Slide 1

Comparison between first and second versions of HCA and QPE

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Objective

1. A year ago, the first versions of the QPE and HCA algorithms have been recommended for implementing in the first deployment of polarimetric WSR-88D.
2. The purpose of this presentation is to summarize the improvements which can be achieved if more advanced versions of QPE and HCA are utilized and make recommendation for their operational implementation.

Recommendation

The advanced versions of the algorithms for polarimetric echo classification and rainfall estimation (HCA v2 and QPE v2) yield substantial benefits compared to HCA v1 and QPE v1 and their operational implementation in the first deployment seems to be feasible and advisable

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Polarimetric Classification of Radar Echo.

Versions HCA v1 and HCA v2 distinguish between 10 classes of echo using 6 radar variables

Classes

1. GC/AP – ground clutter / AP
2. BS – biological scatterers
3. DS – dry aggregated snow
4. WS – wet snow
5. CR - crystals
6. GR – graupel
7. BD – “big drops”
8. RA – light and moderate rain
9. HR – heavy rain
10. HA – hail (possibly mixed with rain)

Variables

1. Z – radar reflectivity
2. Z_{DR} – differential reflectivity
3. K_{DP} – specific differential phase
4. ρ_{hv} – cross-correlation coefficient
5. SD(Z) – texture of Z
6. SD(Φ_{DP}) – texture of Φ_{DP}

The difference between HCA V1 and HCA V2

HCA V1

Basic equation

$$A_i = \frac{\sum_j W_j P_j^{(i)}}{\sum_j W_j}$$

W is a vector of weights

Quality of radar measurements is not accounted for

Beam broadening is not taken into account

There is no "sanity" check

Membership functions P are the same for HCA V1 and HCA V2

i = 1, …10 class

j = 1,…..6 radar variable

Functions P and vector / matrix W are determined by adaptable parameters

Q is determined from the measured radar variables

HCA V2

Basic equation

$$A_i = \frac{\sum_j W_{ij} Q_j P_j^{(i)}}{\sum_j W_{ij} Q_j}$$

W is a matrix of weights

Quality vector Q characterizes the quality of radar measurements

Beam broadening is taken into account

"Sanity" check is introduced

Motivations for using HCA V2 instead of HCA V1

1. Using the matrix of weights W instead of vector of weights W gives much more flexibility for customization of HCA (certain classes can be introduced or deleted easily) and reflects the fact that a particular radar variable generally has different classification efficiency with respect to various classes.
2. Introduction of the quality vector helps to mitigate serious errors caused by low signal-to-noise ratio, attenuation, nonuniform beam filling, and noisiness of polarimetric variables due to low ρ_{hv}.
3. Taking into account beam broadening makes classification results look more realistic in the areas of mixed-phase hydrometeors.
4. “Sanity” check is based on “hard” thresholds and prevents absurd class designations.

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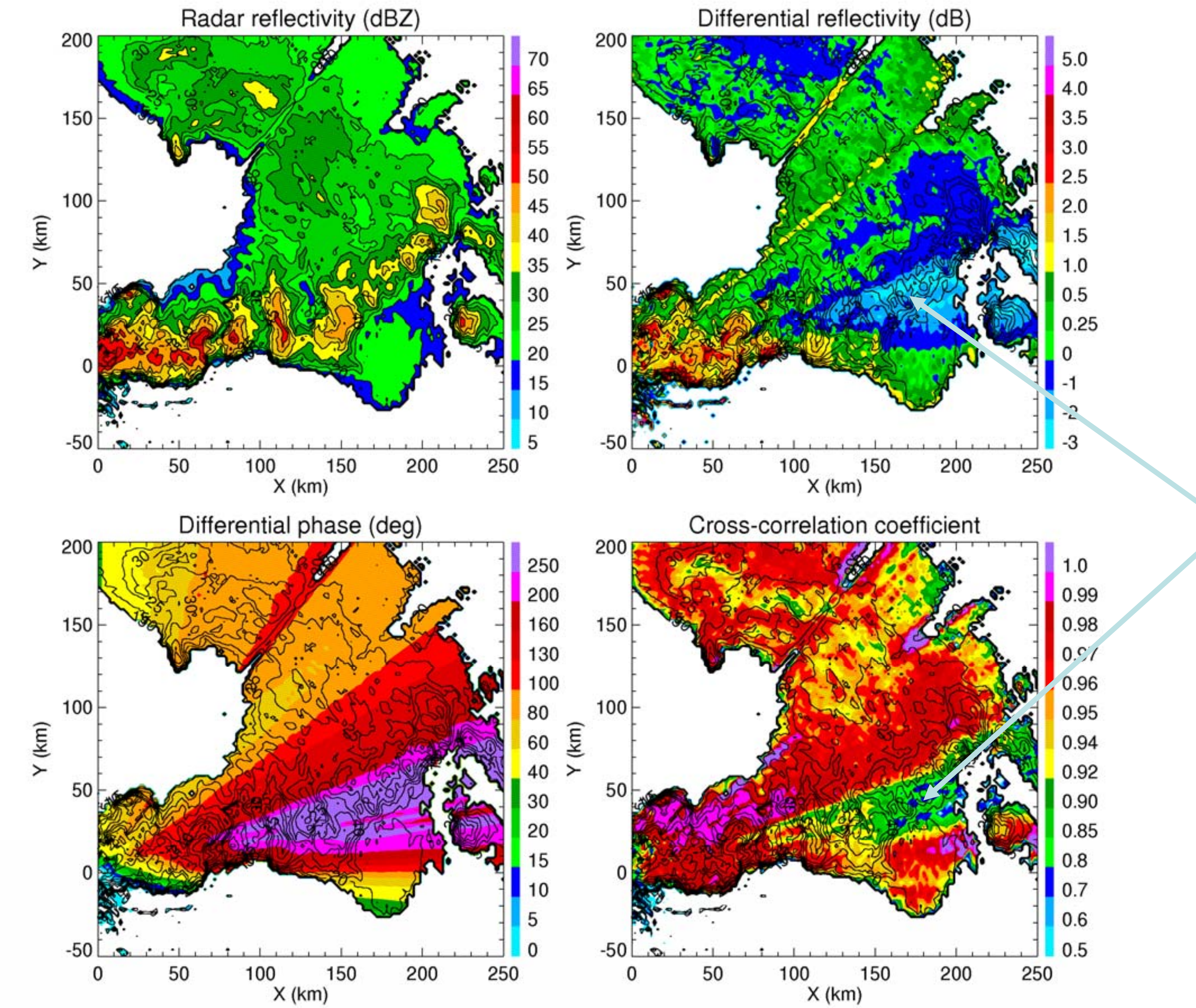
Biases due to attenuation and nonuniform beam filling



