Rainfall Estimation Based on Specific Attenuation

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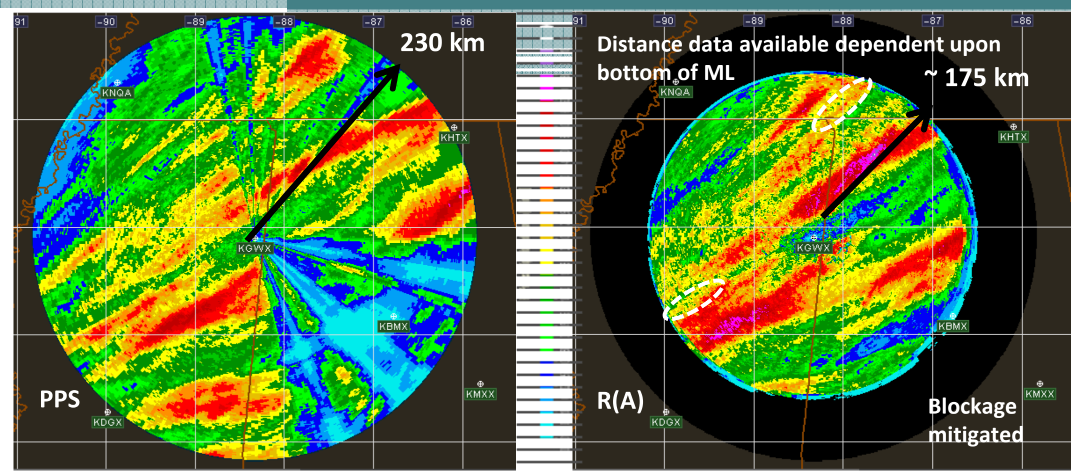

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How to estimate specific attenuation A?

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

$$I(r_1, r_2) = 0.46b \int_{r_1}^{r_2} [Z_a(s)]^b ds \qquad C(b, PIA) = \exp(0.23bPIA) - 1$$

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

Z_a (r) is radial profile of attenuated (and possibly biased) reflectivity

PIA is two-way path-integrated attenuation

In this formulation, the A(r) estimate is immune to the Z_a biases caused by radar miscalibration, partial beam blockage, and wet radome

How to measure PIA?

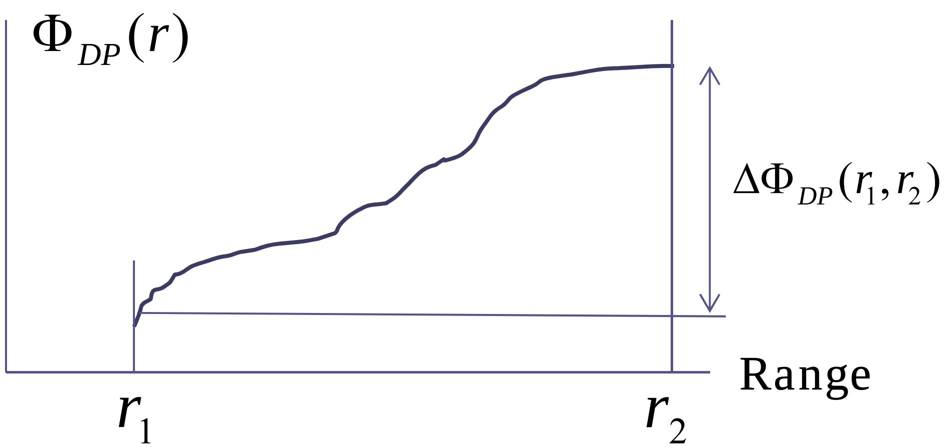
First Method

PIA is estimated using total differential phase shift along the propagation path in rain

