Method to Transfer Flood Risk and its Application to Hurricane Harvey

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Abstract

The magnitude of Hurricane Harvey significantly altered flood frequency statistics in the region that it hit, but hurricane path projections indicate that it could have made landfall in numerous other regions along the Gulf coast. While current flood frequency methods restrict analysis to floods that occur within a specific region, due to the effects of climate change and immense size of Harvey, it is important to determine the impact that Harvey would have had if it hit other regions within its probabilistic landfall path. Therefore, this study investigates the impact that Harvey would have had on flood frequency statistics and regional flood frequency analysis if it had made landfall elsewhere. To this end, spatial rainfall data was shifted to two probabilistic landfall regions in the central and southern Gulf coast of Texas. This shifted rainfall data was then paired with synthetic unit hydrographs to create simulated Hurricane peak flows at USGS streamflow stations in each region. With few exceptions, Log Pearson III analyses of records containing simulated Harvey peak flows resulted in 2-, 5-, 10-, 25-, 50- and 100-year peak flows that were higher than Log Pearson III analyses of the original peak flow records. These increases in peak flows were larger for longer return periods – 100-year peak flows increased by an average of 63.9% in the southern coast region and 21.4% in the central coast region, while 2-year peak flows increased by an average of 9.38% in the southern coast region and 1.51% in the central coast region. These return period peak flows were then applied to regional flood frequency analysis to predict peak flows based upon drainage area and basin shape factor. Application of the equations to example watersheds in the central coast region increased estimated peak flows by up to 75%. This case study shows that moving Hurricane Harvey to different regions within its probabilistic landfall path would have a significant impact on flood frequency statistics and regional flood frequency equations. Therefore, because of the growing impact of climate change on hurricane intensity, it may be important to consider the impact that current and future extreme hurricanes like Harvey have on flood frequency statistics in other regions within their probabilistic landfall path.

Method to Transfer Flood Risk for Regional Flood Frequency Analysis

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Introduction

- Hurricane Harvey was an unprecedented event that resulted in immense damage to life and property.
  - Maximum rainfall of 1539 mm (60.58 in.)
  - 68 direct deaths and 35 indirect deaths
  - $125 billion of damage [1]
- Extreme events such as Harvey are often used to develop flood frequency statistics that are based on local, historic annual peakflow data.
- These methods assume stationarity in the data; however, it is estimated that climate change contributed ~15% of Harvey's intensity [2]
- Previous research showed that Harvey increased the 100-year flood in Northeast Texas by an average of 28% [3].
- Recommended flood frequency procedures in Bulletin 17C do not have procedures for incorporating non-stationarity from climate change [4].
- If climate-enlarged storms like Harvey are the new normal, then perhaps their risk should be considered within regions in which they could have but did not hit.

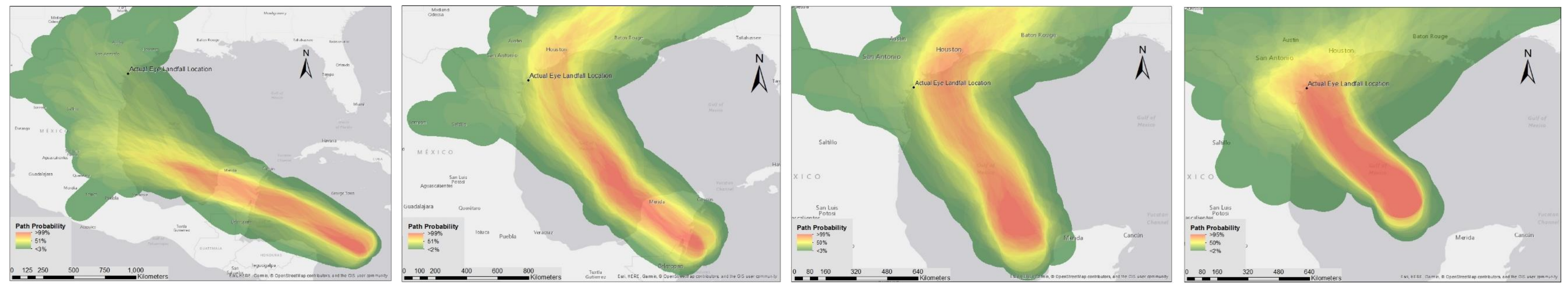
Research Question

How would Hurricane Harvey have affected regional flood frequency analysis had it made landfall elsewhere?

