A Comparison of the Polarimetric Radar Characteristics of Hurricanes Harvey (2017) and Florence (2018)

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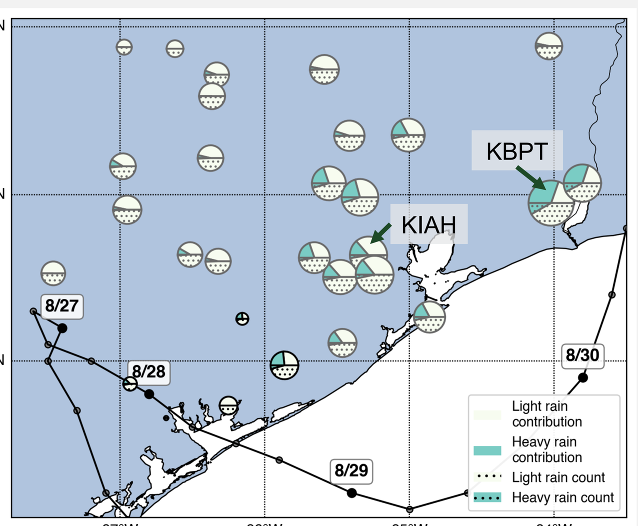
Introduction

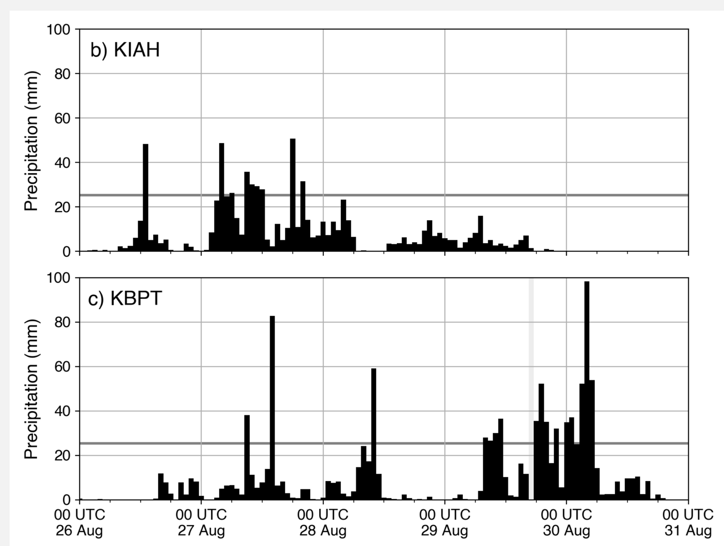
In 2017 and 2018, Hurricanes Harvey and Florence moved slowly over Texas and the Carolinas, respectively, dropping record amounts of rainfall. During Harvey, 1538 mm of rain near Nederland, TX broke the overall and continental records for tropical cyclone rainfall in the United States and rainfall exceeded 500 mm from southeast of Austin to the Texas-Louisiana border. During Florence, 912 mm in Elizabeth Town, NC and 600 mm in Loris, SC set new state records for tropical cyclone rainfall. In each case, the intense rainfall resulted in numerous fatalities and widespread damage.

To better understand how these events unfold, we need to determine the relative roles of event duration and heavy rain, while simultaneously documenting the bulk microphysical characteristics. Our objective is to use rain gauge and polarimetric radar data to address these issues. This analysis will help identify similarities and differences in future extreme events.

Harvey rain gauge observations



Left: Map of Harvey's track and ASOS observations. Size of marker is proportional to total rain, green wedges reflect heavy rain (>= 25.4 mm/hr) count and contribution. **Right:** Time series of hourly rainfall at KIAH and KBPT.