$$PIA = \alpha \Delta\Phi_{DP}(r_1, r_2) \qquad \alpha = A / K_{DP}$$

$$R(A) = 1420 A^{1.03}$$

S band

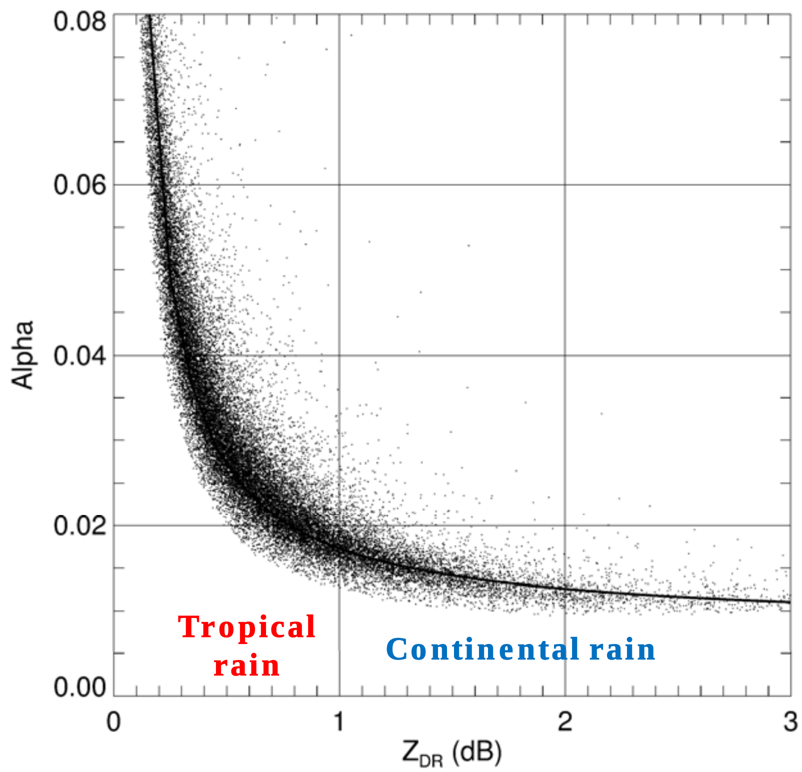


Reliable estimation of the radial profile of A is possible for $\Delta\Phi_{DP}$ as low as 1 - 3°

How to measure PIA?

Second Method

$$PIA = 2\int K_{DP}\,\alpha(Z_{DR})\,ds$$



$$\alpha(Z_{DR}) = 0.008 + \frac{0.009}{Z_{DR}(dB) - 0.03}$$

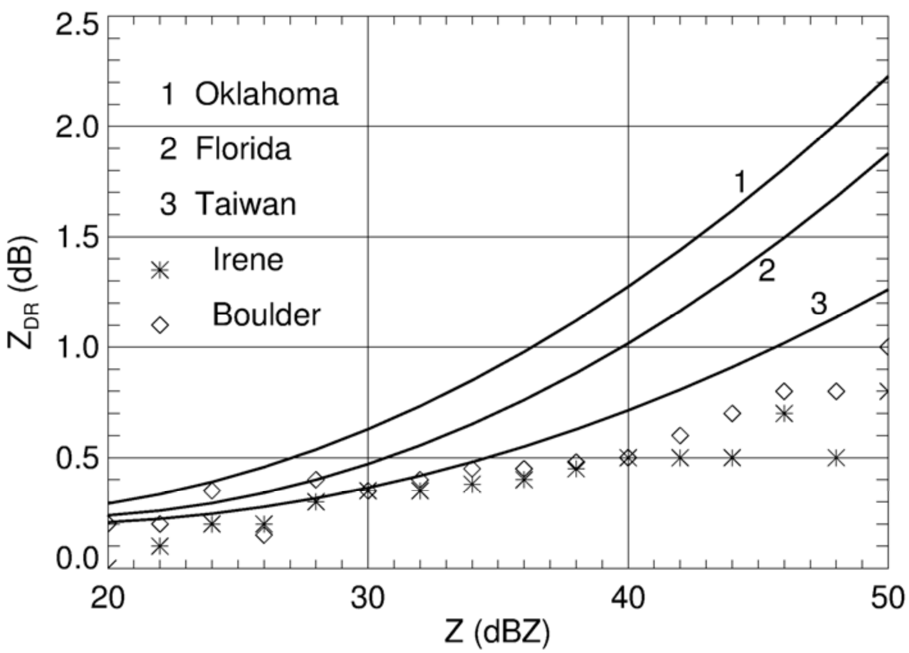
Second method is more accurate but less robust unless the issue of absolute calibration of Z_{DR} is solved on the WSR-88D fleet