Methods

1) Develop probability maps of where Harvey could have hit
2) Shift rainfall data to new landfall locations
3) Create synthetic unit hydrographs for stream gages within the new landfall locations
4) Apply synthetic unit hydrographs to calculate peak flows
5) Perform Log Pearson III analyses using Bulletin 17.C and PeakFQ software [5]
6) Perform Regional Flood Frequency (RFF) analyses using Bulletin 17.C analysis in WREG software [6]

Landfall Probability Distribution



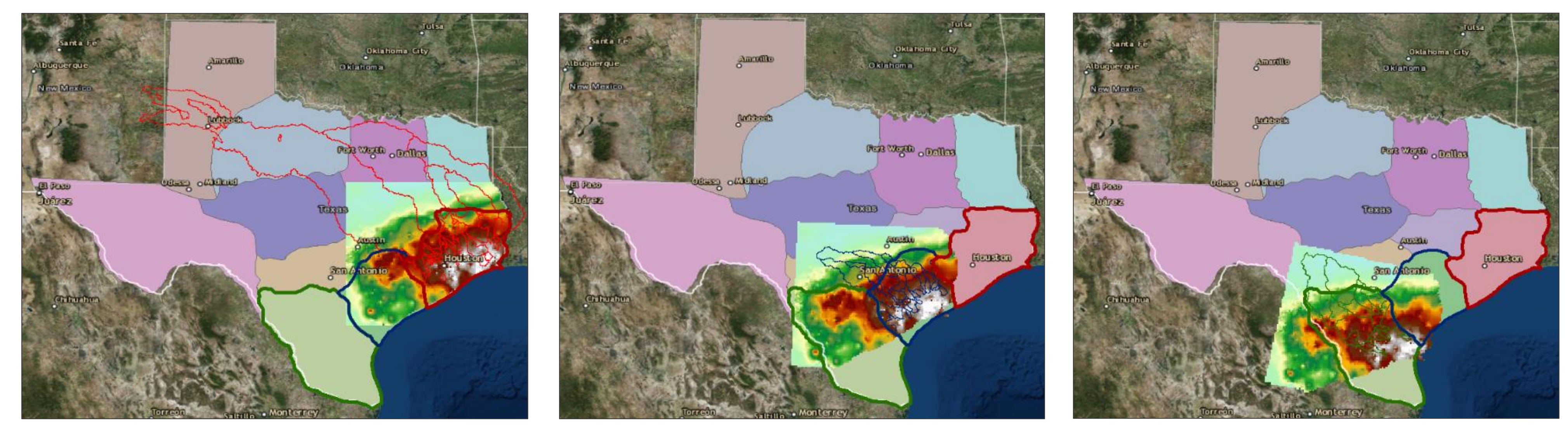
Aug. 21 | Aug. 22 | Aug. 23 | Aug. 24

Figure 1. Daily landfall probability distributions leading up to Hurricane Harvey's landfall.

Figure 1 represents the probability that Harvey's would pass within 60 nautical miles. Probability distributions were made with the GFS and MOGREPS-G ensemble models [7].

The two new storm locations (Figure 2) were chosen for the following reasons:
- In the probable path of the storm
- Different hydrologic characteristics
- Within geographic area for which data had been obtained [8].

New Landfall Locations



Hurricane Harvey rainfall | Rainfall shifted to central region | Rainfall shifted to southern region

Figure 2. Rainfall map of Hurricane Harvey moved to the central Texas coast and the southern Texas coast.

