Assessing Dual-Polarization Radar Estimates of Extreme Rainfall During Hurricane Harvey

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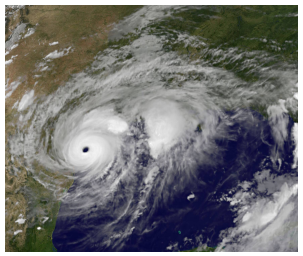
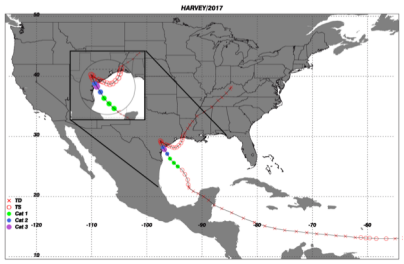
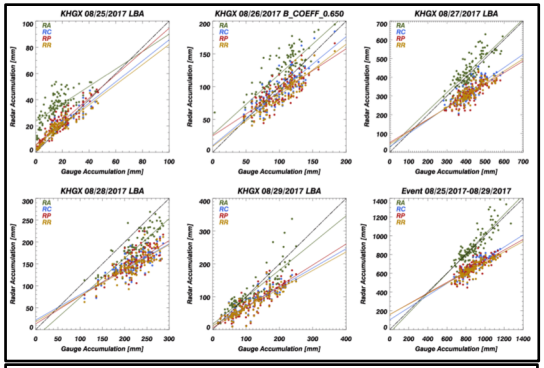




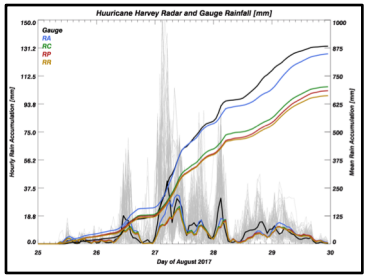
Hurricane Harvey hit the Texas Gulf Coast as a major hurricane on August 25, 2017 before exiting the state as a tropical storm on August 29, 2017. Left in its wake was an historic flood, with some areas measuring more than 60 inches of rain over a five-day period. Although the storm center stayed west of the immediate Houston metropolitan area, training bands of precipitation, with enhanced lift provided by a stalled front parallel to the coast, impacted the Houston area for five days. The National Weather Service (NWS) dual-polarimetric radar (KHGX), located southeast of Houston, maintained operations for the entirety of the event.

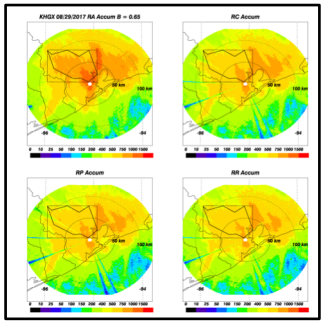


Scatterplots of radar versus gauge daily and event total. In this instance, α=0.015 and β=0.650 in the RA retrieval. The RA estimate performed significantly better than the hybrid estimates except on 8/25, which was prior to the arrival of deep tropical moisture in southeast Texas. The RA bias of total rainfall for the event was just 1.2%.

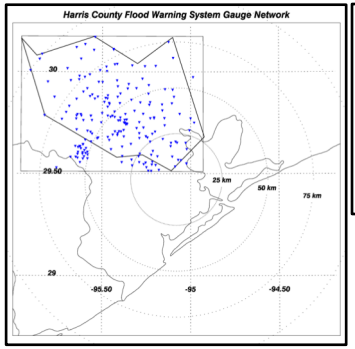
Below: Time series of 15-minute rain accumulations from the gauges and radar retrievals. The thin gray lines represent 15-min accumulations from the individual gauges.

The solid black line is the gauge-averaged accumulation. The RA, RC , RP and RR curves are blue, green, red and golden, respectively. The RA clearly performs better than the hybrid retrievals.





Event total rain maps for RA (top left), RC (top right), RP (bottom left) and RR from (bottom right). In this instance, the RA method used α=0.015 and β=0.650. Note the increased rainfall and lack of blockage in the RA map that is present in all of the other retrievals.