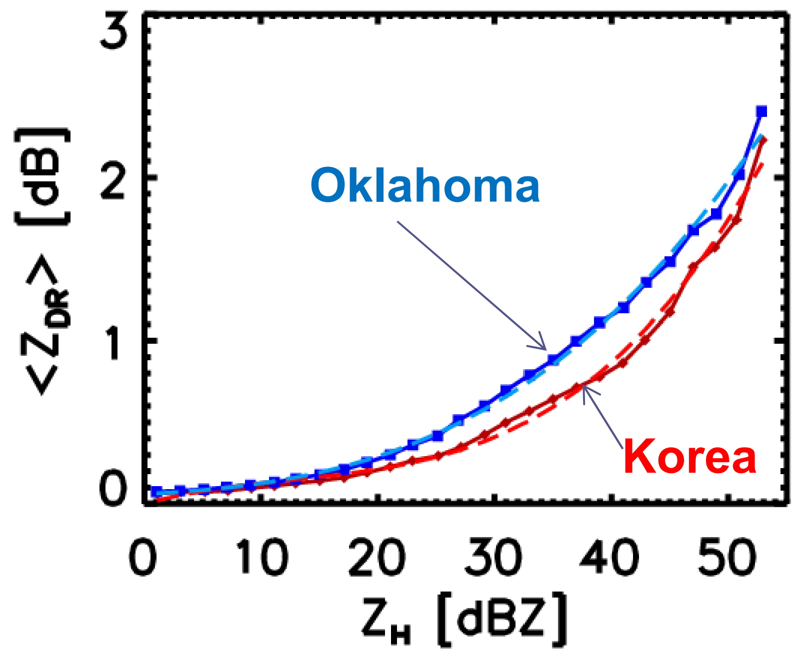
How to estimate parameter α ?

Estimate a slope γ of the Z_{DR} – Z dependence in rain for a given radar volume scan and compute α from γ

