2A.5 A Climatology of Catastrophic Flooding in Texas From Tropical Cyclones

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1. INTRODUCTION

In August 2017, Hurricane Harvey produced catastrophic flooding over a large portion of southeast Texas. Much of the greater Houston area, and the vast majority of the greater Beaumont area, was left underwater due to the record rainfall totals that occurred. Figure 1 shows a spatial map of the observed rainfall totals from Harvey.

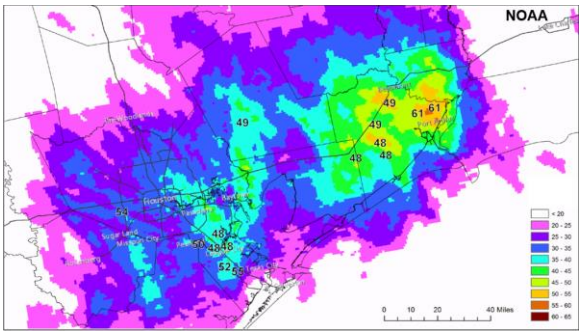

Figure 1: Observed rainfall totals from Hurricane Harvey. Selected values are labeled on the image. The orange shading represents at least 50 inches of rain. Figure is courtesy of NOAA.

The damage from the flooding in the greater Houston and Beaumont areas resulted in Harvey being tied with Katrina as the costliest tropical cyclone (TC) in United States history in terms of the absolute damage value (Blake and Zelinsky, 2018). The flooding was described in the media as historic as well as Harvey being a 10,000 year or greater flood. However, there have been numerous previous cases of catastrophic flooding in east Texas from tropical cyclones including Tropical Storm Claudette in 1979 and Tropical Storm Allison in 2001 (Stewart, 2001). These events, along with lesser floods such as Tropical Storm Frances from 1998 (Lawrence 1998), leads one to ask the following questions: Was Harvey truly unique event that will not be seen again in our lifetimes? How often does major flooding occur in tropical cyclones in Texas?

This study will quantify how frequently tropical cyclones bring certain amounts of rainfall to the Texas coast. It will also identify some of the large-scale weather patterns than can allow tropical cyclones to produce very large amounts of rainfall in Texas.

2. DATA AND METHOD

The rainfall data used for this study is courtesy of David Roth of WPC (Roth 2018). This dataset contains rainfall totals from all TCs to impact the United States since 1948. For the state of Texas, there were 99 tropical cyclones that impacted Texas directly. Included in these 99 TCs are some East Pacific TCs that made landfall in Mexico and moved northeast into Texas. The rainfall data was used to calculate the number of TCs that produced 12 inch, 18 inch, 24 inch, 36 inch, and 48 inch rainfall totals. The rainfall totals for Texas were also compared to rainfall from other states to determine if Texas has a higher frequency of major TC rainfall events.

To determine the weather patterns that may lead to major Texas TC flood events, monthly mean wind data was used. The data has a 2.5 degree horizontal resolution. Mean 200 to 850mb winds are calculated for each month from June through October from the monthly mean data to determine the mean steering flow for each

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month. Anomalies are then calculated for the given month in which a major TC rain event occurred.

3. RESULTS

Texas features more heavy rainfall events from TCs than any other state in the continental United States. This is shown in Table 1. Of the 10 wettest TCs, as defined as the TCs with the highest peak rainfall totals, six of them occurred in Texas. Only one other state, Florida, had two of the 10 wettest TCs to affect the continental United States.

Rank	Storm	Rainfall	State
1	Harvey 2017	60.58	Texas
2	Amelia 1978	48	Texas
3	Easy 1950	45.2	Florida
4	Claudette 1979	45	Texas
5	Allison 2001	40.68	Texas
6	Georges 1998	38.46	Florida
7	Danny 1997	37.75	Alabama
8	Unnamed 1960	29.76	Texas
9	Alberto 1994	27.85	Georgia
10	Beulah 1967	27.38	Texas

Table 1: Top 10 wettest TCs to impact the continental United States from 1948-2017. The yellow shaded tabs denote storms that impacted Texas.

The results here are more impressive when one considers the difference in the number of TCs to impact Texas compared to Florida, a state known for tropical storm and hurricane impacts. Since 1948, there were 99 total TCs to impact Texas compared to 187 to impact Florida. Despite having little more than half the TC frequency of Florida, there are more rain events of at least 18, 24, 36, and 48 inches in Texas than in Florida. These results are shown in Table 2.