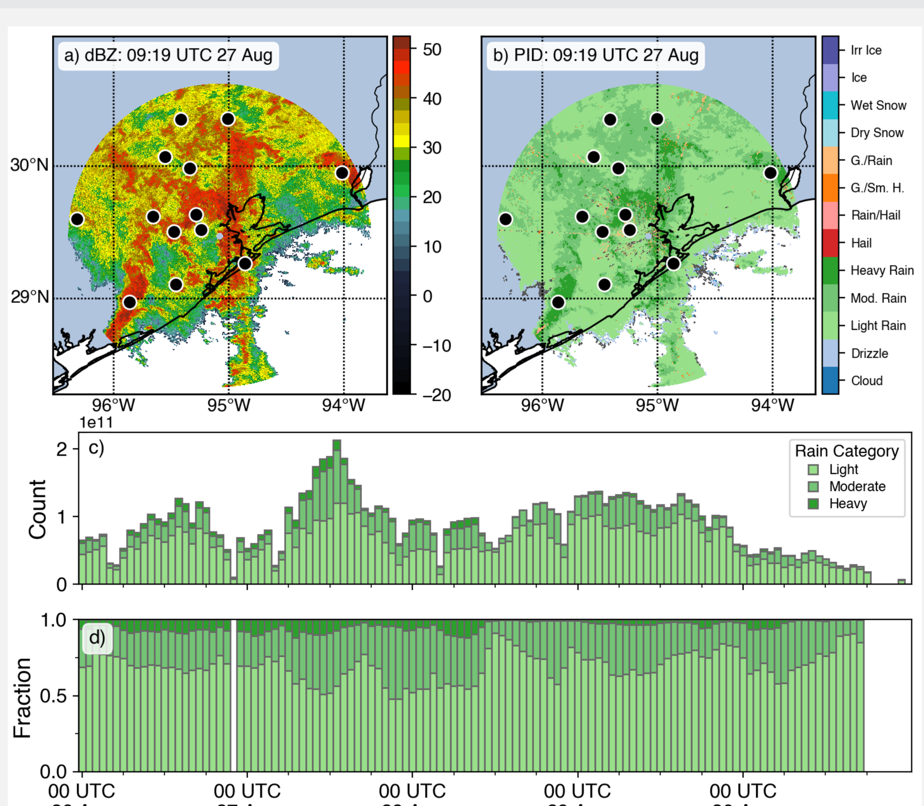
- Heavy rain infrequent, but non-negligible
- More heavy rain = more total rain
- Varies spatially: 1/3 of KIAH rain was heavy, 2/3 of KBPT rain was heavy

- Harvey's track dominates evolution
- Heaviest rain hit KIAH before KBPT
- Longer onshore flow for KBPT: outer convection then heavy inner core rain

Polarimetric data and methods

Radar data: S-band NEXRAD (KHGX, KMHX)

1) Isolate data points (0.5º sweep) identified as rain by the NCAR PID using LROSE algorithm
2) Require 0.95 ≦ ρ_{HV} ≦ 1.0
3) Remove sweeps with high Z_{DR} and partially blocked beams
4) Correct Z_{DR} bias (Cunningham et al. 2013): -0.25, -0.07 dB at KHGX, KMHX
5) Calculate area-weighted counts and fractional coverage within 128 km at each hour



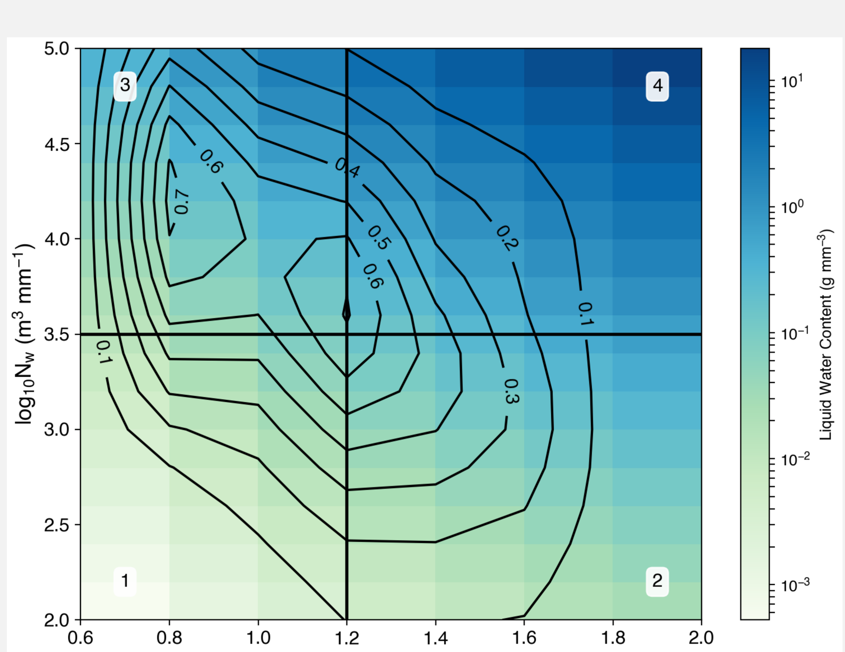
Top Left: 0.5º reflectivity. **Top Right:** PID categories. **Middle:** Time series of area-weighted count of PID rain categories. **Bottom:** As in middle, but fractional area.