In a more tropical rain, the slope γ is lower but the parameter α is higher

The estimate of the slope γ is immune to the Z_{DR} bias



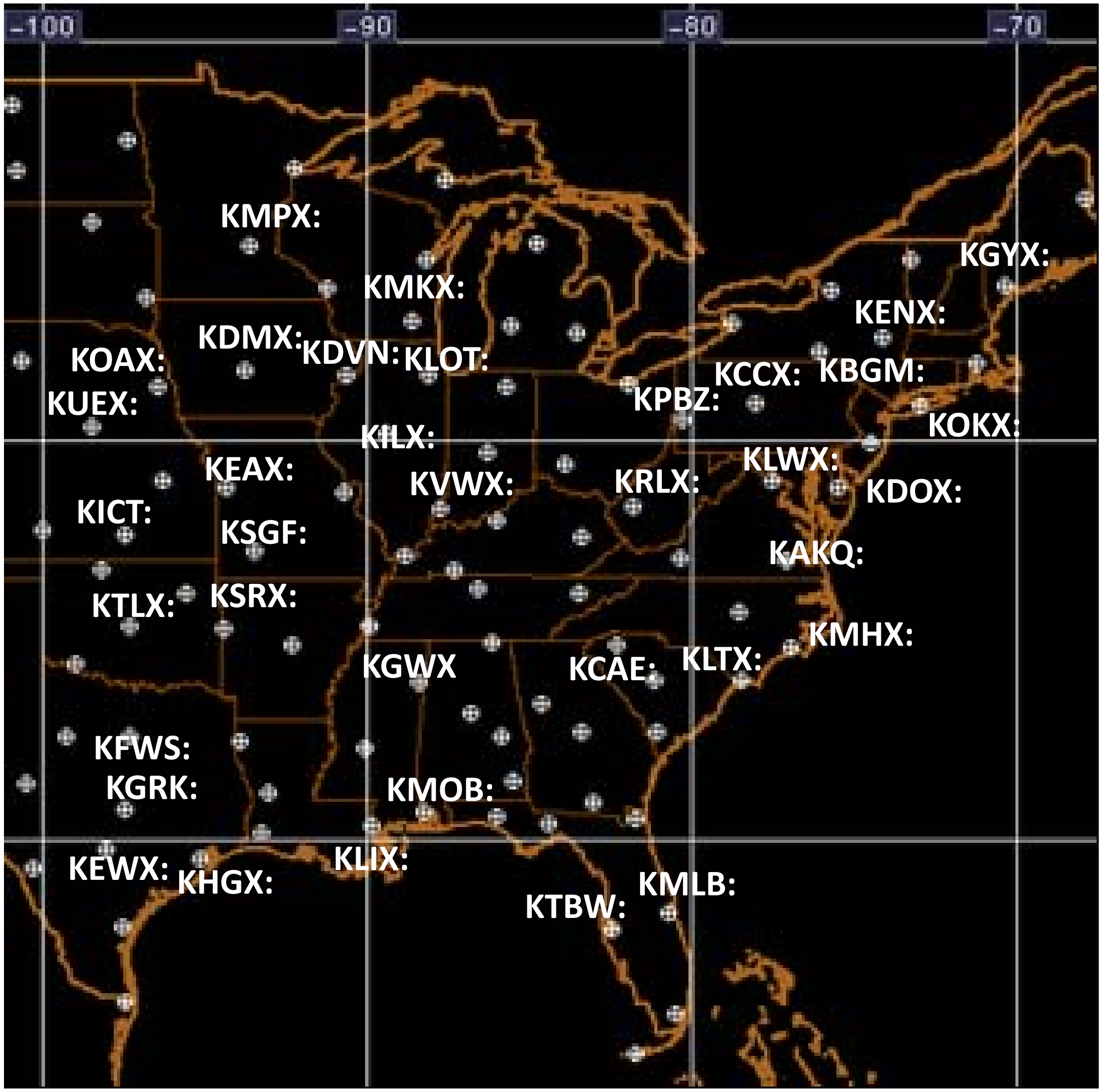


Practical advantages of the R(A) method

1. Low sensitivity to the DSD variability
2. Immunity to radar miscalibration, partial beam blockage, attenuation, and impact of wet radome
3. High spatial resolution (similar to R(Z))
4. Uniformly good performance for light and heavy rain
5. Ideal for networking and compositing (particularly for the radars operating at different wavelengths)

Caveats

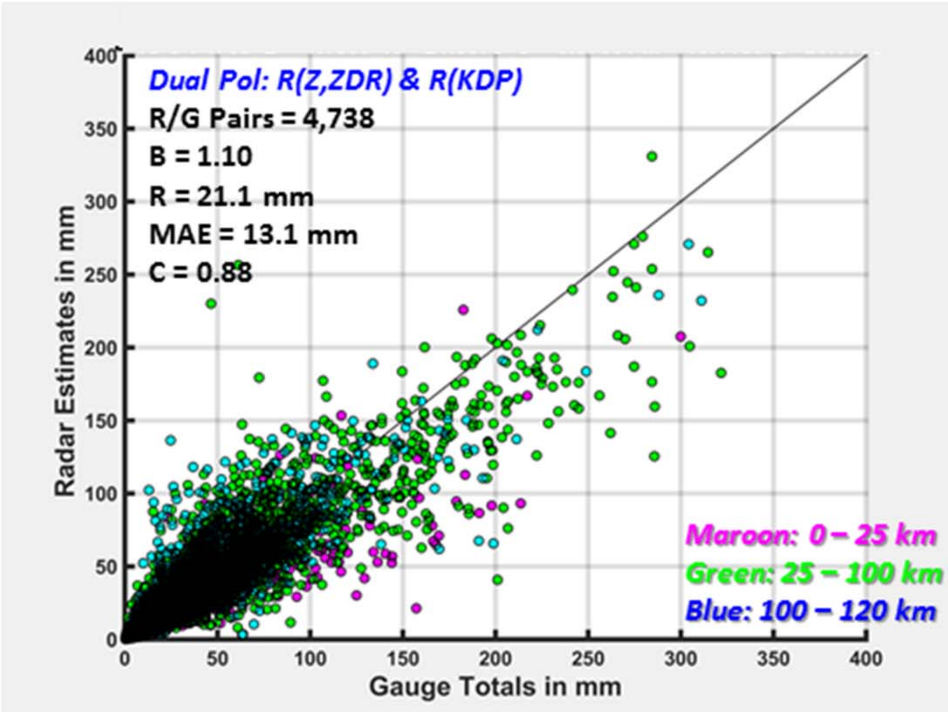
1. Has to be complemented by R(Z) for $\Delta\Phi_{DP} < 1 - 3°$ and by $R(K_{DP})$ in hail cores