Problems with data quality to be addressed with HCA 2

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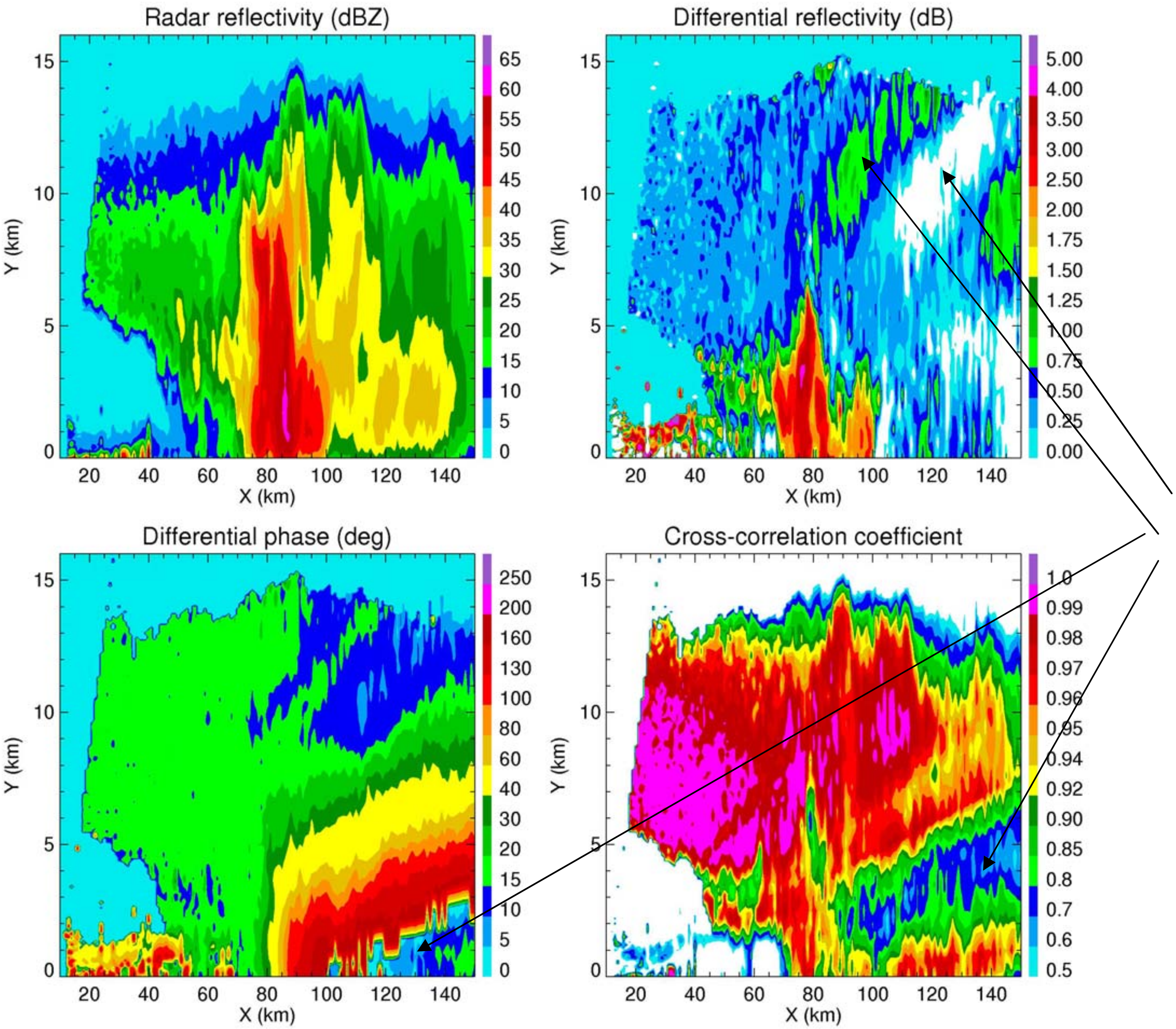
Biases due to attenuation, nonuniform beam filling, and depolarization



Problems with data quality to be addressed with HCA 2

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HCA 1 uses two slant range boundaries (R_b and R_t), whereas HCA 2 uses four

1. $0 < R < R_{bb}$

GC, BS, BD, RA, HR, HA

2. $R_{bb} < R < R_b$

GC, BS, WS, GR, BD,RA, HR, HA

3. $R_b < R < R_t$

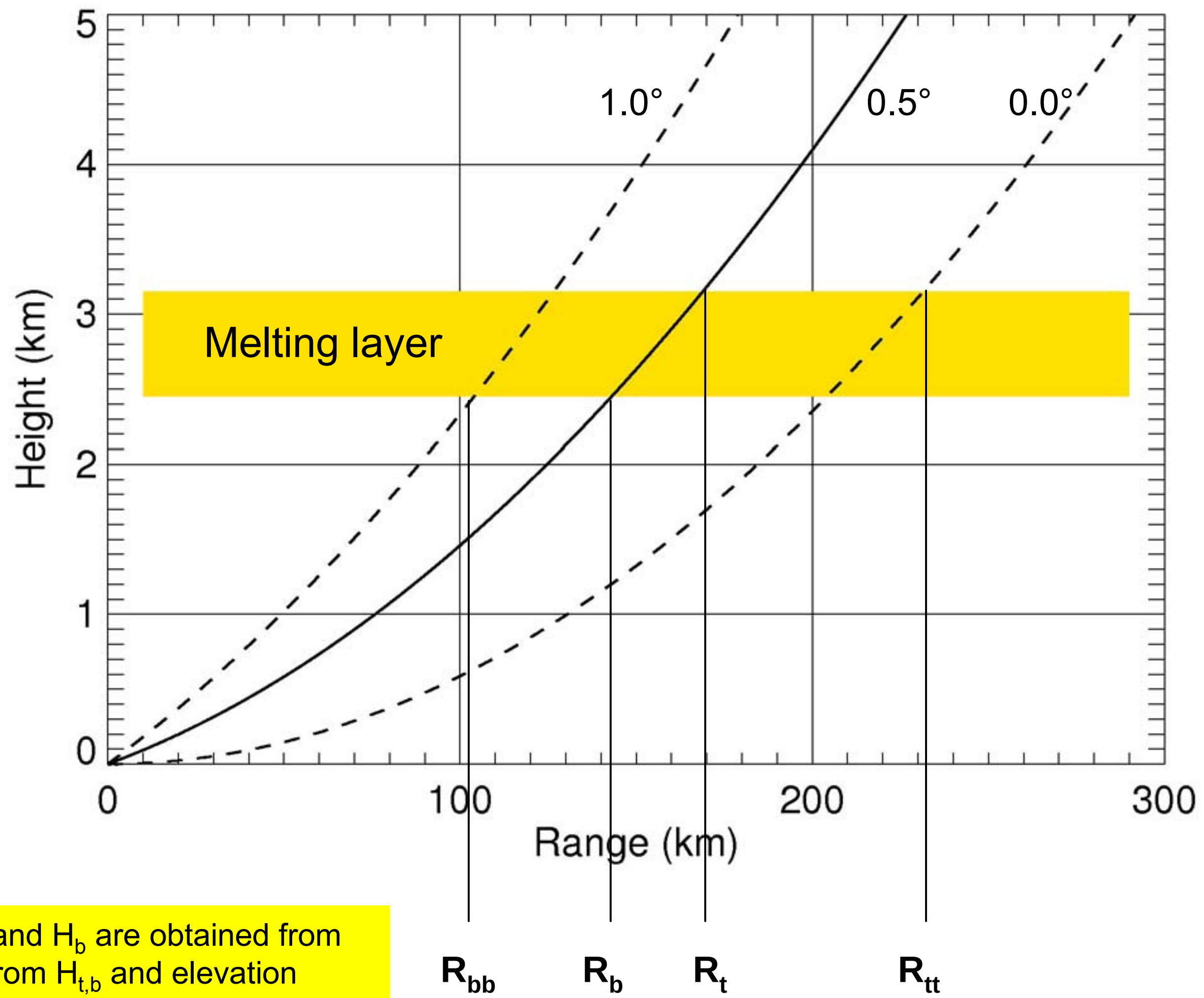
GC, BS, DS, WS, GR, BD, HA

4. $R_t < R < R_{tt}$

GC, BS, DS, WS, CR, GR, BD, HA

5. $R > R_{tt}$

DS, CR, GR, HA



The top and bottom of the melting layer H_t and H_b are obtained from MLDA and 4 slant ranges are determined from $H_{t,b}$ and elevation angle

GC – ground clutter, BS – bio, DS – dry snow, CR – crystals, WS – wet snow, BD – big drops, GR – graupel, RA – rain (light to moderate), HR – heavy rain, RH – rain-hail mixture