Microphysical analysis: Bringi et al. (2013) (CSU_RadarTools)

Uses Z_H and Z_{DR} to estimate N_W and D_0 parameters that describe the normalized gamma drop size distribution (DSD) related by:

$$N_W = \frac{1.81 \times 10^5 LWC}{\pi \rho_W D_0^4}$$

N_W and D_0 are proxies for number concentration and median diameter



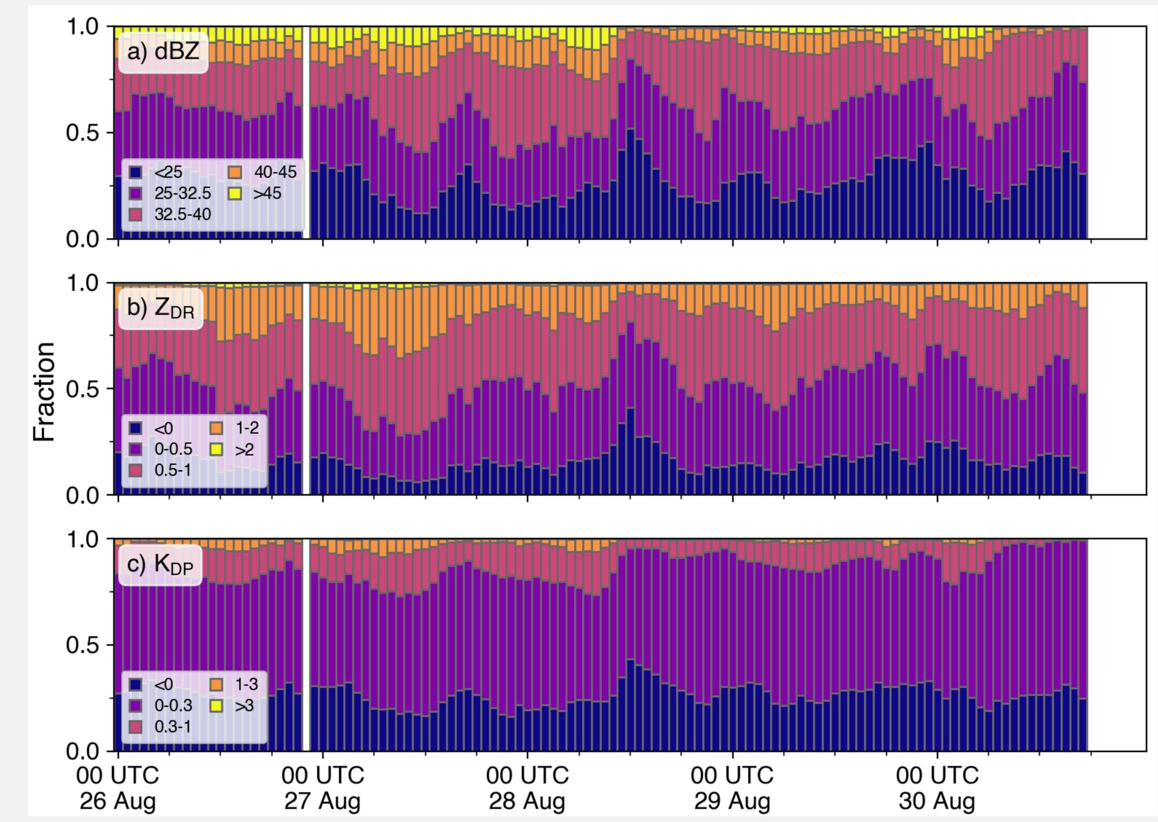
Right: PDF of $\log_{10}N_W$-D_0 distribution (contours) and LWC (colors).