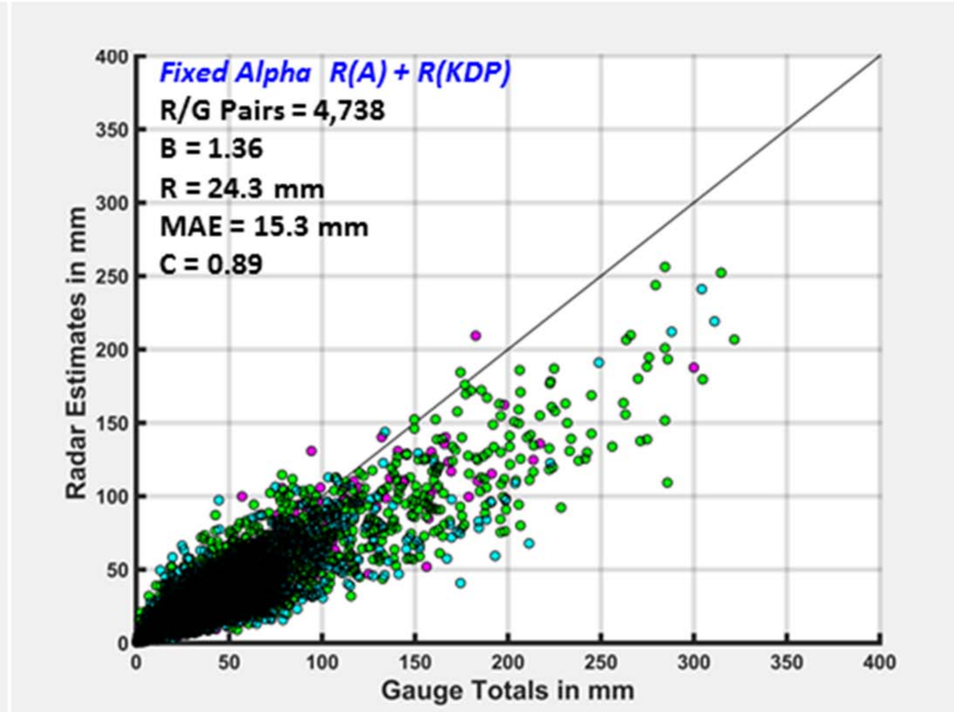


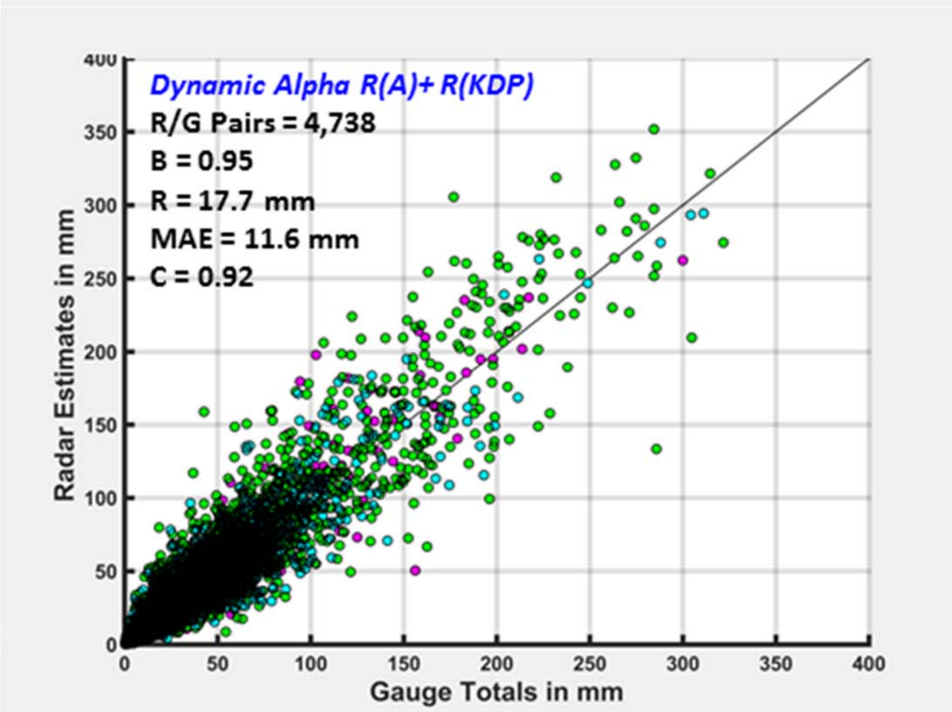
- **Using this methodology, calculated R(A) + R(KDP) via two methods:**
  - **assuming a fixed alpha for all of precipitation event**
  - **Estimating alpha for each 0.5° tilt**

- **For validation used data from 36 radars on 44 calendar days during 2014 – 2016 warm seasons**
  - *Radars chosen spanned a large cross-section of the Eastern US*
  - *Many cases comprised of MCSs with tropical, continental or mixed rain regime characteristics*

- **R(A) estimates were used below ML while R(KDP) used in strong convection (Z > 50 dBZ)**
  - *Farthest estimates made from radar was 120 km to avoid the ML; however, we used RhoHV, model & rawinsonde data manually and adjusted a handful of cases to values less than 120 km*