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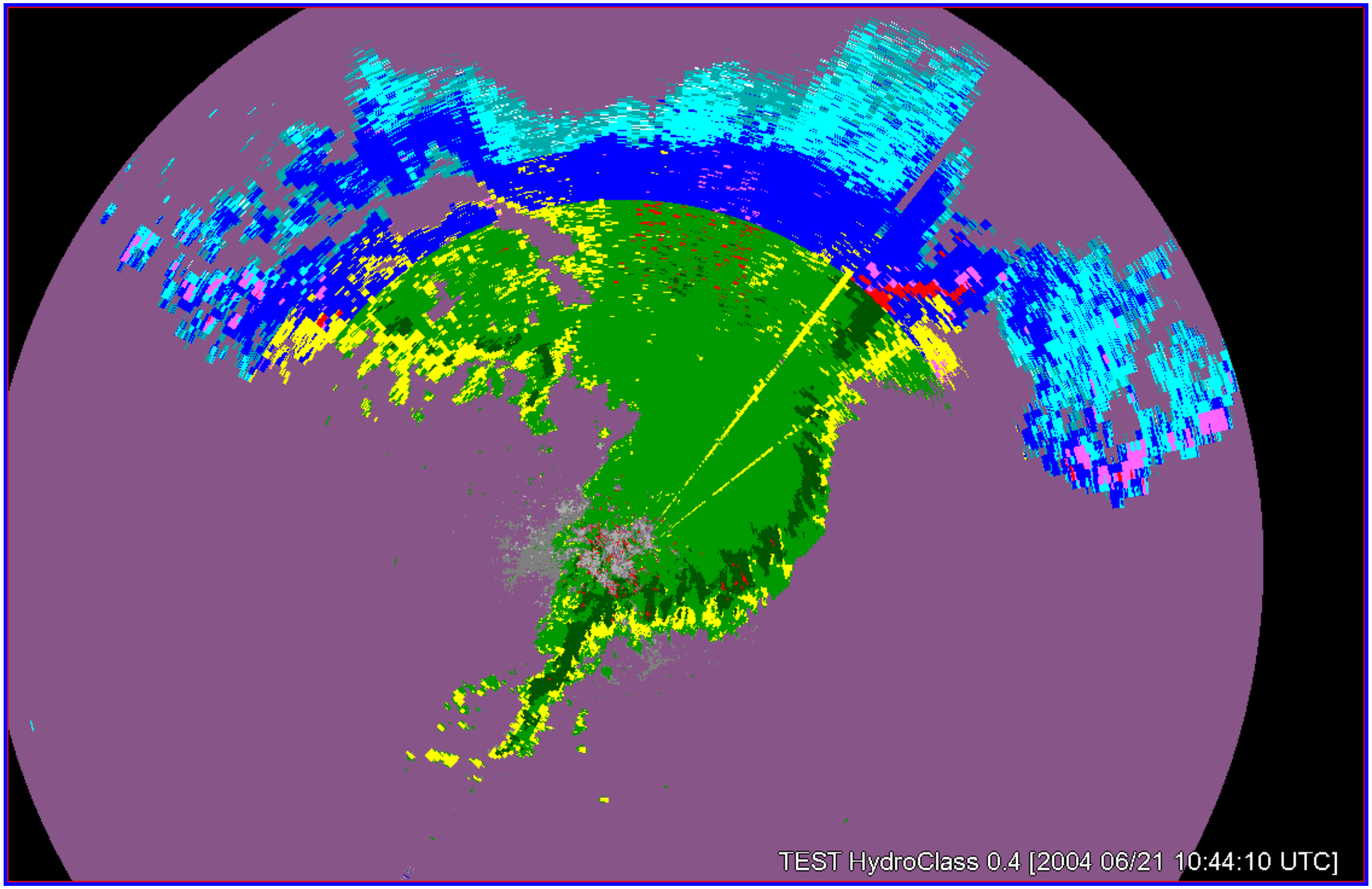
HCA 1 output – artificially looking boundaries between rain and snow



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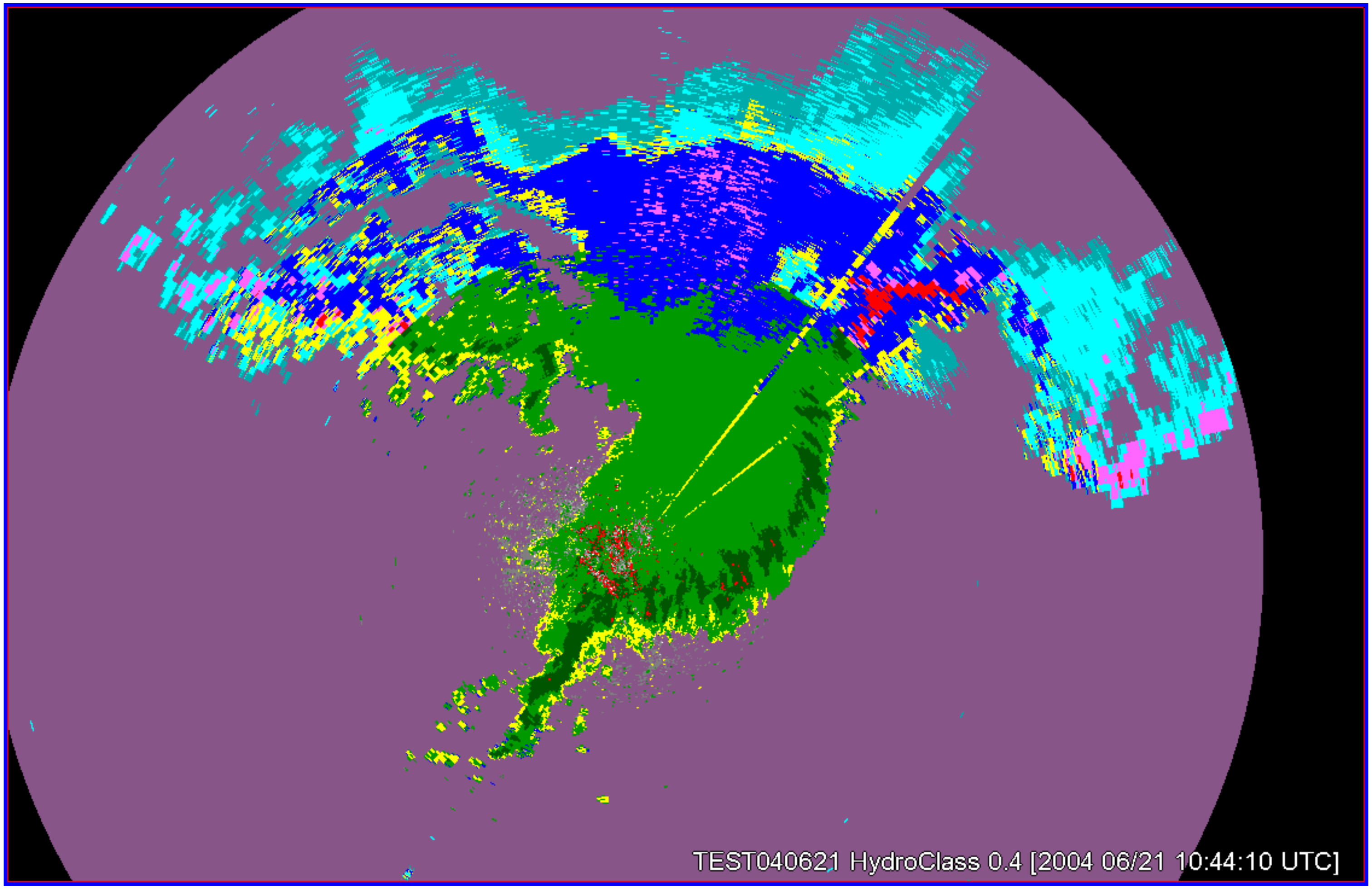
HCA 2 output – transition between rain and snow is more realistic