Harvey bulk microphysics

Polarimetric values are modest, typical of a TC

Distributions skew toward larger values through 12 UTC 28 Aug

Big variations: periods of high Z_H, Z_{DR} (27 Aug) and high Z_H, lower Z_{DR} (28, 30 Aug)



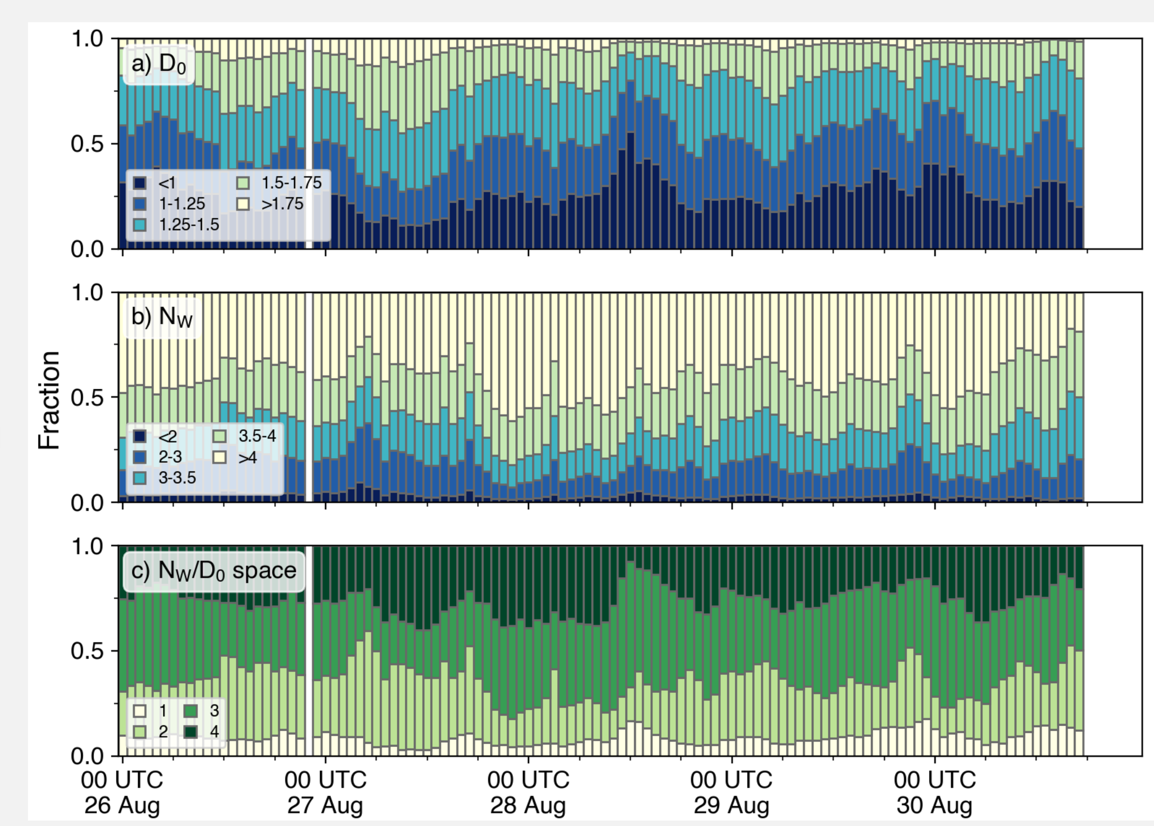
Top to bottom: Time series of fractional coverage of a) horizontal reflectivity, b) differential reflectivity, and c) specific differential phase for KHGX