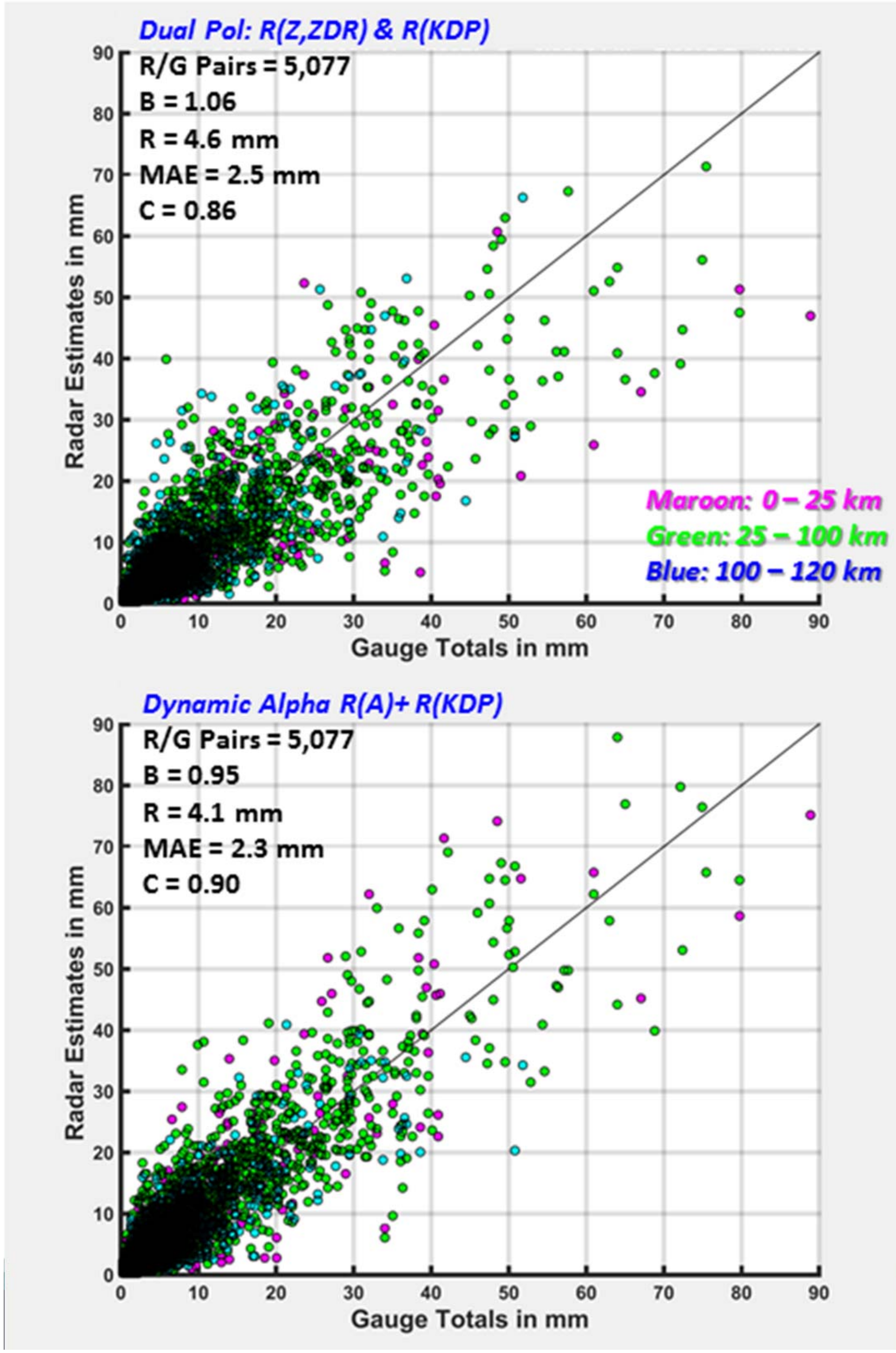




- 24-hr *Dual Pol (top left), Fixed (top right) & Dynamic Alpha (bottom left) QPE* to QC'd CoCoRaHS/automated gauges for ***all cases***

- It is clear using a fixed alpha value causes a distinct under-estimate trend/significantly higher errors