Inches of Rain	Number of Florida Storms	Number of Texas Storms
12+	64	41
18+	16	19
24+	7	9
36+	2	4
48+	0	2

Table 2: Frequency of TCs from 1948-2017 that produce at least, 12, 18, 24, 36, and 48 inches of rainfall in Florida and Texas.

TCs produce 12 inches or more of rainfall about every 3 out of 5 years on average in Texas. 18 inches or more occur in Texas roughly every 3 out of 10 years. TCs bring at least 24 inches of rain to Texas about once every 8 years. 36 inches or more occur in Texas TCs about once every 18 years. It is worth stressing that these are for any occurrence within the state of Texas. These rates of occurrence do not represent the return period for a specific location.

Now that it has been established that Texas is more prone to extreme TC flood events than other states in the continental United States, it is worth exploring a possible reason why this is the case. One could hypothesize that this is due to the warm waters of the Gulf of Mexico bringing increased moisture over the state. However, if this were the case, other Gulf States as well as Florida would see a similar frequency, or greater in the case of Florida, in the number of rainfall events as does Texas. This is not the case, however. Thus, the Gulf waters cannot fully explain why Texas is so prone to extreme rainfall events. We will investigate the mean steering flow over Texas from the months in which TCs brought major flood events to determine if there is a signal in the steering flow.

We begin our investigation of the steering flow around TCs that caused major flooding in Texas by evaluating the flow from the time of Hurricane Harvey from August 2017. We first examine the mean 1948-2017 200 to 850mb steering flow. This is shown in Figure 2.

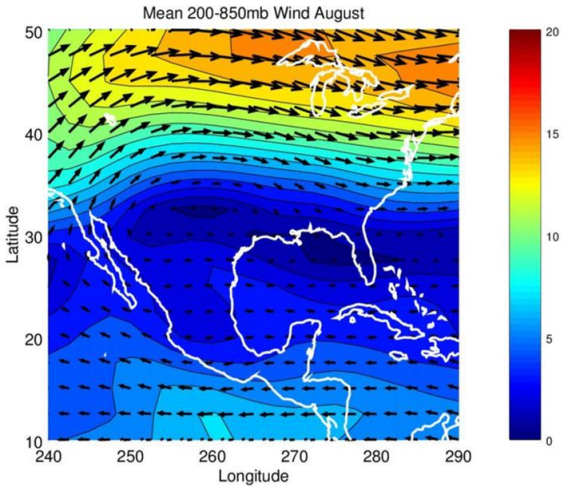

Figure 2: Mean 200-850mb wind (ms^{-1}) for August from 1948-2017. The magnitude is shaded while the arrows represent the direction.

The mean August flow is east to west over most of Texas, beneath a ridge of high pressure. Evaluating the monthly mean wind from August 2017, the ridge was displaced a bit to the south of the usual position. This allowed for anomalous northwesterly flow over Texas. This flow may have been part of the reason why Harvey stalled over coastal Texas, which allowed it to produce the catastrophic flooding. Figure 3 shows the mean wind from August 2017.

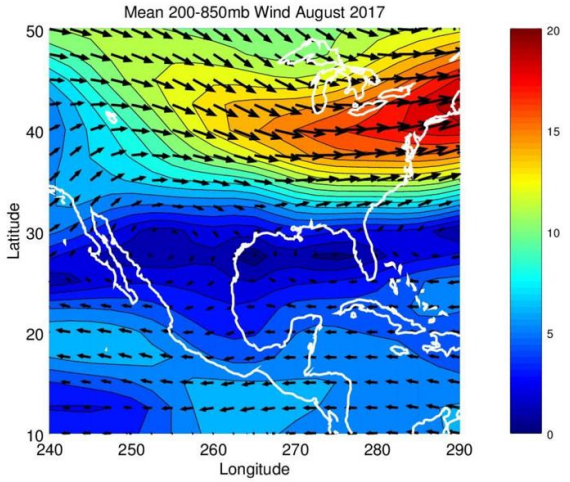

Figure 3: Mean 200-850mb wind (ms^{-1}) for August 2017. The magnitude is shaded while the arrows represent the direction.

To further investigate how the monthly mean steering flow affected the track of Harvey, we will evaluate the effect of the V component of the monthly mean wind. Figure 4 shows the August 2017 200 to 850mb mean V wind anomaly.