D_0 mirrors Z_{DR}

N_W is consistent in time

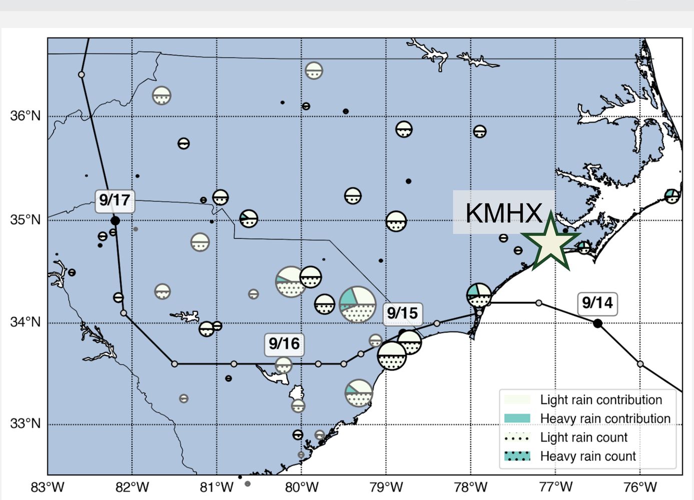
Bigger drop DSDs dominant on 27 Aug, frequent drop DSDs dominant on 28, 30 Aug

Frequent drop DSDs dominate overall, but microphysical processes vary



Top to bottom: Time series of fractional coverage of a) D_0, b) N_W, and c) N_W/D_0 phase space for KHGX

Florence comparison

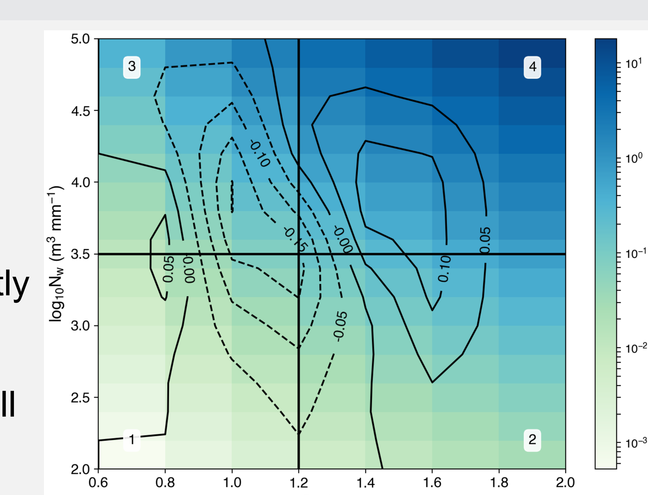


Top: Map of Florence's track and ASOS observations. Same as Harvey figure.

Many gauges missing data.

Available rain rates similar to Harvey's, slightly weaker.

No stall: rain fell for ~3 days.



Top: Difference PDF between Harvey and Florence $\log_{10}N_W$-D_0 distribution (contours) and LWC (colors).