Log Pearson III Analysis

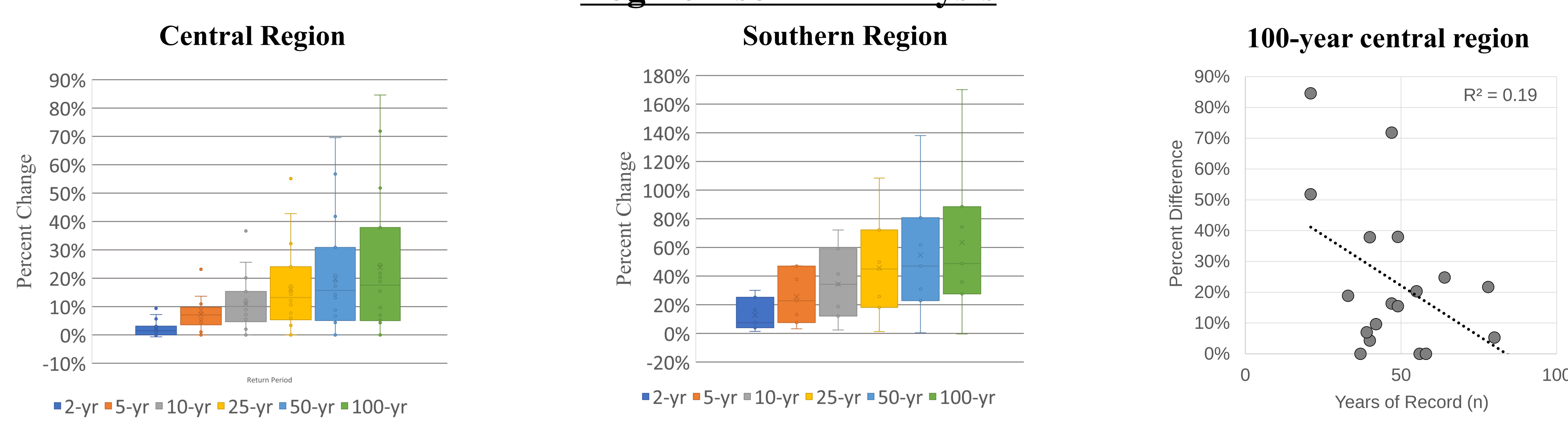


Figure 3. Change in Log Pearson III flowrates upon the inclusion of Harvey simulation in the record.