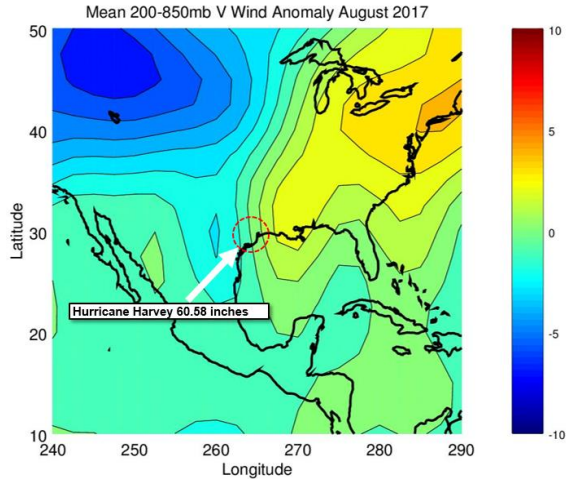

Figure 4: Mean V wind anomaly for August 2017. The arrow points to the location of the peak recorded rainfall for Harvey.

The mean flow for Harvey shows an anomalous northerly component of the mean 200 to 850mb wind northwest of Harvey, and an anomalous southerly component to the mean wind northeast of Harvey. A similar

pattern was present in June of 2001 with Tropical Storm Allison, which flooded many of the same areas that were flooded by Harvey, though not to the same degree. The mean June 2001 V wind anomaly is shown in Figure 5.

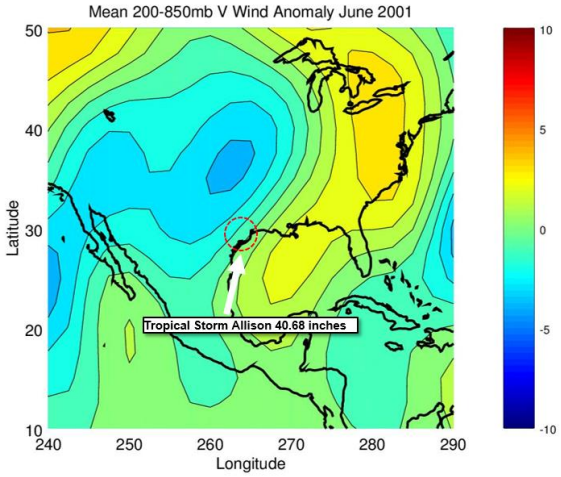

Figure 4: Mean V wind anomaly for June 2001. The arrow points to the location of the peak recorded rainfall for Allison.

In the case of Allison, the anomalies are not as large as those with Harvey. However, the pattern is somewhat similar with anomalous northerly flow to the northwest of Allison with anomalous southerly flow to the northeast of Allison. A similar signal was present with Hurricane Beulah in 1967, which also produced heavy flooding, though in the Rio Grande Valley and not in southeast Texas. The fact that these signals are detectable in monthly mean data means that it may be possible to for the long range forecast models to predict if the environment will favor major flooding by indicating anomalous northerly flow to the northwest of southeast Texas and anomalous southerly flow well to the northeast of southeast Texas.

4. DISCUSSON

TCs bring extreme rainfall events to Texas more frequently than to any other state in the continental United States. TCs bring at least 24 inches of rain to Texas on average once every 8 years. This means a severe flood can be expected more than once a decade in Texas due to a landfalling TC. More than 36 inches of rainfall occur about once every 18 years. This means a flood on the order of Tropical Storm Allison could occur more than once every 20 years. More than 48 inches of rain has occurred twice since 1948. This means that flooding approaching the magnitude of Harvey has occurred before in the not too distant past. While the record is not long enough to conclude that another Harvey is likely again in within the next few decades, it does indicate that there is the possibility that a Harvey level flood, at least at a specific location, may occur again within the next few decades. It may not be several hundred or thousand years before the waters rise to those levels again.

Monthly mean wind data showed a signal that may favor major Texas TC flooding. Anomalous northerly flow to the northwest of Texas and anomalous flow to the northeast of Texas, especially over the northeast United States, is the pattern that has been associated with major Texas TC floods in the past. That this is shown in monthly mean data, may allow for long range predictions that show months when major flooding is possible, if a TC were to move into Texas.

5. ACKNOWLEDGEMENTS

The rainfall data was courtesy of David Roth of the WPC. The monthly mean data was courtesy of the NCEI.

6. REFERENCES

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