The Harris County Flood Warning System (HCFWS) had 120 rain gauges deployed in its network. In this study, we used the full radar data set to retrieve daily and event-total precipitation estimates within 120 km of the KHGX radar for the period August 25-29, 2017. These estimates were then compared to the HCFWS gauges.

How do α and β effect the RA rain retrievals?

The parameter α, which is a coefficient describing the Path Integrated Attenuation (PIA; Meneghini and Nakamura 1990; Iguchi and Meneghini 1994, Testud et al. 2000, Bringi et al. 1990), given as

$$PIA = \alpha \, \Delta\Phi_{DP}$$

Where α is the net ratio of the attenuation A and specific differential phase K_{DP} along the ray (Ryzhkov et al. 2014).

The β parameter, which has been used in previous studies with values of β = 0.6-0.9 for microwave frequencies (Ryzhkov et al. 2014) was shown to be highly sensitive to changes in the environmental conditions and hence Drop Size Distribution (DSD) characteristics.

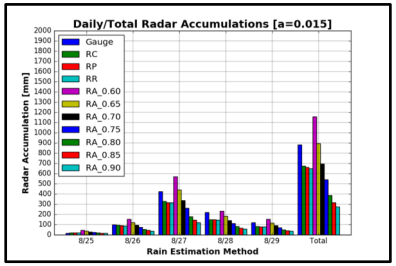
We ran the RA rainfall retrievals using two α (0.015 ad 0.025) and seven β (0.6-0.9 in 0.05 increments) to test their inherent sensitivity. The table below shows the daily and total rainfall **accumulations** over Harris County during Hurricane Harvey (August 25-29, 2017). Three hybrid polarimetric estimators (RC, RP, and RR) and the attenuation-based RA method using α=0.015 and varying parameter β from 0.6 to 0.9 in 0.05 increments. The results show that the RA rain retrievals are highly sensitive to the chosen β parameter.

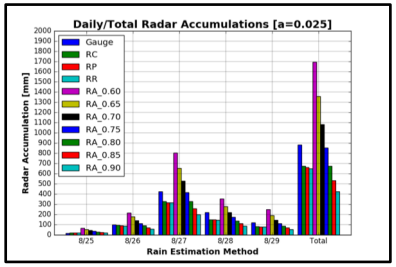
Date	Gauge	RC	RP	RR	RA_0.60	RA_0.65	RA_0.70	RA_0.75	RA_0.80	RA_0.85	RA_0.90
8/25/17	17.75	19.65	21.21	18.78	43.99	35.85	29.52	24.7	21	18.3	16.06
8/26/17	101.18	94.43	92.52	87.71	154.35	120.03	93.93	73.98	53.7	45.55	39
8/27/17	424.33	327.72	314.65	318.38	569.16	440.7	337.47	261.34	177.89	143.86	122.2
8/28/17	218.89	149.7	152	147.33	233.4	181.34	141.91	111.81	81.8	65.66	58.42
8/29/17	120.7	81.92	81.03	78.77	154.72	118.04	91.02	71.03	51.56	43.3	36.83
Total_Accum	882.85	673.3	661.49	650.85	1157.04	897.11	694.87	543.65	386.67	317.2	272.98

Daily and total rainfall radar/gauge **biases** over Harris County during Hurricane Harvey (August 25-29, 2017). Three hybrid polarimetric estimators (RC, RP, and RR) and the attenuation-based RA method using α=0.015 varying parameter β from 0.6 to 0.9 in 0.05 increments. The results show that the RA biases are highly sensitive to the chosen β parameter.=

