MRMS Dual-pol Radar Synthetic QPE

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38th Conference on Radar Meteorology
Chicago, IL, USA

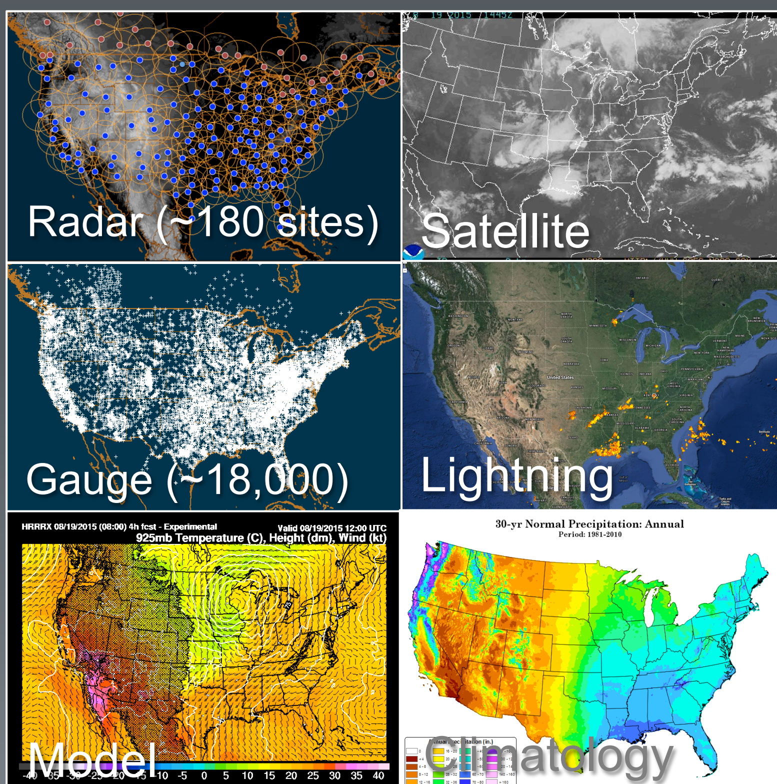
Outline

1. Background
2. MRMS dual-pol radar synthetic QPE overview and evaluations
3. Summary

What is MRMS?

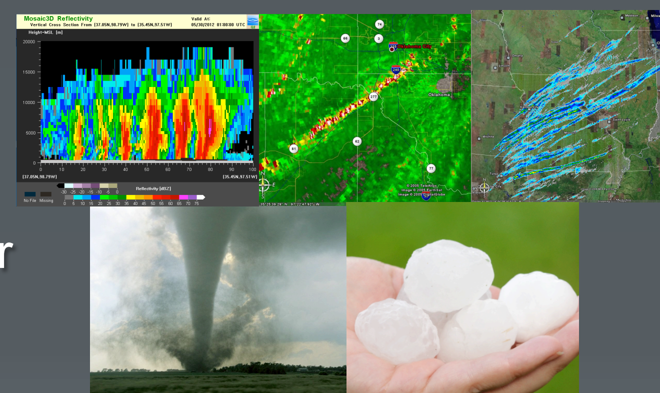
An *operational system* for the integration of Multi-Radar Multi-Sensor data and creation of high-resolution (*1km, 2min*) severe weather and QPE products over CONUS and southern Canada.

INPUT DATA

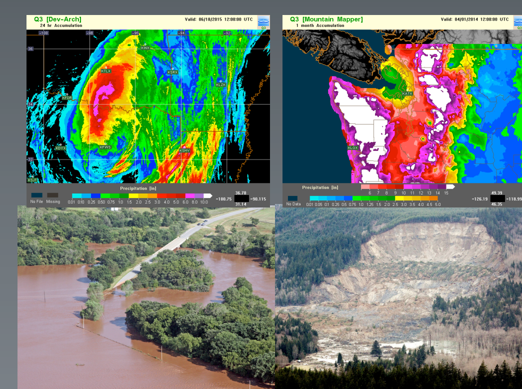


PRODUCTS

Severe Weather



QPE



MRMS QPE Suites

- Radar-Based QPE
  - Precipitation *rate, type* and *quality index,*
  - 1, 3, 6, 12, 24, 48 and 72-hr accumulations
  - *1km, 2-min update cycle; little latency (< 5 min)*
  - A forcing for a *national flash flood model*
  - An input for the *River Forecast Centers*' hydrological forecasts
- Local Gauge Bias Corrected Radar QPE
  - 1, 3, 6, 12, 24, 48, 72hr accumulations, *Gauge Influence Index*;
  - *1km, 1-hr update cycle; ~1hr latency*
  - A forcing for the *National Water Model*
- Gauge and Precip Climatology merged QPE – Mountain Mapper
  - 1, 3, 6, 12, 24, 48, 72hr accumulations
  - *1km, 1-hr update cycle; ~1hr latency*
- Multi-Sensor merged QPE
  - Phase 1: a combination of radar, gauge, precipitation climatology (*~Jan 2018*)
  - Phase 2: integration of satellite QPEs and model QPFs (*~Jan 2019*)

MRMS Radar QPE History

Single Radar

PPS (*Fulton et al. 1998*):
single radar,
single R(Z)/per radar; manually set

DPR (*Giangrande & Ryzhkov 2008*):
single radar,
Hydrometeor classification
$R(Z)/R(Z,Z_{DR})/R(K_{DP})$ synthetic

Stage-II (*Baldwin & Mitchell 1996*):
multi-radar,
Mosaic of PPS

Q2RAD (*Zhang et al. 2011*):
multi-radar,
single-pol QC,
multi R(Z), automated precip classification
bright band (BB) correction