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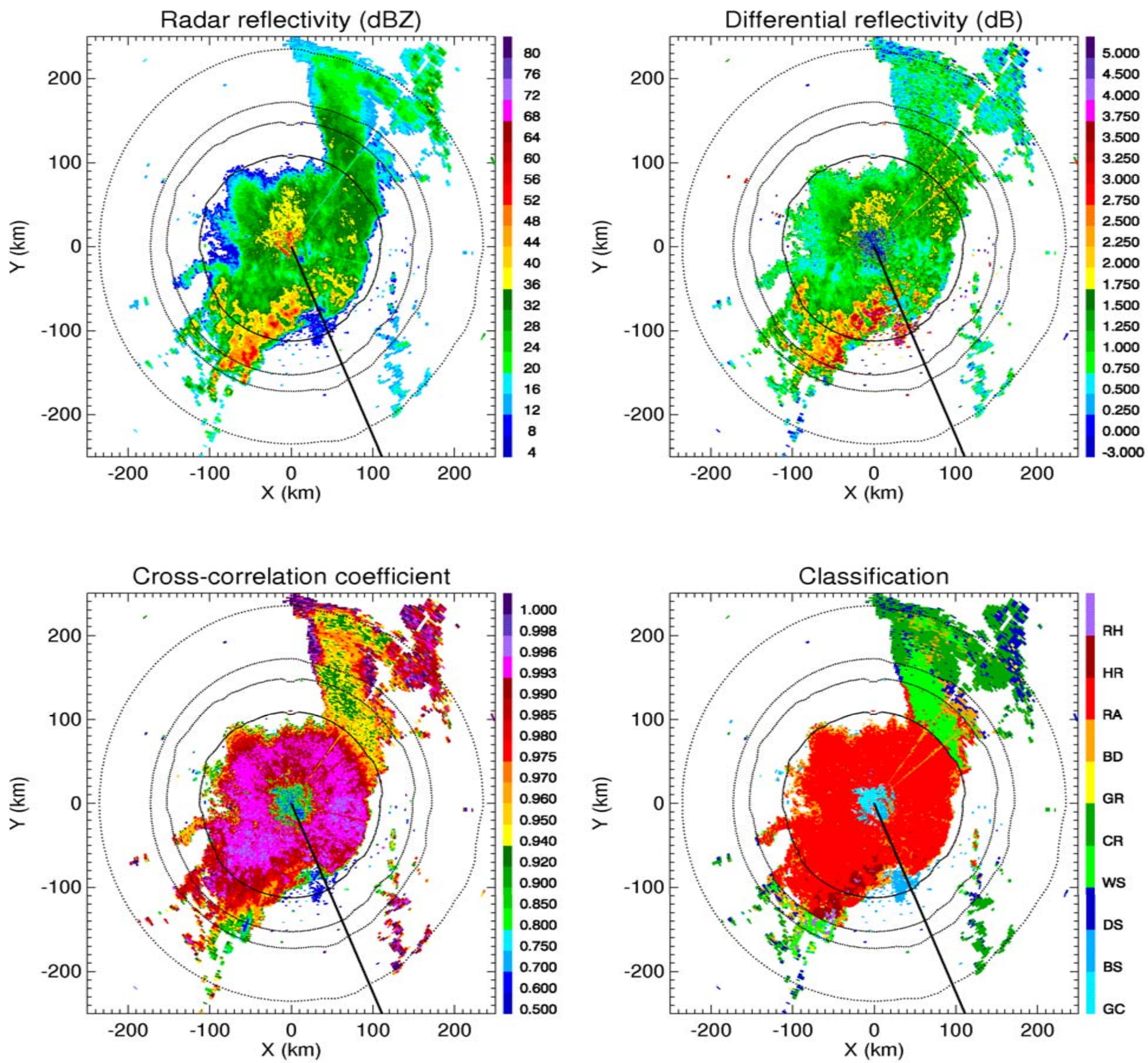
Example of HCA v2 product (05/13/2005)

El = 0.5°



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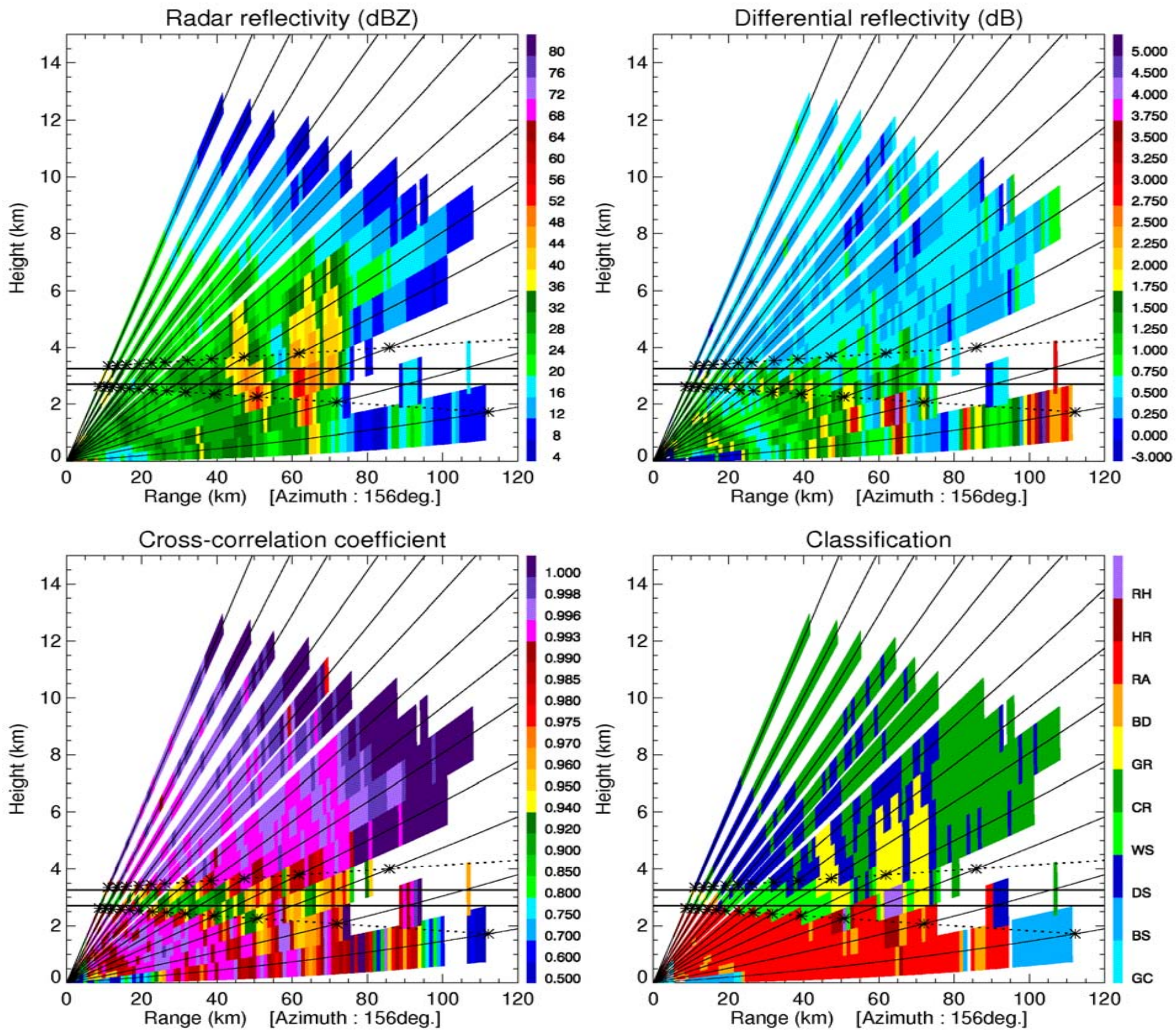
Example of HCA v2 product (05/13/2005)



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The difference between QPE 1 and QPE 2

QPE 1

0 < range < 120 km

$$R = R(Z, Z_{DR}) \quad \text{if} \quad R(Z) < 6\,\text{mm/h}$$
$$R = R(K_{DP}, Z_{DR}) \quad \text{if} \quad 6 < R(Z) < 50$$
$$R = R(K_{DP}) \quad \text{if} \quad R(Z) > 50$$

120 < range < 200 km

$$R = R(K_{DP})$$

range > 200 km

$$R = R(Z)$$

The choice between rainfall relations is based on the value of Z and distance from the radar

QPE 2

$$R = 0 \quad \text{in GC/AP and BS}$$
$$R = R(Z, Z_{DR}) \quad \text{in RA, HR, and BD}$$
$$R = R(K_{DP}) \quad \text{in RH below ML}$$
$$R = 0.6R(Z) \quad \text{in WS}$$
$$R = 0.8R(Z) \quad \text{in GR and RH above ML}$$
$$R = 2.8R(Z) \quad \text{in DS and CR}$$

The choice between rainfall relations is based on the results of classification

R(Z) is the standard WSR-88D relation

GC/AP – ground clutter/AP, BS – bio, DS – dry snow, CR – crystals, WS – wet snow, BD – big drops, GR – graupel, RA – rain (light to moderate), HR – heavy rain, RH – rain-hail mixture