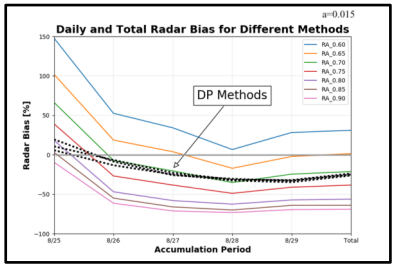
Date	RC	RP	RR	RA_0.60	RA_0.65	RA_0.70	RA_0.75	RA_0.80	RA_0.85	RA_0.90
8/25/17	10.65	19.48	5.75	147.74	101.9	66.28	39.13	18.27	3.04	-9.53
8/26/17	-6.67	-8.56	-13.31	52.55	18.63	-7.16	-26.88	-46.93	-54.98	-61.45
8/27/17	-22.77	-25.85	-24.97	34.13	3.86	-20.47	-38.41	-58.08	-66.1	-71.2
8/28/17	-31.61	-30.56	-32.69	6.63	-17.15	-35.17	-48.92	-62.63	-70	-73.31
8/29/17	-32.13	-32.87	-34.74	28.19	-2.2	-24.59	-41.15	-57.29	-64.13	-69.49
Total_Bias	-23.74	-25.07	-26.28	31.06	1.62	-21.29	-38.42	-56.2	-64.07	-69.08

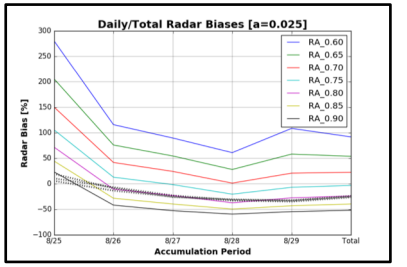
Gauge and Radar daily and total accumulations for hybrid estimators (RC, RP, and RR) and RA using β=0.6 – 0.9 in 0.05 increments for α=0.015 (top) and α=0.025 (bottom). In general, larger values of β provide for smaller rain rates and larger values of α provide for larger rain rates. The spread of results for α=0.025 for various βs is larger than those for α=0.015.



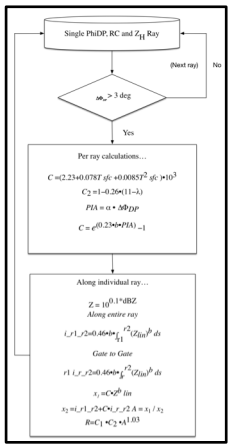


Gauge and Radar daily and total biases for hybrid estimators (RC, RP, and RR) and RA using β=0.6 – 0.9 in 0.05 increments for α=0.015 (top) and α=0.025 (bottom). For α =0.015 (0.025), the RA estimator is closest to the hybrid estimates for β =0.70 (0.80). On 8/25 the optimal β was 0.85 and somewhat greater than 0.9 for α =0.025. On 8/27 which the optimal β for α =0.015 (0.025) was 0.65 (0.75).





Three different hybrid polarimetric rainfall retrievals were used: Cifelli et al. 2011, hereafter RC; Bringi et al. 2004, hereafter RP; and Chen et al. 2017, hereafter RR. We also utilized the differential phase F_{DP} to employ an attenuation-based retrieval, hereafter RA, following Ryzhkov et al. 2014. The immediate advantage of using the RA approach is that it is relatively immune to blockage and calibration errors of both the reflectivity, and differential reflectivity. The hybrid retrievals have demonstrated robust performance in the past; however, on most of the days during August 26-29, 2017 and the event-total comparisons from each of these retrievals compared to those of HCFWS gauge network resulted in significant underestimates. The attenuation method performed significantly better than any of the hybrid methods, particularly during days with the heaviest rain. The exponent of the RA method, varied between 0.6-0.9 in previous studies was shown to be highly sensitive to changes in the environmental conditions and hence Drop Size Distribution (DSD) characteristics.



CONCLUSIONS

- All three hybrid rain estimators performed similarly. They do fairly well in continental convection but severely underestimate deep tropical convection due to the large number of large drops present in tropical cyclones.
- The RA method, for a properly selected b, outperforms all of the hybrid estimators regardless of precipitation regime.
- The selection of a=0.015 was shown to be less volatile to estimated rain rates than a =0.025. Increases in a result in significant increases in rain rates.
- The selection of b for a specified alpha shows significant effect on resultant rain rates such that an increase in b results in a decreased rain rate.

Acknowledgements

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