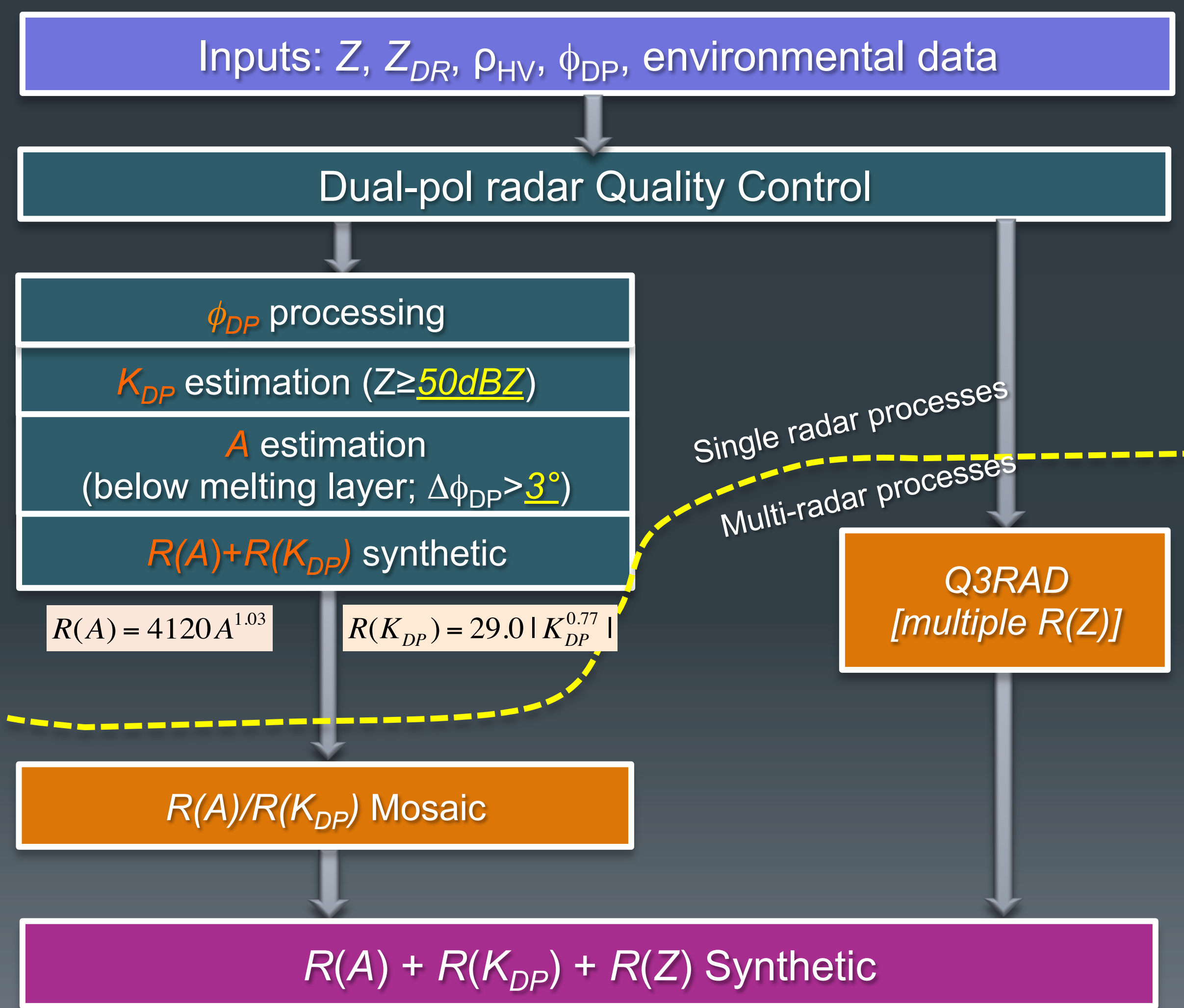
Q3RAD (*Zhang et al. 2016*):
multi-radar,
dual-pol QC,
multi R(Z), auto precip classification
BB correction
new mosaicking

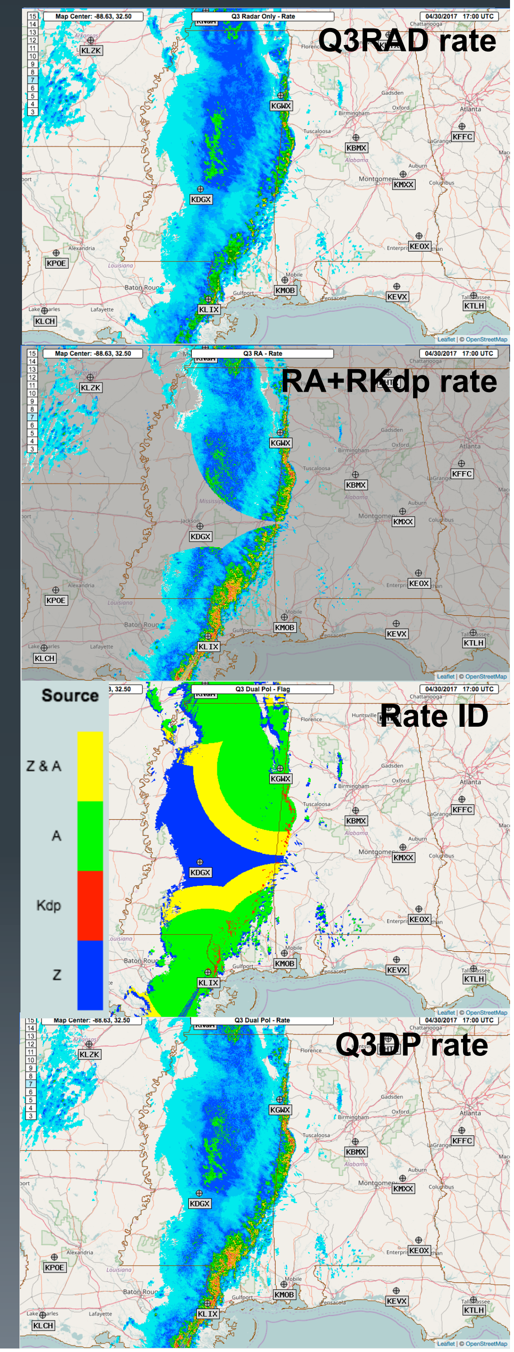
Q3DP (*Ryzhkov et al. 2014*):
multi-radar,
dual-pol QC,
$R(A)/R(K_{DP})/R(Z)$ synthetic
BB correction