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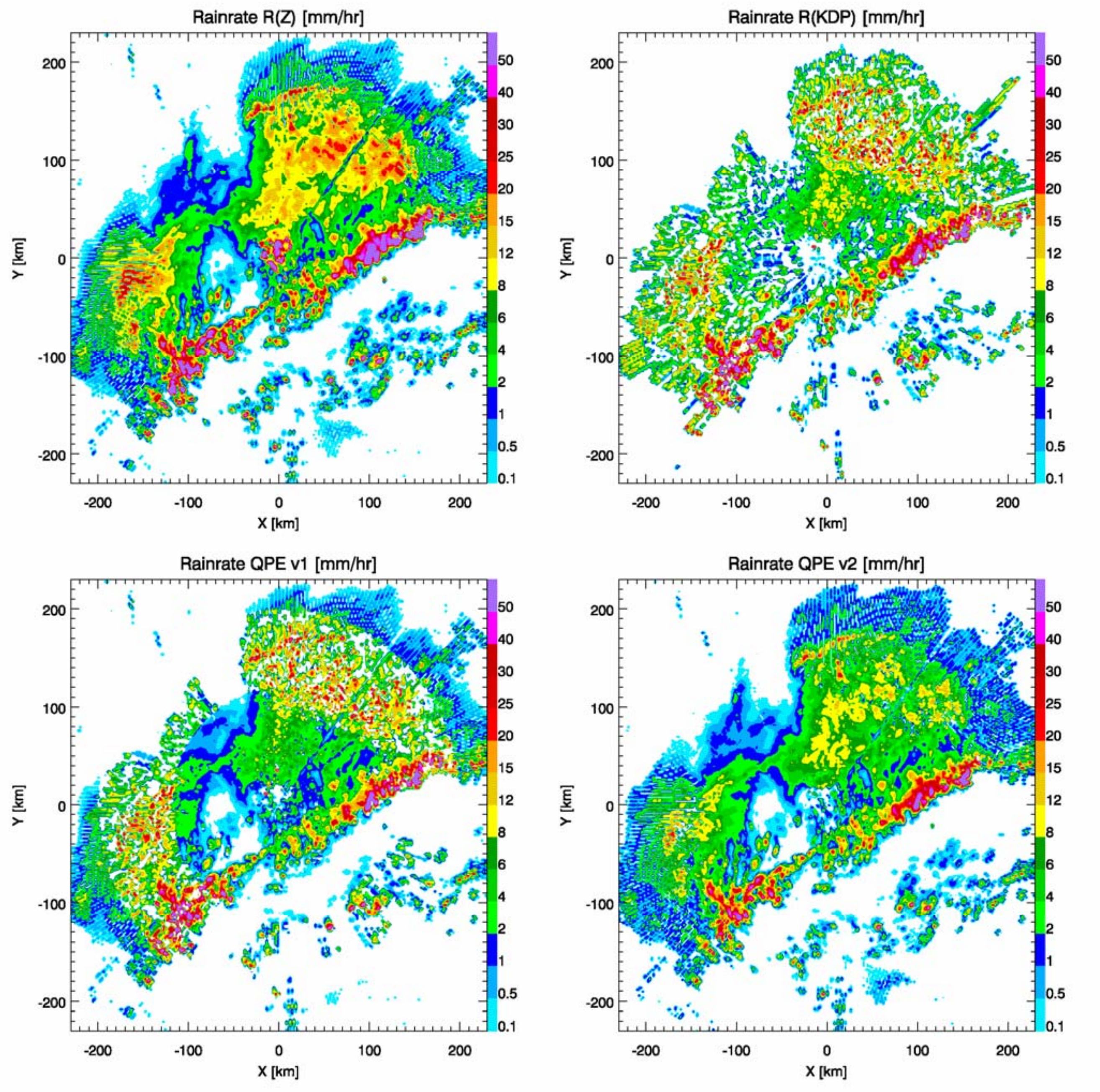
Rain rate fields from R(Z), R(K_{DP}), QPE v1, and QPE v2



June case

High freezing level

The field of rain rate generated by QPE 1 is too noisy in the regions where K_{DP} is used

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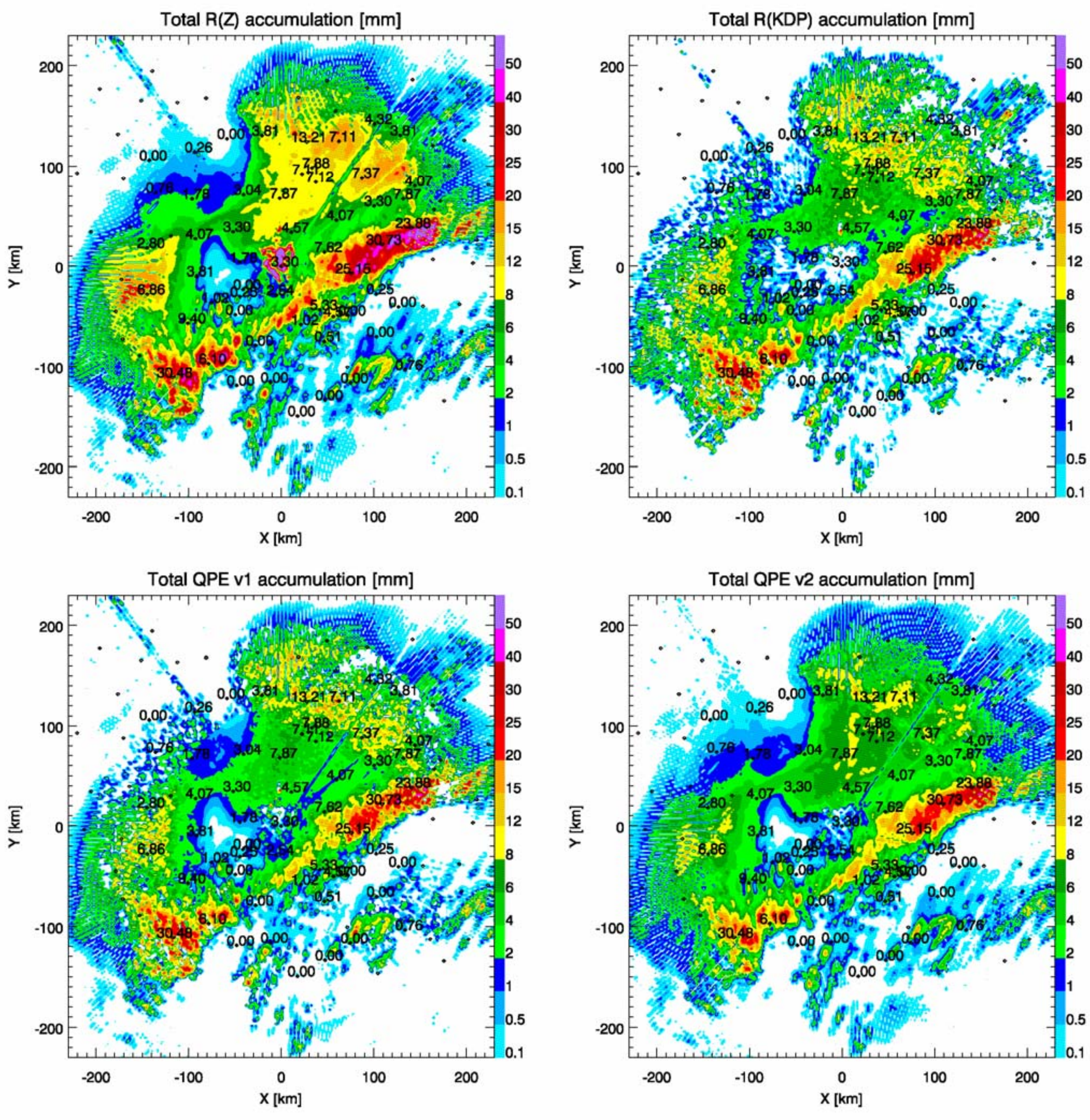
Fields of hourly rain totals from R(Z), R(K_{DP}), QPE v1, and QPE v2



June case

High freezing level

Residual noisiness and "white holes" still remain in the field of hourly rain total estimated from QPE 1

The R(Z) relation overestimates precipitation in the squall line and in the areas of bright band contamination