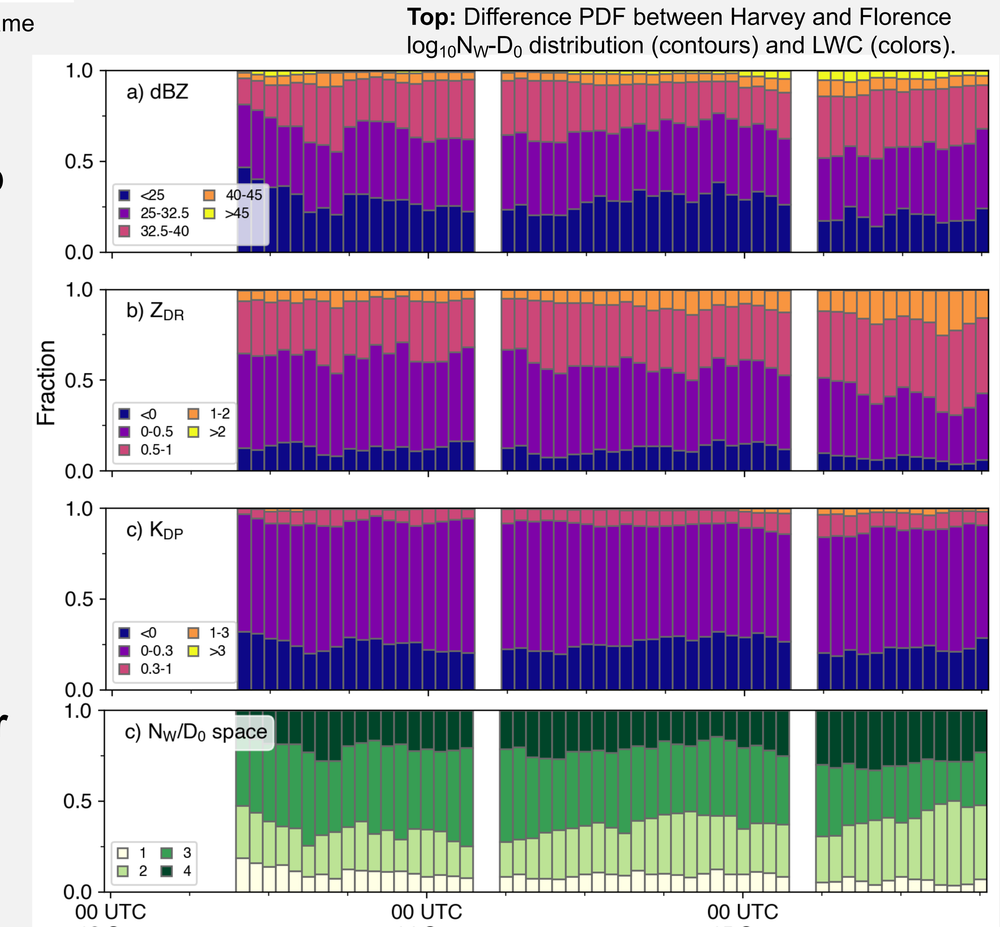
KMHX went offline ~18Z 15 Sep

Distributions similar to Harvey, but skew toward weaker values with less variation

Slight increase on 15 Sep

Compared to Harvey, shift from phase 4 to 3: less coverage by heaviest rain rates

Total rain lower due to shorter duration, weaker rain rates



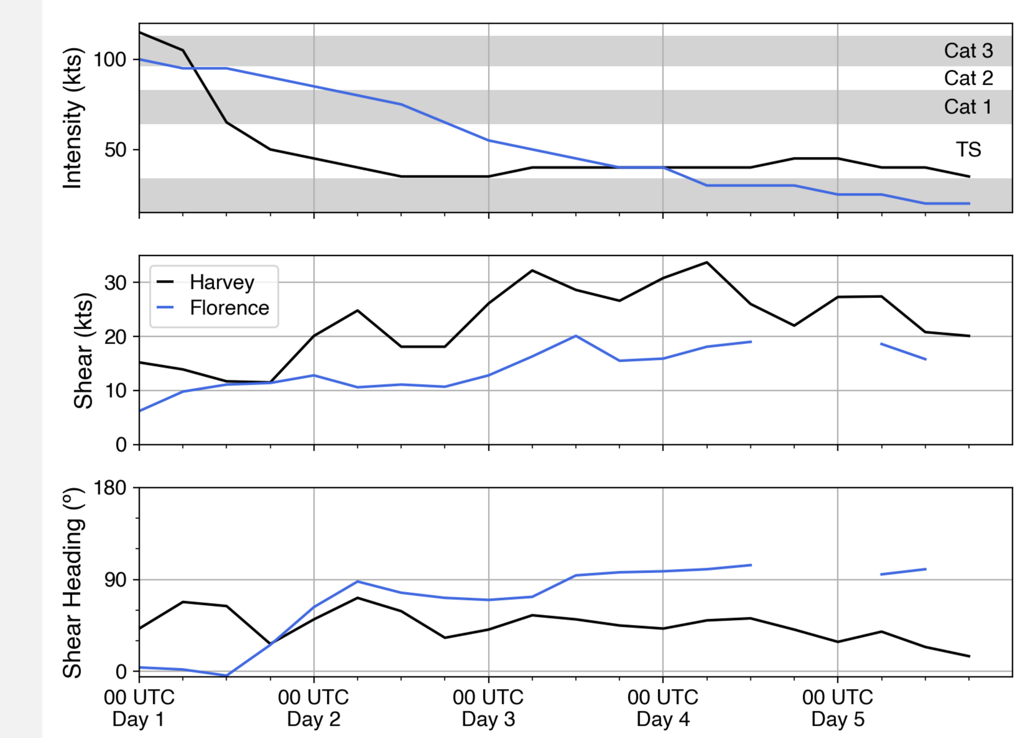
Top to bottom: Time series of fractional coverage of a) Z_H, b) Z_{DR}, c) K_{DP}, and d) N_W/D_0 phase space for KMHX