Regional Flood Frequency Analysis

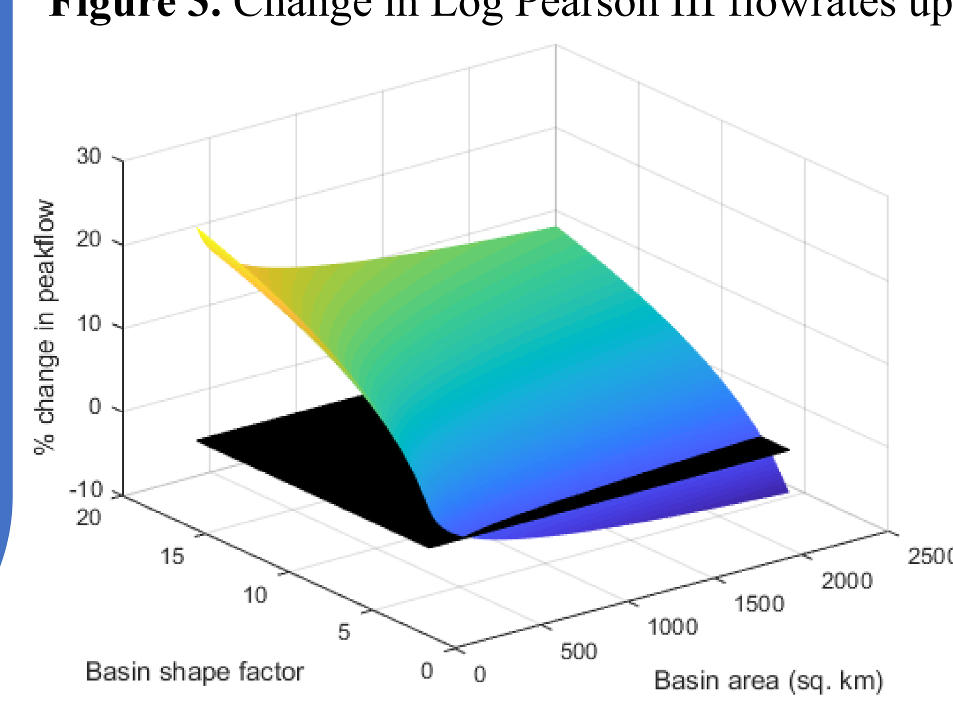
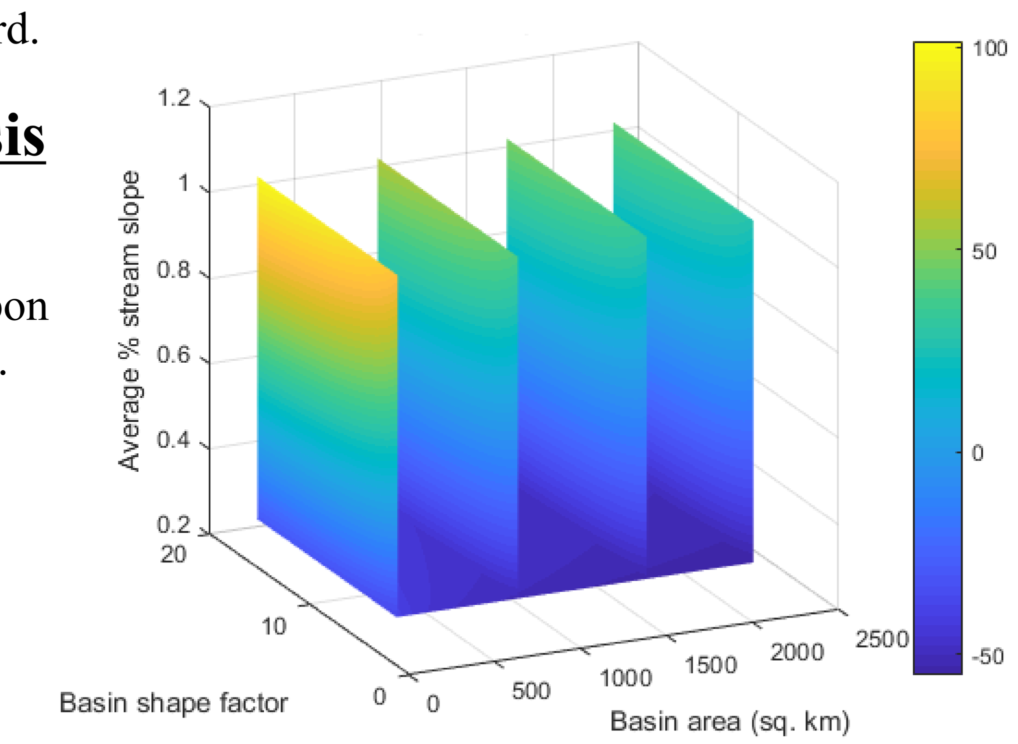


Figure 4 (Left). Change in Regional Flood Frequency Analysis for 10-year return period upon the inclusion of Harvey simulation in the record.

Figure 5 (Right). Change in Regional Flood Frequency Analysis for 100-year return period upon the inclusion of Harvey simulation in the record.



Discussion

- Simulating Hurricane Harvey in other regions of Texas had a similar impact on Flood Frequency statistics (24-64%) as did the original storm (28%)
- Increases in Log Pearson III peakflows were larger in the southern region than in the central region. This could be due to differences in hydrologic characteristics between the two regions or a limited number of gages in the southern region.
- Watersheds with shorter periods of record experienced larger increases in Log Pearson III peakflows than those with longer periods of record.
- The Regional Flood Frequency analysis in the central region showed that basin shape factor was a significant predictor of change in peakflows for return periods of 10 years and higher, while stream slope was a significant predictor for return periods of 25 years and higher.

Conclusion

Hurricane Harvey would have increased the 100-year flood by 23.8% in the central region and 63.5% in the southern region had it primarily hit these locations.

References

[1] Blake and Zelinsky (2017); [2] van Oldenborgh et al. (2017); [3] W. M. McDonald and J. B. Naughton (2018); [4] J. F. England et al. (2019); [5] Veilleux, Cohn, Flynn, Mason, and Hummel (2013); [6] K. Eng, Y. Chen, and J. Kian (2013); [7] Automated Tropical Cyclone Forecasting System (ATCF) (2017); [8] USGS and Naughton (2017)

For full references, scan the QR code or contact Elizabeth Regier at elizabeth.regier@marquette.edu

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