Multi-Radar Multi-Sensor

Z: reflectivity; Z_{DR}: differential reflectivity;
K_{DP}: specific differential phase; A: specific attenuation

Q3DP Flowchart





R(A) Methodology (*Ryzhkov et al. 2014*)

At S-band:

$$A(r) = \frac{Z_a^b(r)C(b,PIA)}{I(r_1,r_2) + C(b,PIA)I(r,r_2)}$$

Z_a: attenuated reflectivity

r_1 & r_2: beginning and ending ranges of rain segments in a given radial

$$I(r_1,r_2) = 0.46b\int_{r_1}^{r_2} Z_a^b(s)\,ds$$

$$I(r,r_2) = 0.46b\int_{r}^{r_2} Z_a^b(s)\,ds$$

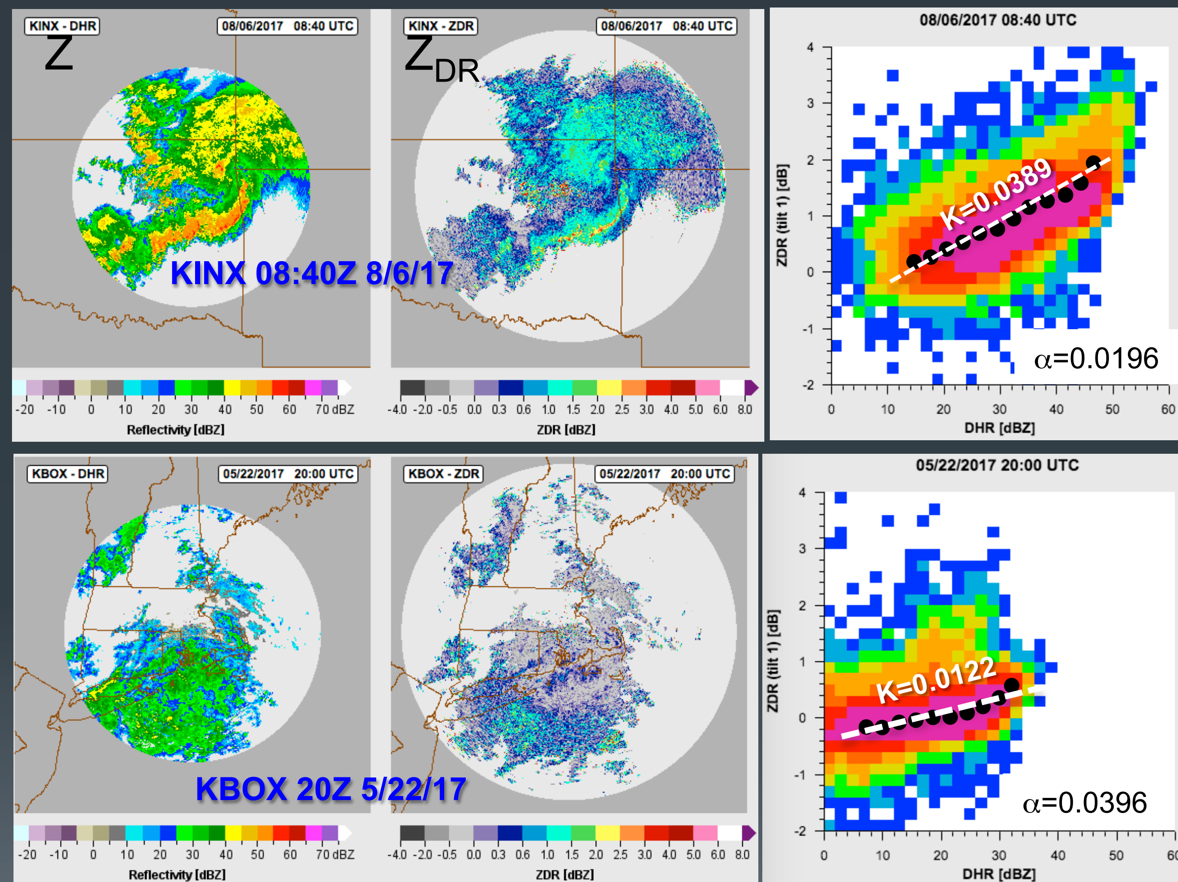
$$C(b,PIA) = \exp(0.23bPIA) - 1$$

$$PIA(r_1,r_2) = \alpha[\phi_{DP}(r_2) - \phi_{DP}(r_1)]$$

b: ≈ 0.62

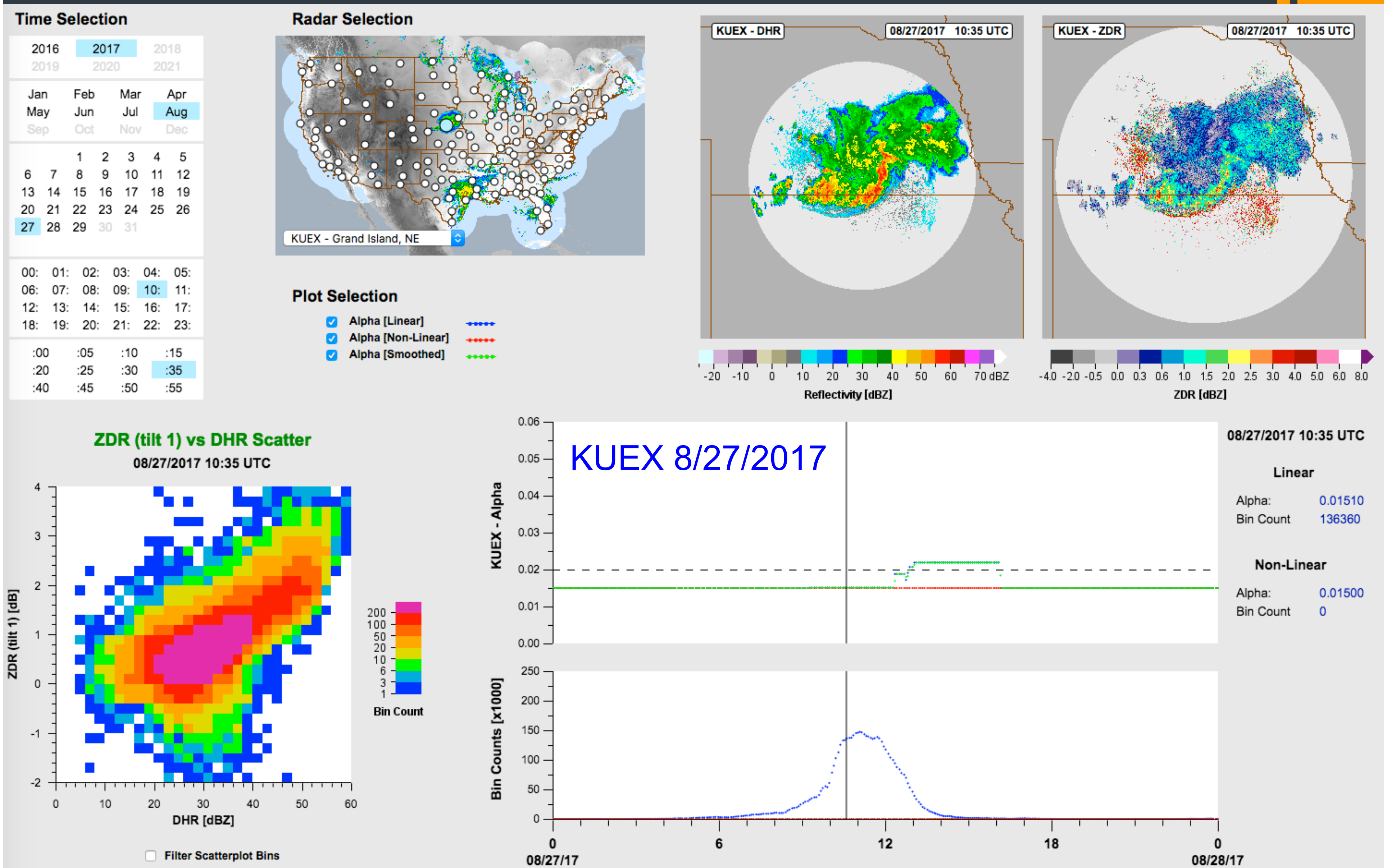
α: determined by Z_{DR}/Z slope (K)