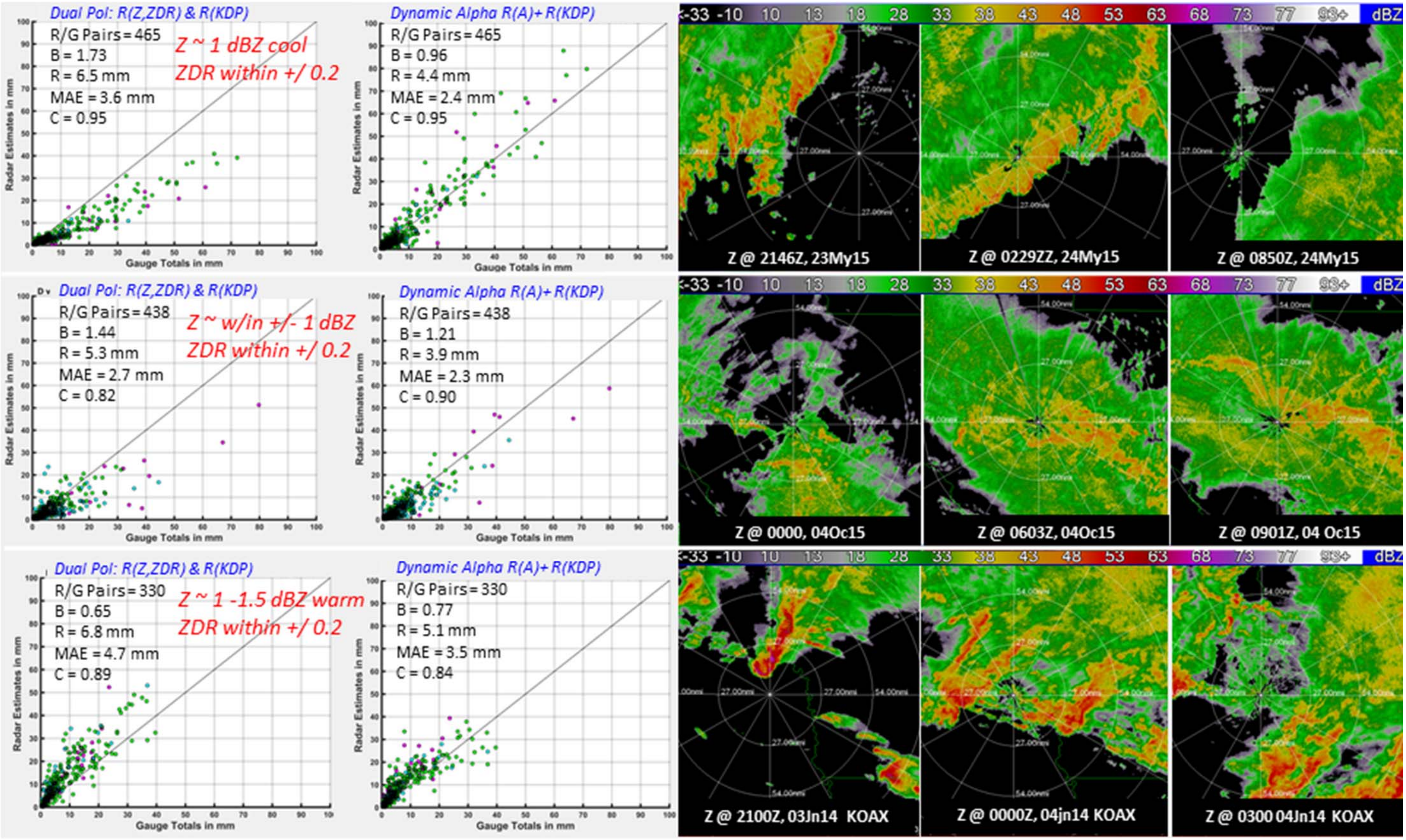
- Despite known alpha variability within precipitation events, Dynamic Alpha performed better than Dual Pol, *especially for* gauge totals > 150 millimeters



- A comparison of 1-hr _Dual Pol (top left), Dynamic Alpha (bottom left) QPE_ estimates to quality controlled CoCoRaHS and automated rain gauges for ***13 cases only***

- *Differences are a more subtle however there is higher correlation and better performance for higher rainfall totals (G > 40 mm)*

- *The following slide illustrates some hourly results for individual cases*



- **Hourly scatter plots (left two columns) & reflectivity (right three columns) for precipitation events on 23-24 May 15 (top), 03-04 Oct. 15 (middle) and 03-04 Jun. 14 (bottom)**
  - *For events with widespread convection and rainfall, R(A)+R(KDP) exhibited overall lower errors, less bias and better correlation (top two rows)*
    - *there is an overestimate bias present in some convective events (bottom row)*