Numbers show gage totals

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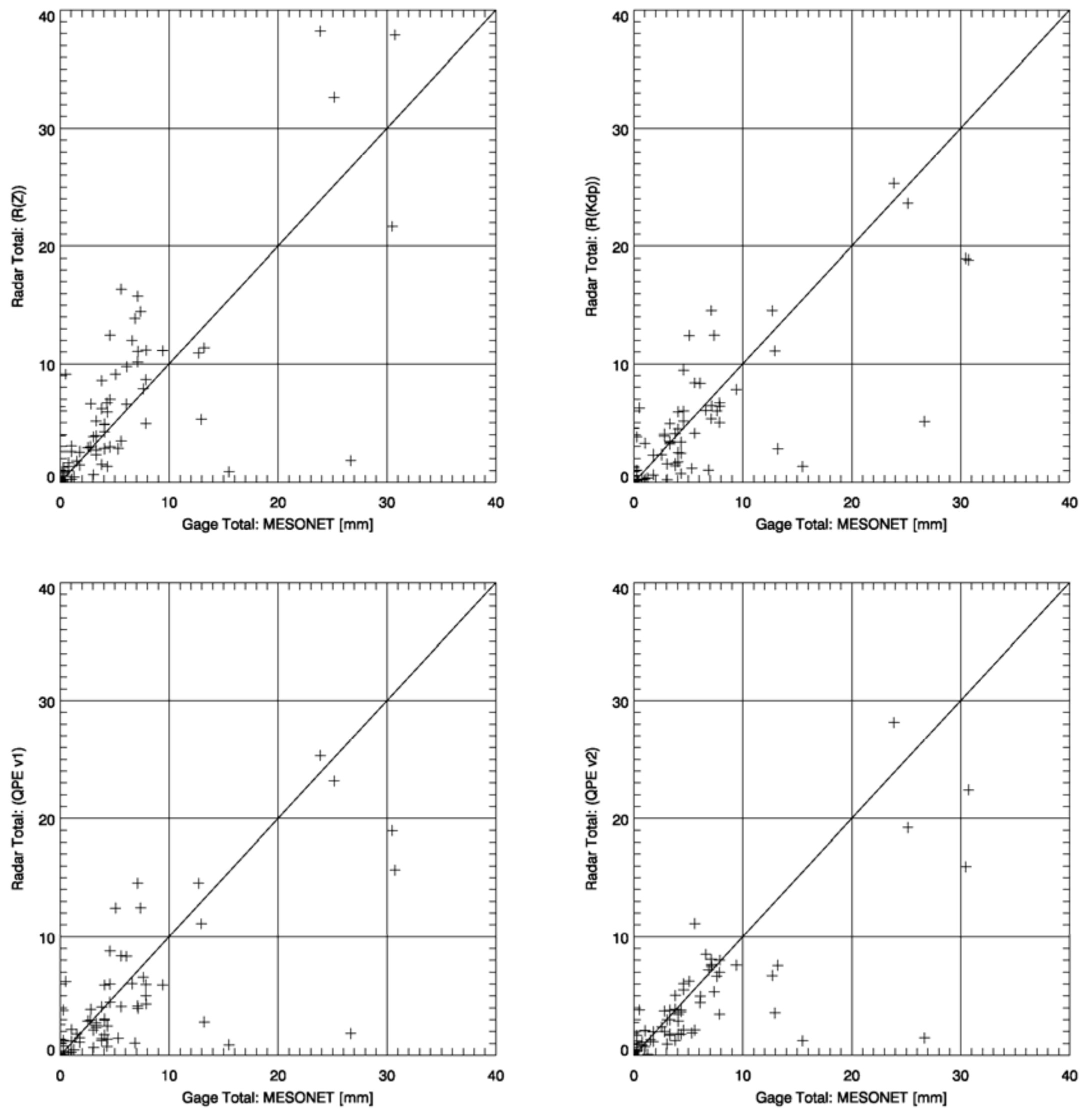
Radar – gage scatterplots for June case

R(Z)

$R(K_{DP})$



QPE 1

QPE 2

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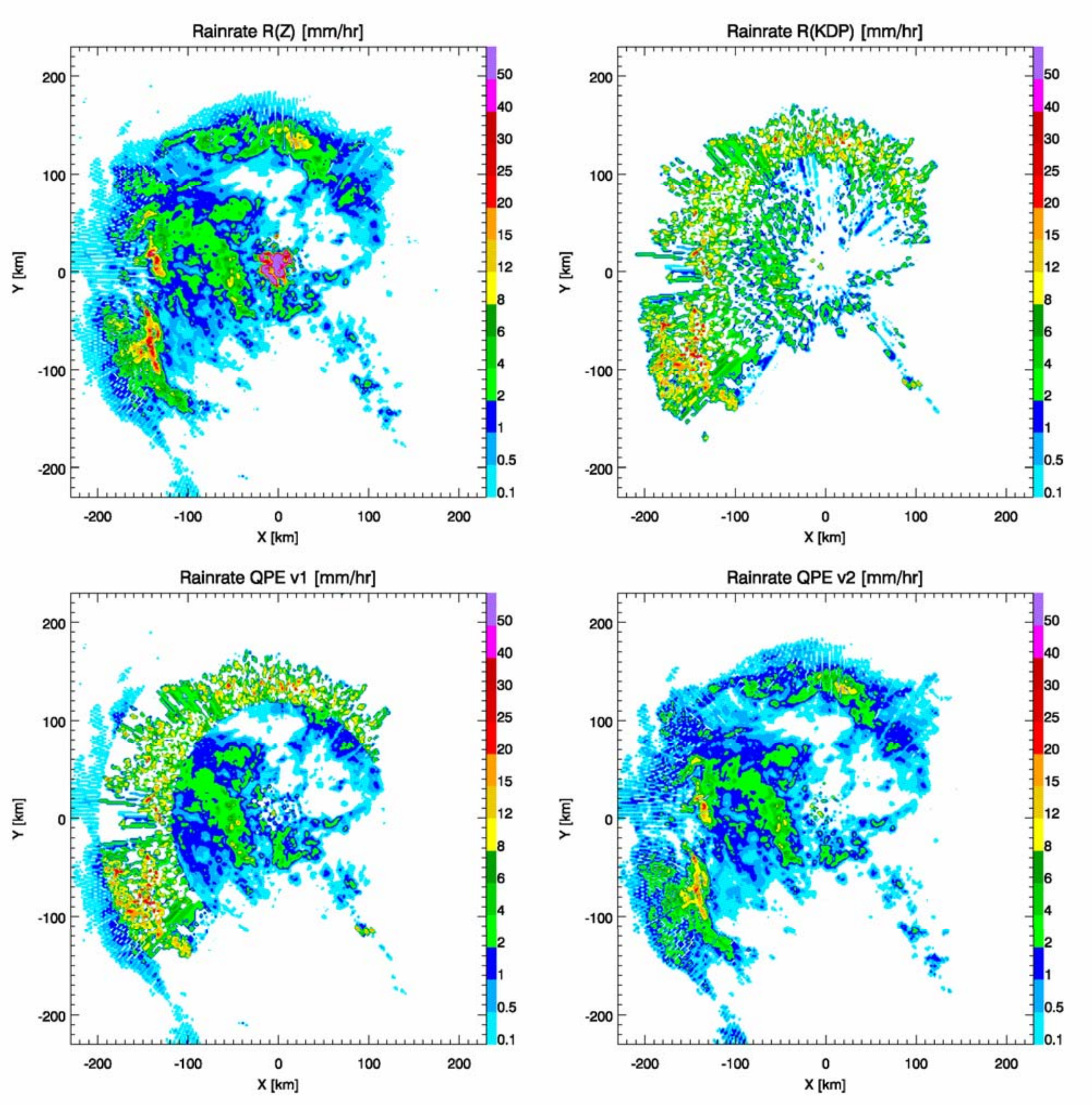
Rain rate fields from R(Z), R(K_{DP}), QPE v1, and QPE v2