α = -0.75K + 0.04875

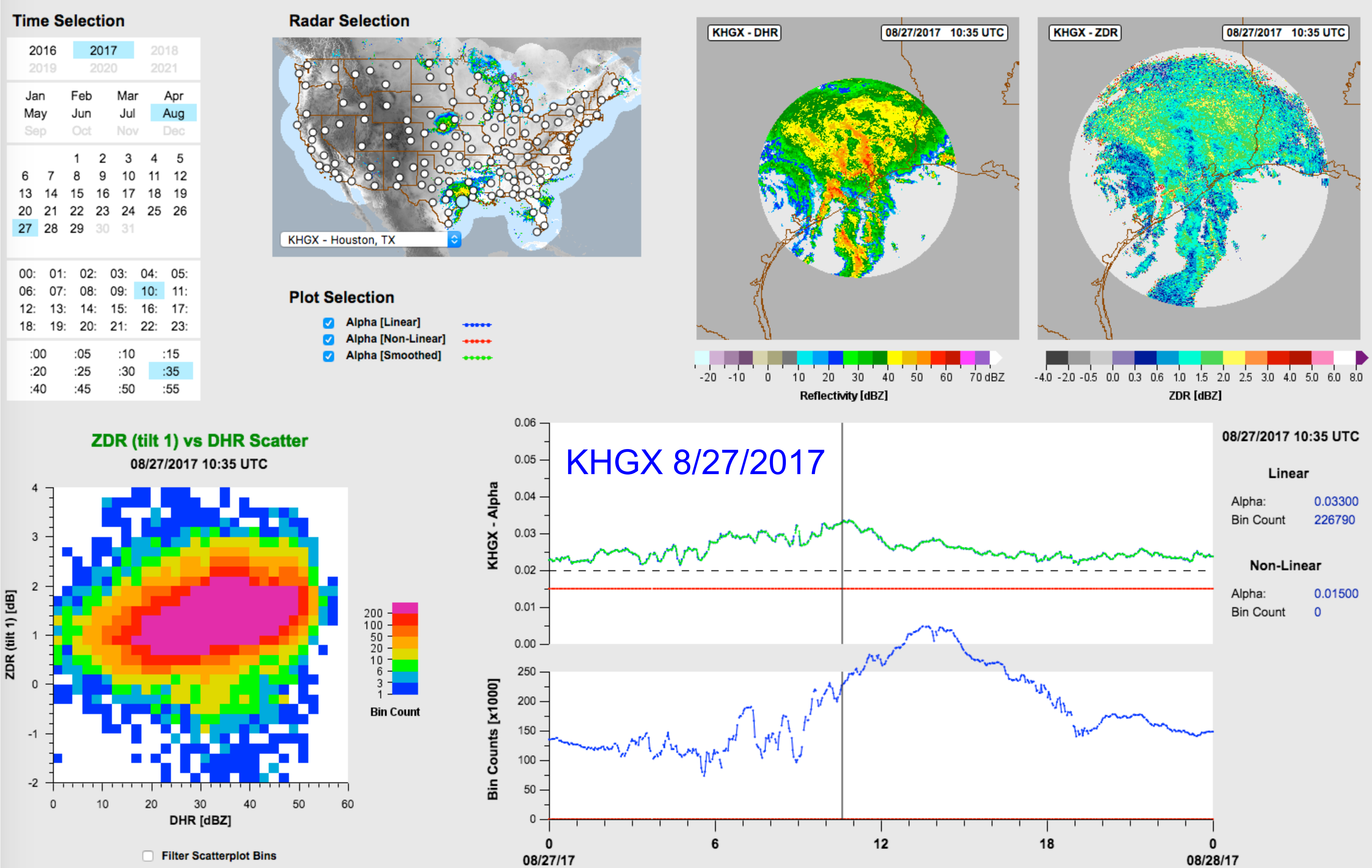


● *median Z_{DR} in 2-dBZ reflectivity intervals*

Physical Significance of α: Continental

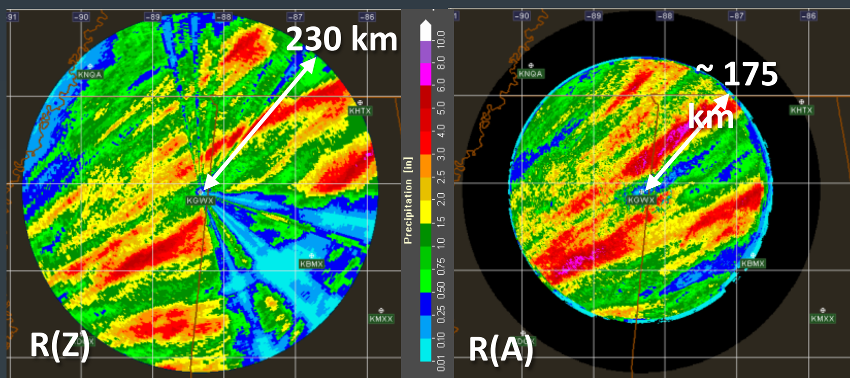


Physical Significance of α: Tropical

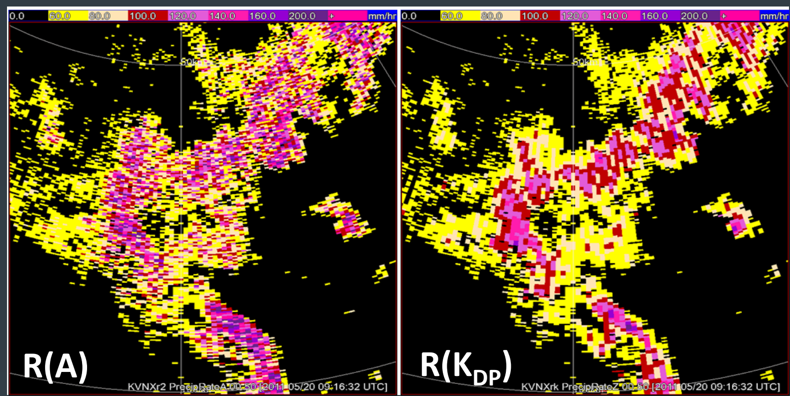


Advantages of Using R(A) for QPE

- Immune to radar miscalibration, partial beam blockage, attenuation, and impact of wet radome

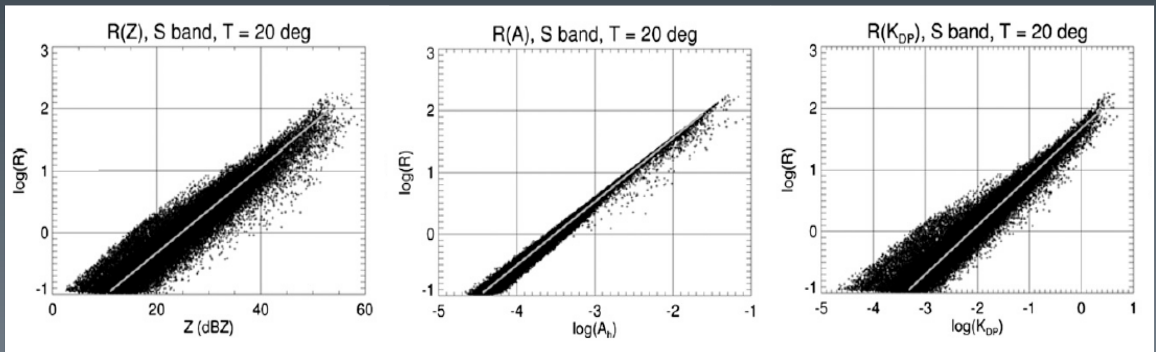


- Higher spatial resolution than $R(K_{DP})$



(Ryzhkov et al. 2014)