Why do Harvey and Florence differ?

Harvey weakened quickly during landfall under strong wind shear (200-850 hPa)

Florence decayed slowly and shear was weaker

SSTs were ~1º cooler for Florence (not shown)



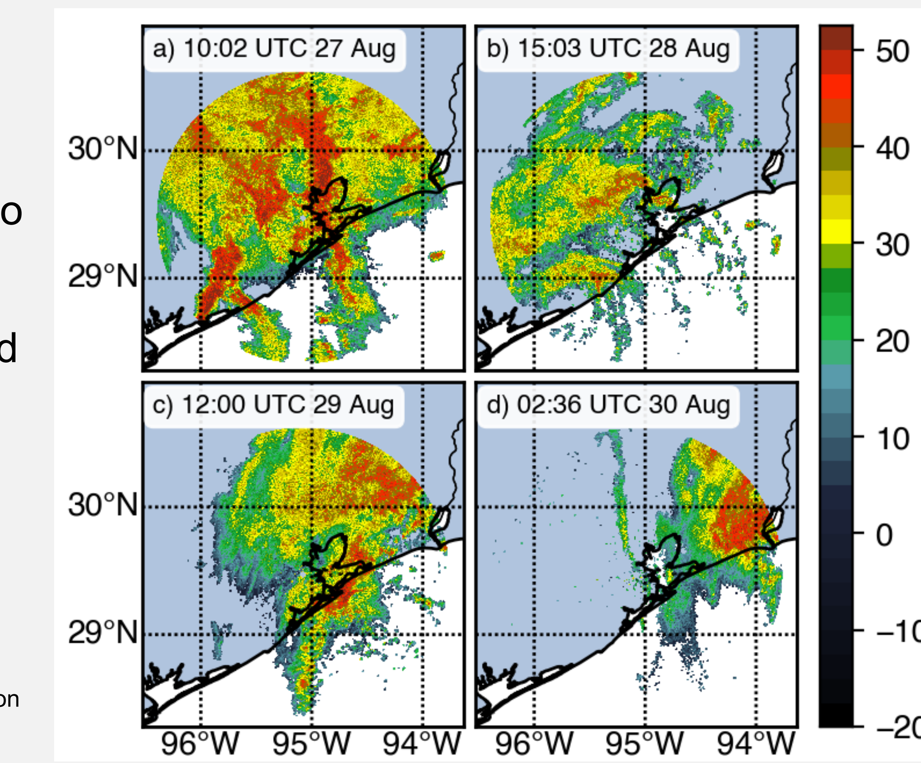
Top to bottom: Time series of a) intensity, b) shear magnitude, and c) shear heading for Harvey and Florence.