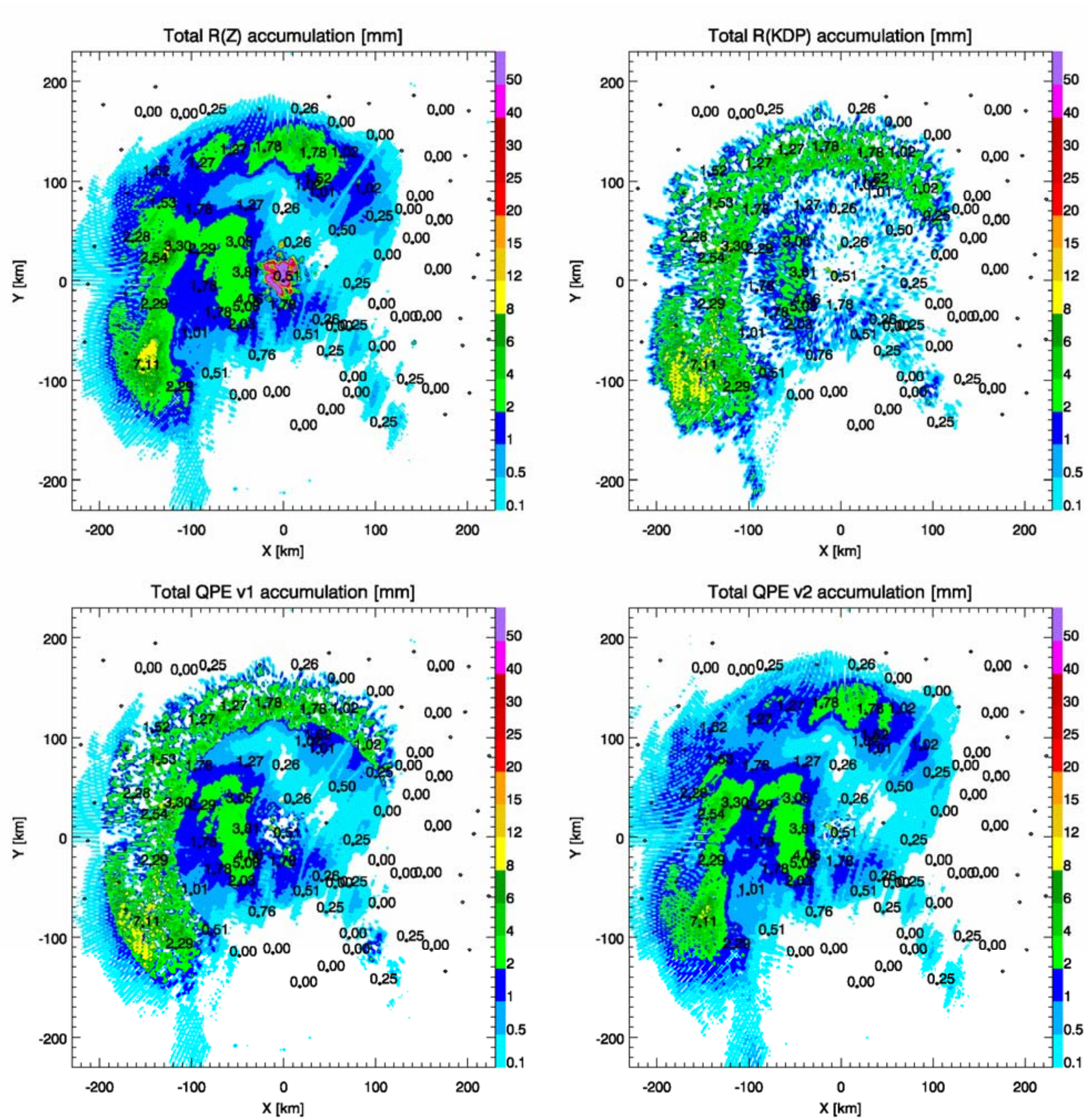


November case

Low freezing level

The field of rain rate generated by QPE 1 is too noisy in the regions where K_{DP} is used

Slide 18 Fields of hourly rain totals from R(Z), R(K_{DP}), QPE v1, and QPE v2



November case

Low freezing level

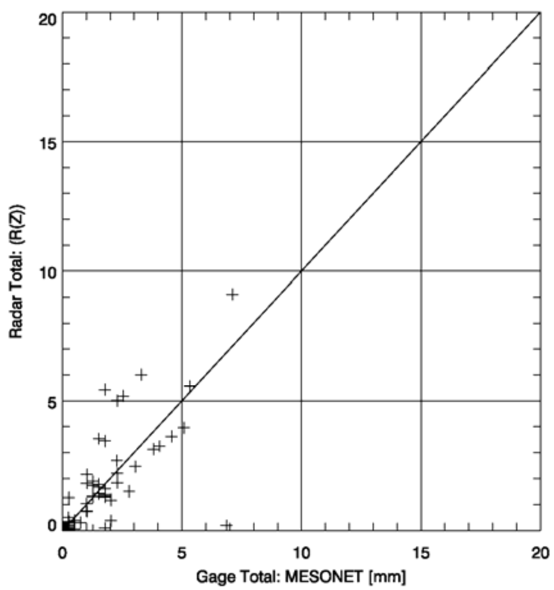
Residual noisiness and “white holes” still remain in the field of hourly rain total estimated from QPE 1

The R(Z) relation overestimates precipitation in the areas of bright band contamination

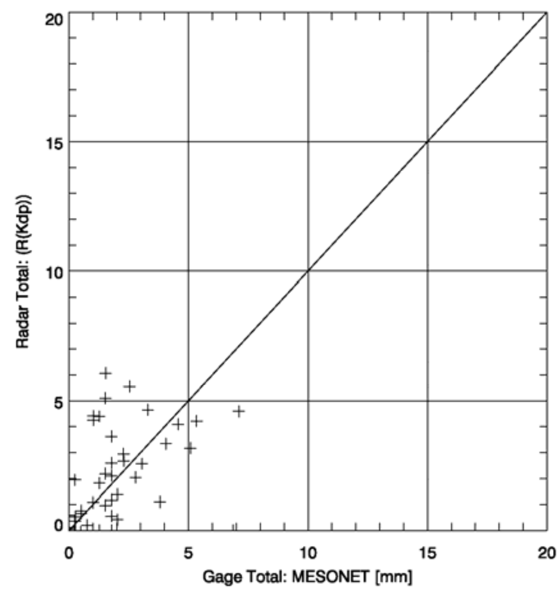
Numbers show gage totals

Radar – gage scatterplots for November case

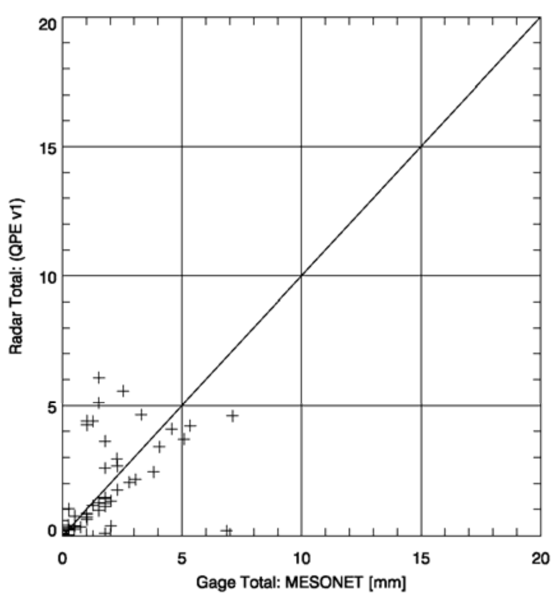
R(Z)



