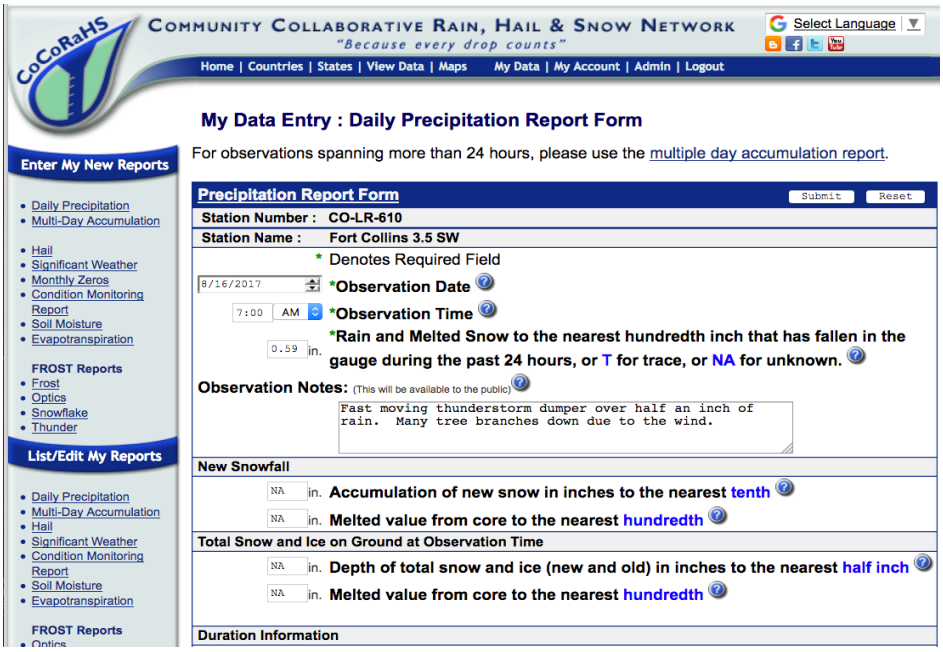


Fig3: NWS Rainfall Outlooks showing wetter than average conditions for Texas through next spring.

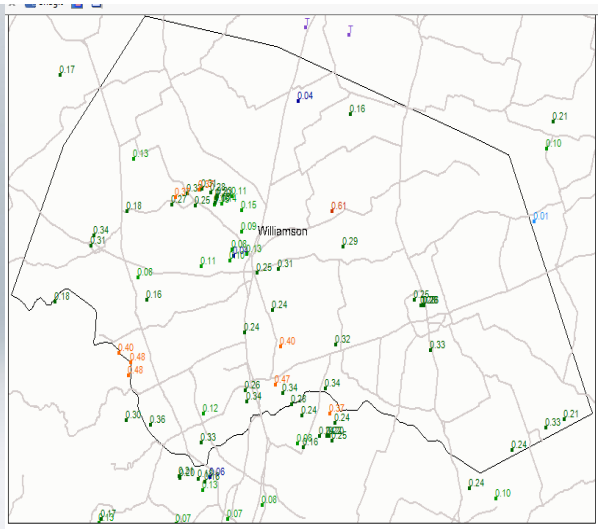
CoCoRaHS Training Tips and Information

Here are some important training reminders for all observers to stay up-to-date on the proper observing standards. The below two images show where all the different type of reports are located and displayed on the CoCoRaHS website. Please review training material online or call a local or regional coordinator if you have any questions on how to make any of these reports.





One of the most confusing situations some observers encounter is finding water in their gauge on mornings when condensation forms and drains inside the inner tube. Just because there is water in your gauge doesn't mean that precipitation occurred. Please read below about how to list in comments that condensation collected in your gauge and to leave the precipitation box as zero rain. Also one last important reminder is to always look at your county map each day to check how your observation compares to nearby stations. See lower right of page. This is an easy way to double check that you entered the correct daily amount in your precipitation box and to look and see if a multi-day value was entered by mistake as a daily report.



CoCoRaHS Webinars

Upcoming WxTalk Webinars:

Thursday, January 17, 2019 - 1:00PM EST

Winter Weather, Climate and Snow
Elizabeth Burakowski
Research Assistant Professor
University of New Hampshire
Durham, NH

(Biography)

Are you a skier, snowboarder, snowmobiler, ice fisher, or snowshoer? Or do you just love waking up on a winter morning to freshly fallen snow? In this webinar, we'll celebrate the many ecosystem services that snow provides, and discuss how your CoCoRaHS snow observations help hydrologists, climate scientists, wildlife biologists, and many more stakeholders and scientists understand how snow plays a critical role in human-environment interactions.

REGISTER

Thursday, March 21, 2019 - 1:00PM EDT

Doppler Radar on Wheels
Karen Kosiba
Center for Severe Weather Research
Boulder, CO

Texas CoCoRaHS Observer

The official newsletter of Texas CoCoRaHS

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