- Less sensitivity to the DSD variability than R(Z) and $R(K_{DP})$



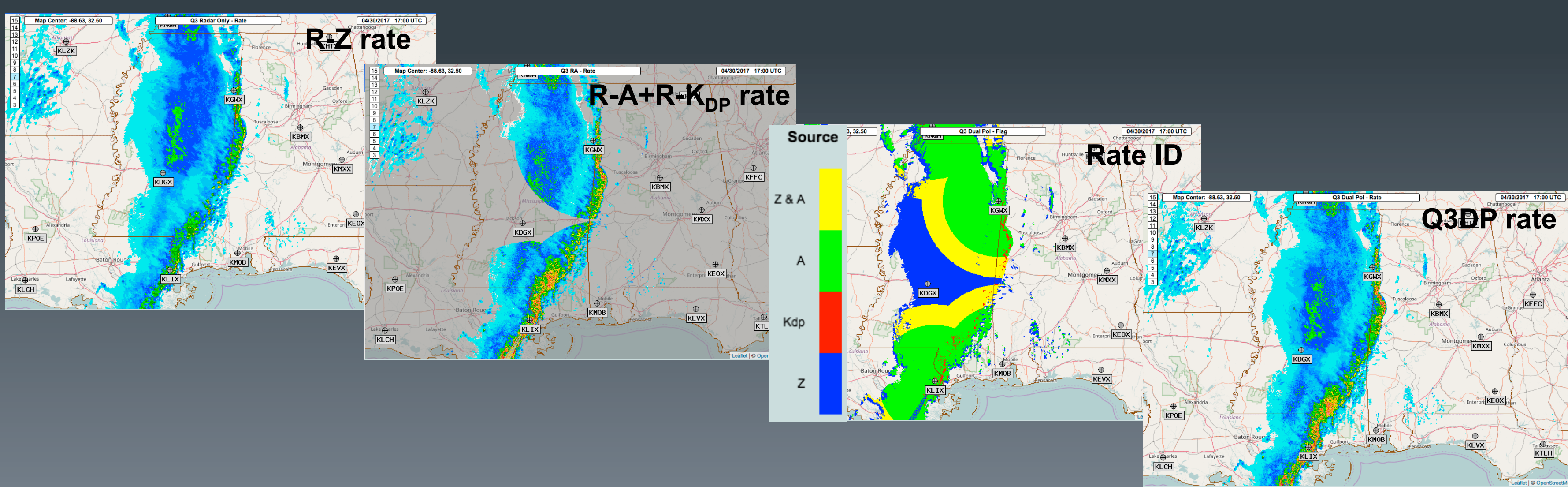
(Ryzhkov et al. 2014)

Limitations of Using R(A) for QPE

1. Does not work when the path $\Delta\phi_{DP}$ is too small [*using R(Z)*]
2. Does not work in the presence of hail [*using R(K_{DP})*] or other frozen hydrometeors [*using R(Z) in and above the melting layer*]
3. The parameter α = A/K_{DP} generally varies with different precipitation types (e.g., continental vs tropical)

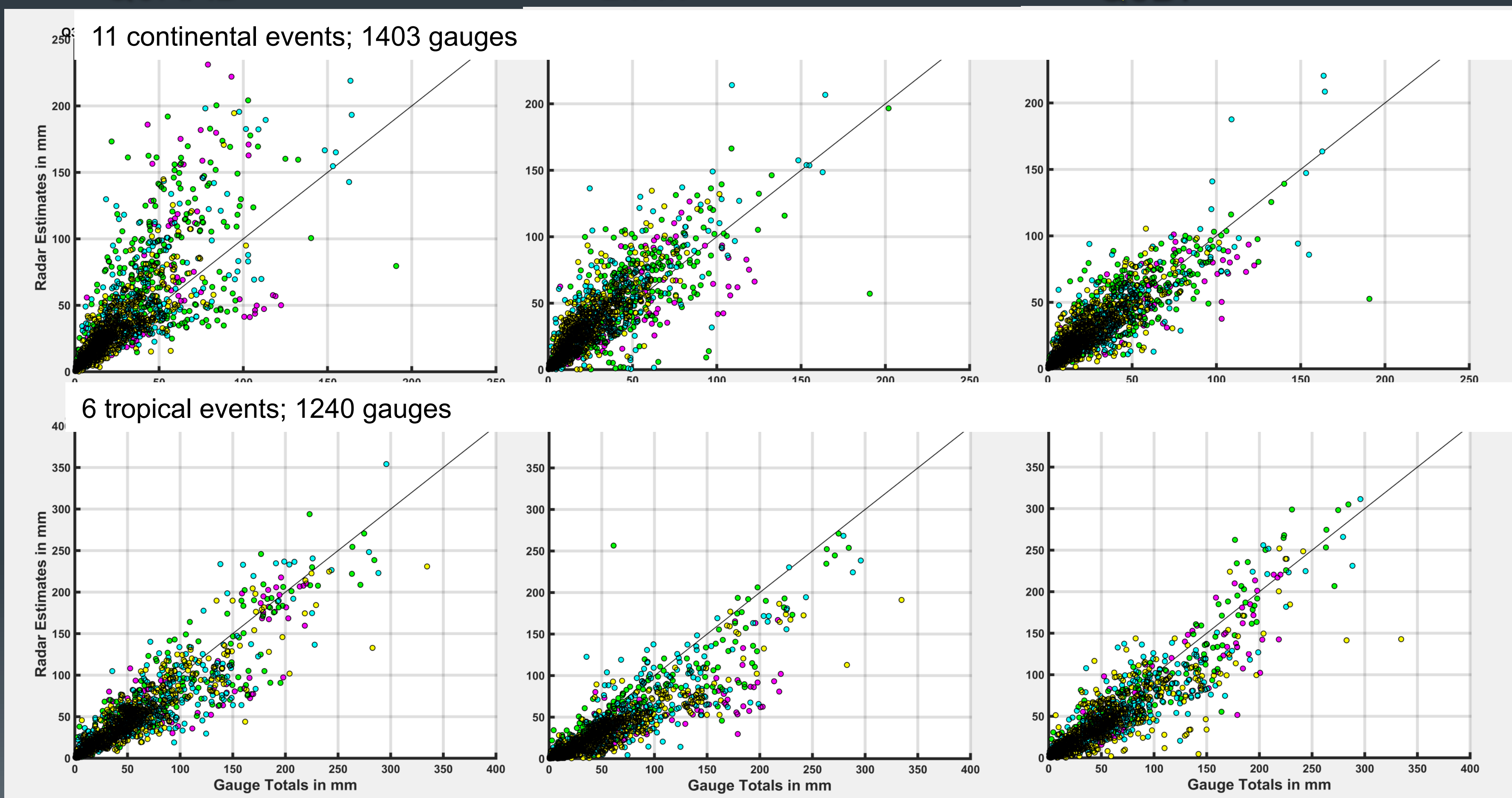
Mitigation: calculate α dynamically for each volume scan based on Z_{DR} *slope*.