Harvey: highly asymmetric

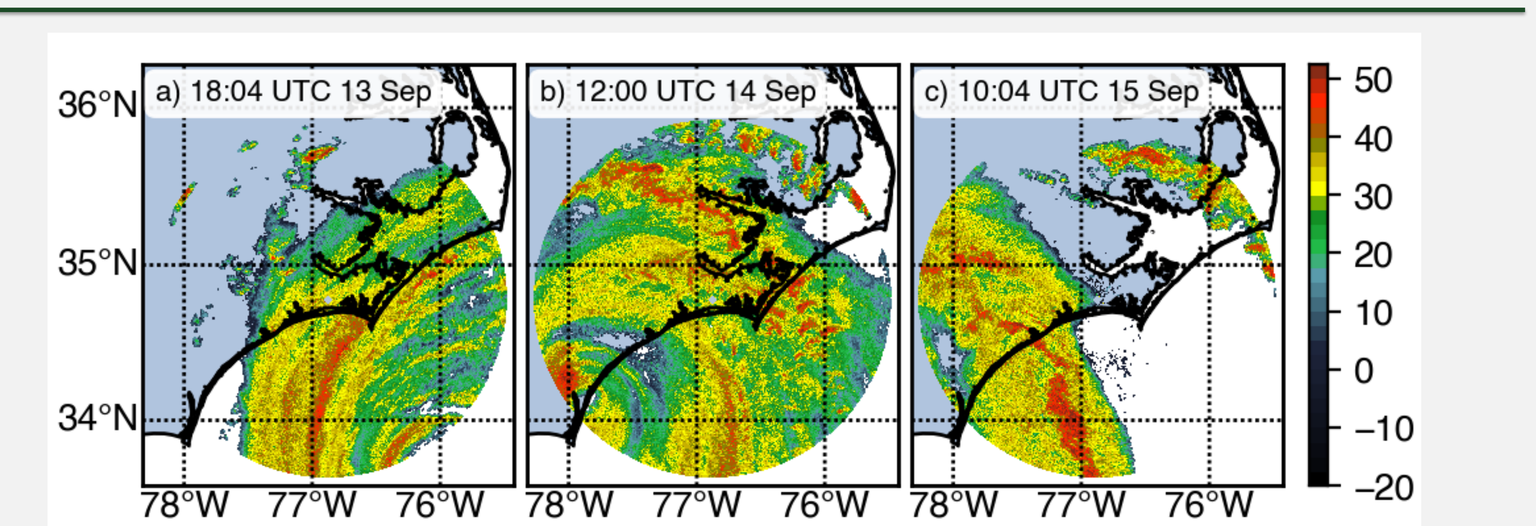
Evolution from strong convective rainbands to weaker precipitation to broad, strong precipitation

Rain preferentially occurs over land downstream of onshore flow

Southwesterly shear persistent, placing SE TX in the left-of-shear quadrants, which often experience heavier rain



Clockwise from Top Left: Maps of KHGX reflectivity (0.5º) on a) 27 Aug, b) 28 Aug, c) 29 Aug, and d) 30 Aug.



Left to Right: Maps of KMHX reflectivity (0.5º) on a) 13 Sep, b) 14 Sep, and c) 15 Sep.

Florence: more axisymmetric and reduced onshore flow influence

Heavy rain coverage is less, constrained to eyewall and parts of rainbands

Shear varied from southerly to westerly, which placed the Carolinas in the downshear and left-of-shear quadrants, but the magnitude was weaker

Conclusions

- Heavy rain rates and long duration both important in Harvey's record rainfall, but the contribution of heavy rain varied spatially. Numerous drop DSDs were most frequent, but strong variations occurred, indicative of varied precipitation types and processes.
- Polarimetric data from Florence distributions suggest that the reduced total rain over the domain occurred due to both shorter duration and weaker rain intensities. There was less variation in DSD types over time, suggesting more consistent distribution of precipitation processes over the domain.
- Several mechanisms could explain the differences between Harvey and Florence, but structural decay and shear asymmetries likely contribute.

Funding provided by: NSF CAREER award AGS-1701225 and ONR Young Investigator Program awards N000141613033, N000141712230
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