Summary

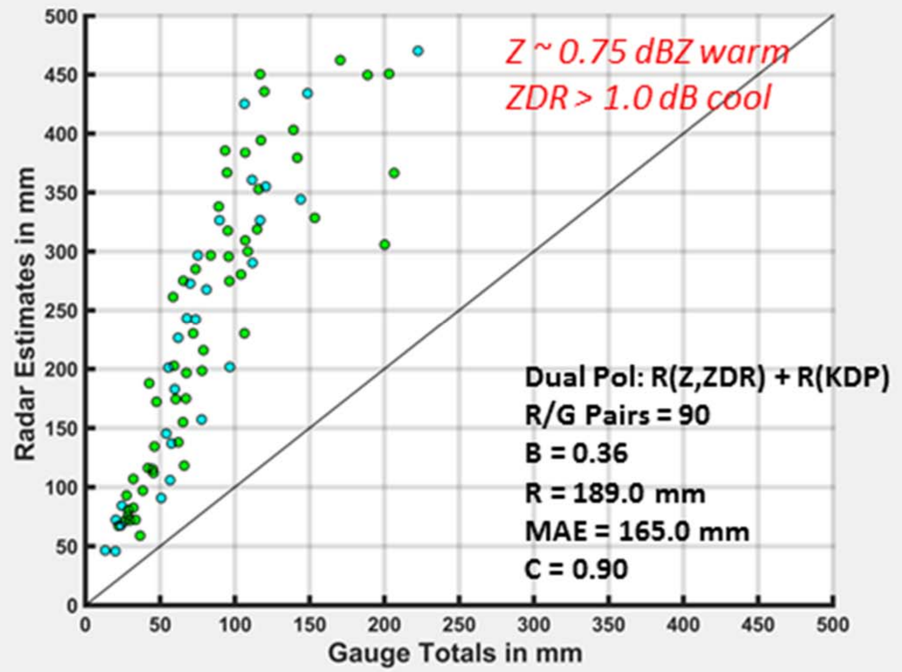
- Extensive validation of a new method for rainfall estimation based on specific attenuation showed that it outperforms the existing dual-polarization WSR-88D QPE algorithm in rain

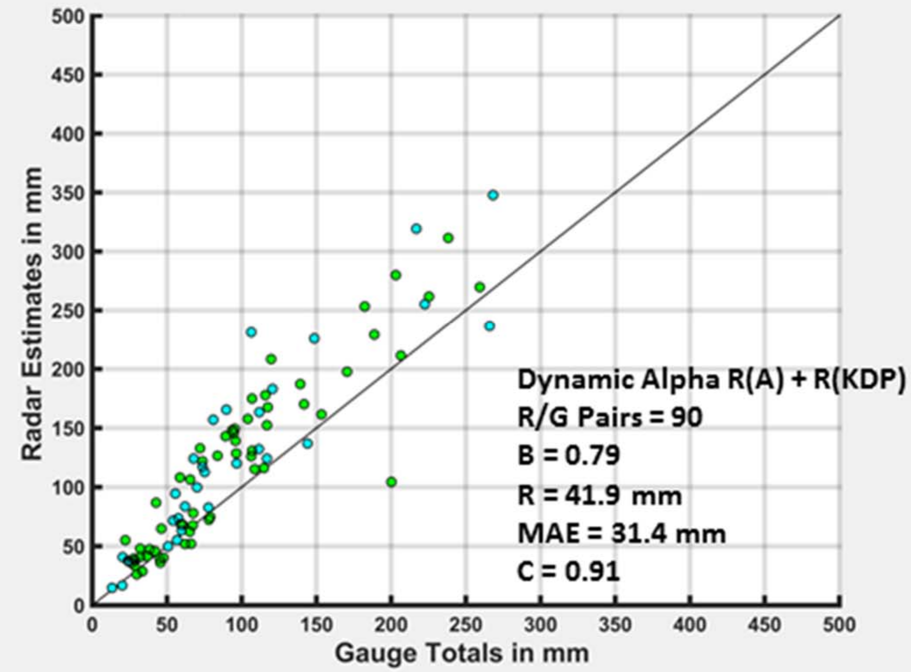
- Particularly obvious improvement is achieved in the situations of partial beam blockage or radar miscalibration

- The work should continue on the algorithm refinement to further improve its performance in a wide range of rain types and climate regions

QUESTIONS

BACKUP SLIDES





- **24-h acc. Dynamic R(A) (top left) and operational Dual Pol (top right) estimates vs. QC'd. 1200 UTC CoCoRaHS & HADS gauges (12 Aug., 2016)**

- **Despite ZDR/Z calibration challenges associated with Dual Pol, the new QPE substantially reduced errors**