Future: account for spatial variability of α.



Evaluations of MRMS dual-pol QPE

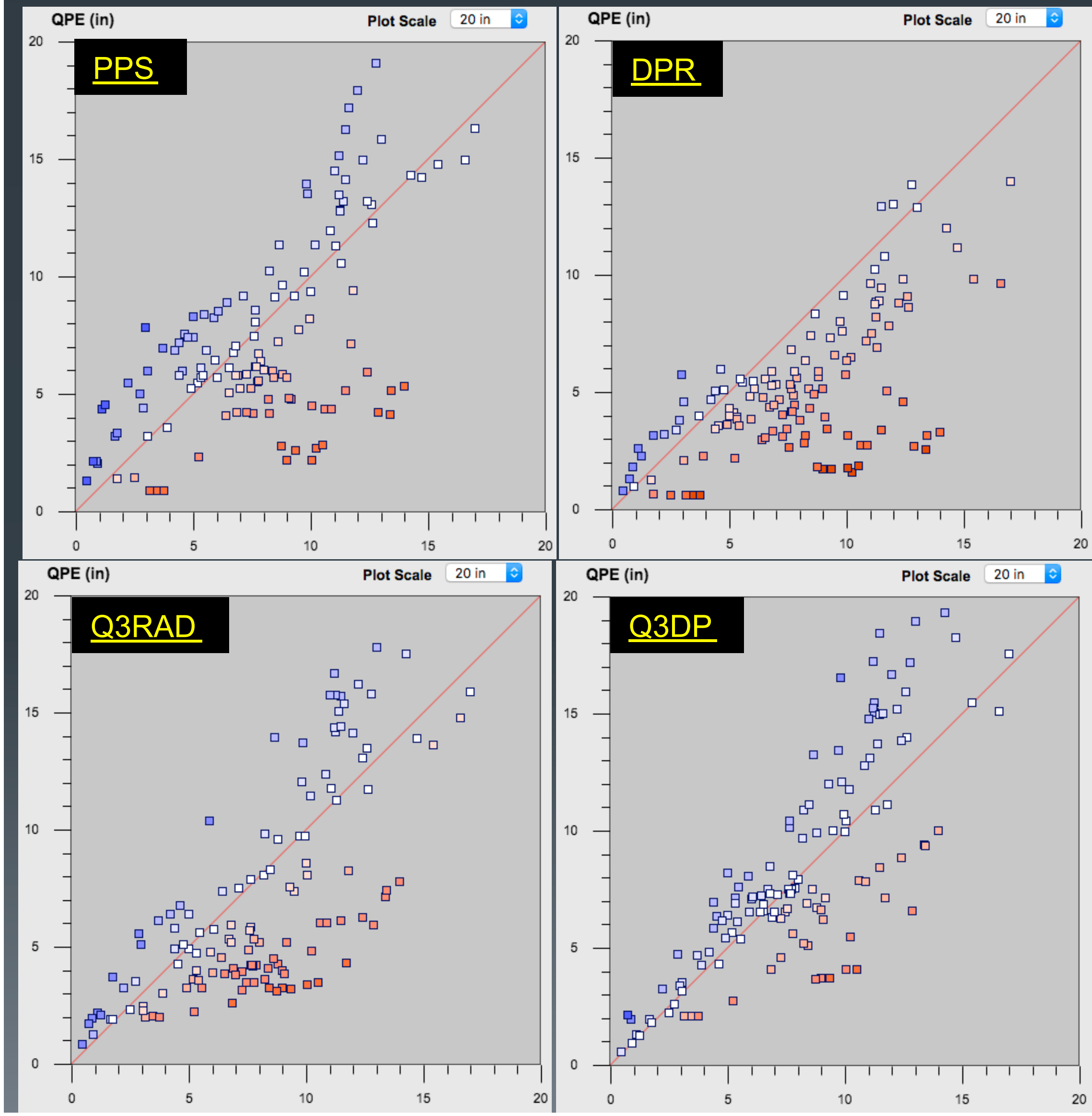
Q3RAD DPR Q3DP



Maroon r ≤ 25 km
Green r=25~100 km
Blue r=100~150 km
Yellow r= 150~200 km

Contributing factors:
Q3RAD overestimation: Inaccurate identification of tropical rain in MCSs
DPR scatter and underestimation: sensitivity to Z_{DR} errors, single $R(Z,Z_{DR})$ relationship unrepresentative of DSD variability

Hurricane Harvey 24h QPEs: KHGX



12Z 8/26 - 12Z 8/27/2017

KHGX, 230km range

Number of gauges: 128

Gauge mean: 7.92 in

Gauge max: 17.00 in

Prod	Bias (Q/G)	MAE (in)	CC
PPS	0.94	2.60	0.64
DPR	0.66	3.00	0.66
Q3RAD	0.88	2.59	0.73
Q3DP	1.04	2.04	0.81