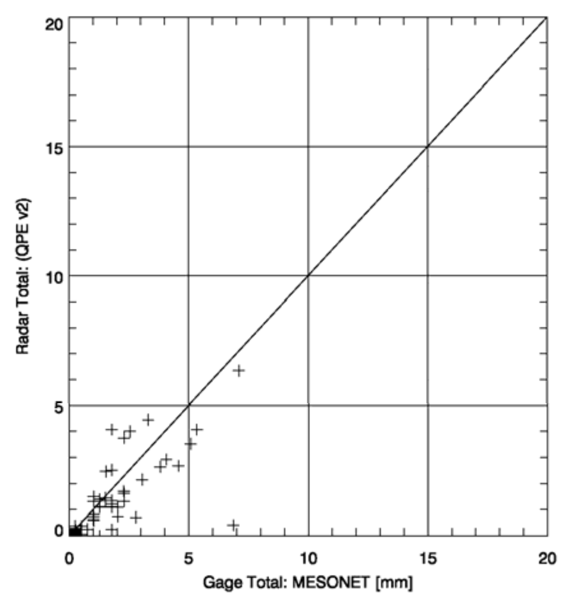
$R(K_{DP})$



QPE 1



QPE 2



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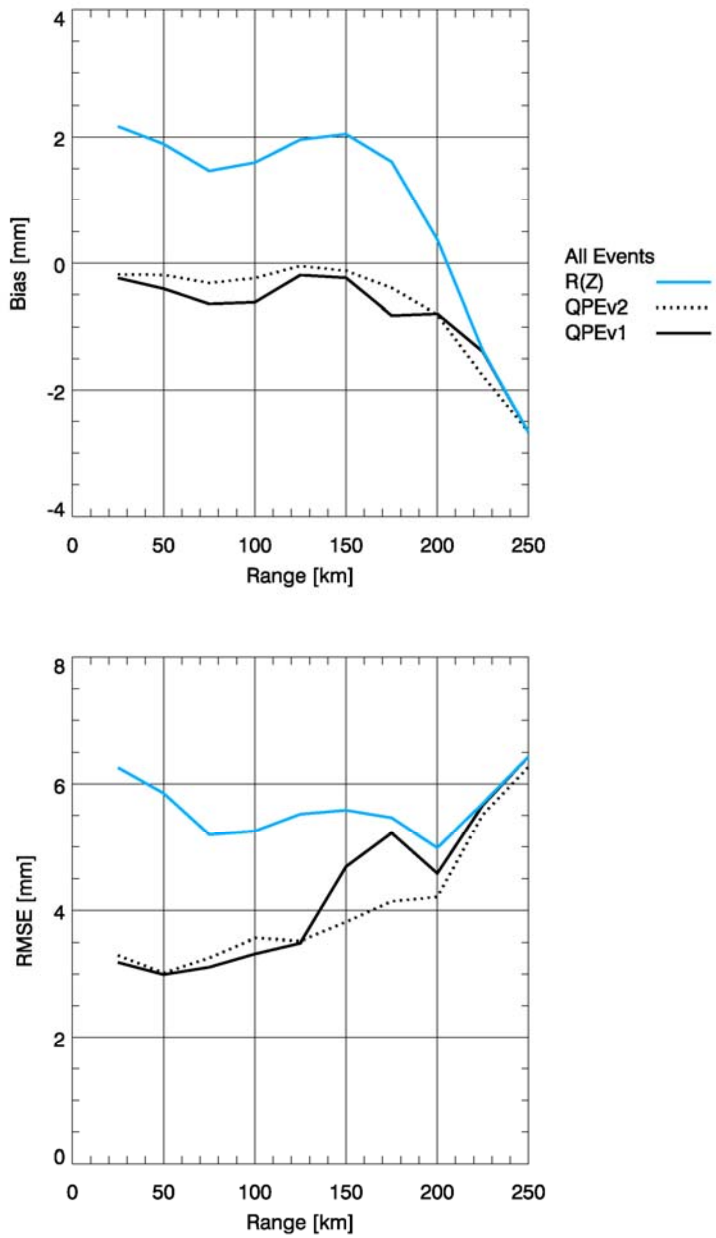
The bias and RMS error of hourly rainfall estimates as functions of range for different algorithms



Statistical analysis of a 4-year KOUN dataset (46 rain events, 179 hours of observations)

QPE v2 shows significant improvement in the RMS errors of hourly totals at the distances beyond 120 – 130 km from the radar

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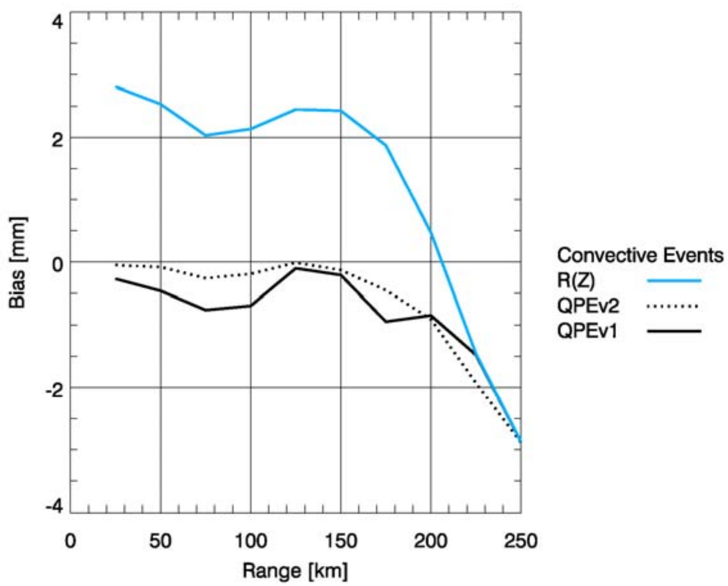
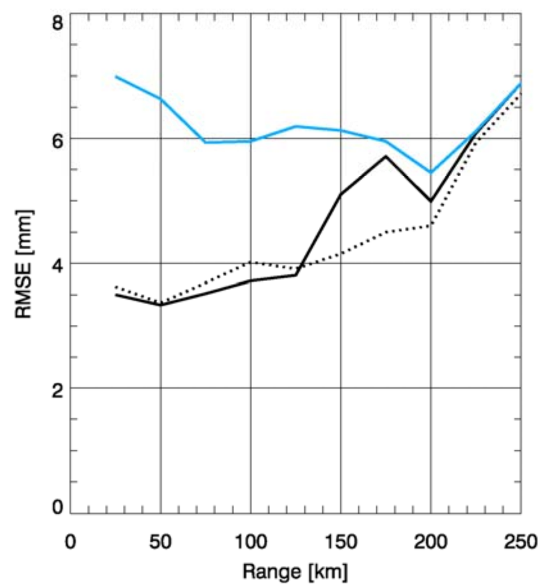
The bias and RMS error of hourly rainfall estimates as functions of range for different algorithms





Convective rain events (36 events, 153 hours of observation)

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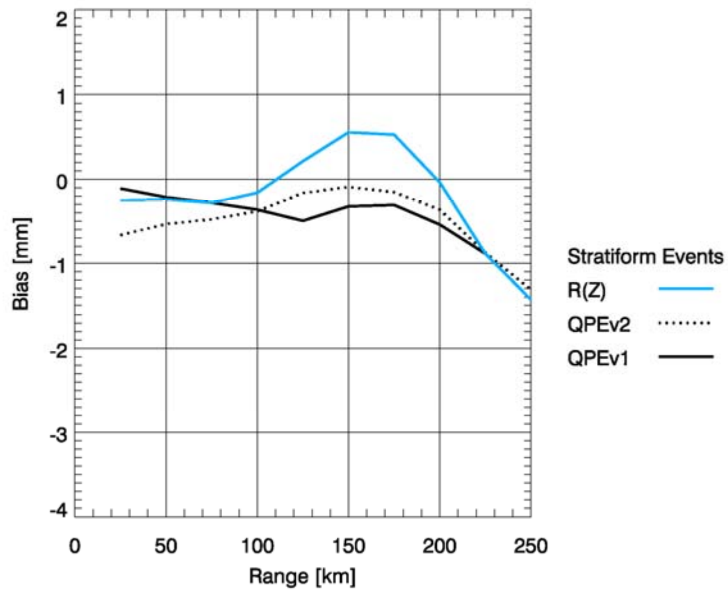
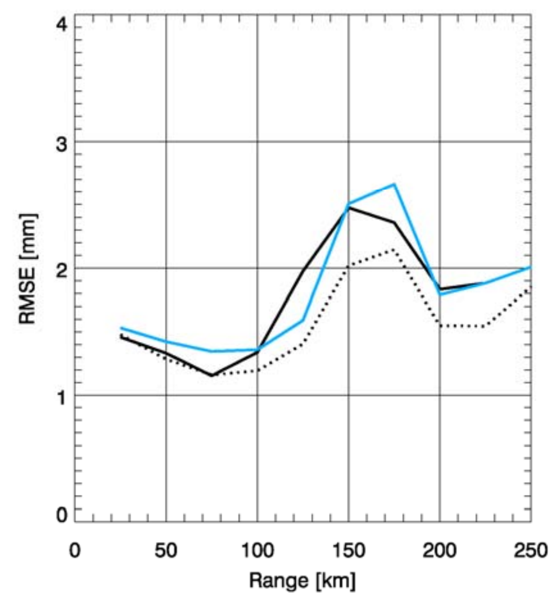
The bias and RMS error of hourly rainfall estimates as functions of range for different algorithms





Stratiform rain events (10 events, 26 hours of observation)

Conclusions

1. HCA v2 has several advantages compared to HCA v1 which result in more flexibility of the algorithm and in better quality of classification
2. QPE v2 is linked to HCA v2 and implies that precipitation quantification is contingent on hydrometeor classification so that different rainfall relations are applied for different types of scatterers in the radar resolution volume
3. QPE v2 yields less noisy and more realistically looking fields of rain rates and rain accumulations than QPE v1
4. Validation of QPE on a 4-year KOUN dataset demonstrates that QPE v2 noticeably outperforms QPE v1 at the distances beyond 100 – 120 km from the radar in terms of bias and standard error
5. The transition from HCA v1 to HCA v2 would result in only modest increase in the algorithm complexity and amount of computation for operational implementation, whereas no such increase is anticipated if QPE v1 is replaced with QPE v2