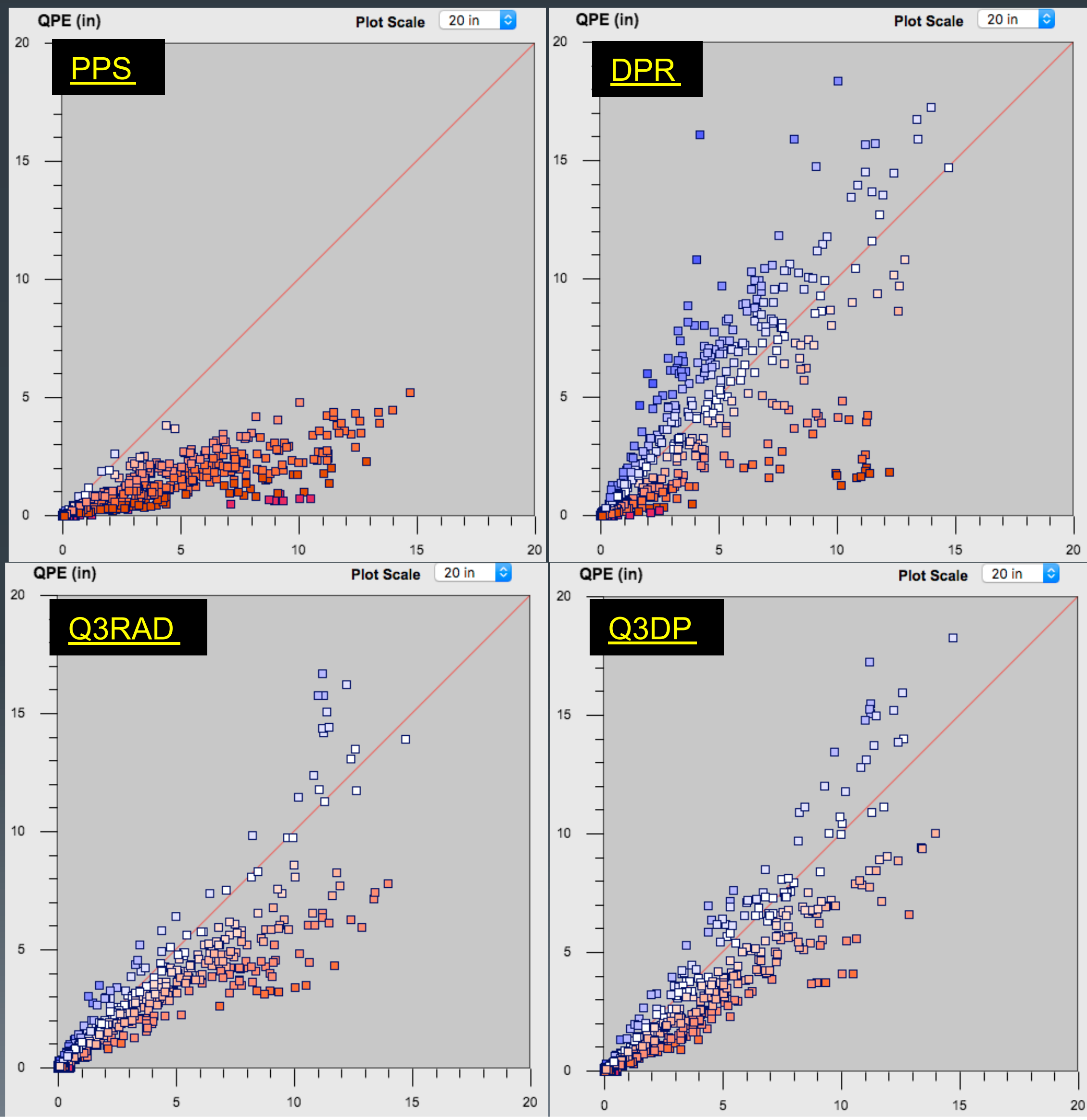
PPS: ***$R=250Z^{1.2}$***

DPR: ***$R=0.007Z^{0.927}ZDR^{-3.43}$***

Q3RAD: ***multiple R(Z)s, mostly $R=250Z^{1.2}$***

Q3DP: ***$R=4120A^{1.03}$***

Hurricane Harvey 24h QPEs: KGRK



12Z 8/26 - 12Z 8/27/2017

KGRK, 230km range

Number of gauges: 521

Gauge mean: 3.67 in

Gauge max: 14.72in

Prod	Bias (Q/G)	MAE (in)	CC
PPS	0.32	2.51	0.84
DPR	0.98	1.45	0.79
Q3RAD	0.76	1.13	0.88
Q3DP	0.83	1.03	0.92

KGRK radar issue:

Z bias: ~ (- 4dBZ)

Z_{DR} bias: ~ (-1.8dB)

Summary

A new dual-pol radar synthetic QPE combining R(A), R(K_{DP}), and R(Z) was developed in the MRMS system

- *R(A) is applied in areas where radar beam samples rain (below the melting layer)*
- *R(K_{DP}) is applied in areas of hail*
- *R(Z) with a Vertical Profile of Reflectivity correction is applied elsewhere*

Advantages of using R(A) for QPE

- Immune to to radar miscalibration, partial beam blockage, attenuation, and impact of wet radome
- Higher resolution than R(K_{DP})
- Less sensitivity to the DSD variability than R(Z) and R(K_{DP})

Further improvement for R(A) QPE

- To account for the spatial variability of the parameter α.

Thank You!

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Operational MRMS product website:
https://mrms.nssl.noaa.gov

Hurricane Harvey composite reflectivity loop:
https://mrms.nssl.noaa.gov/qvs/harvey/Harvey-CREF-20170825-20170829.gif