Modification of the QPE algorithm to account for partial beam blockage

Update on the HCA and QPE algorithm development

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November 19, 2009

Outline of the talk

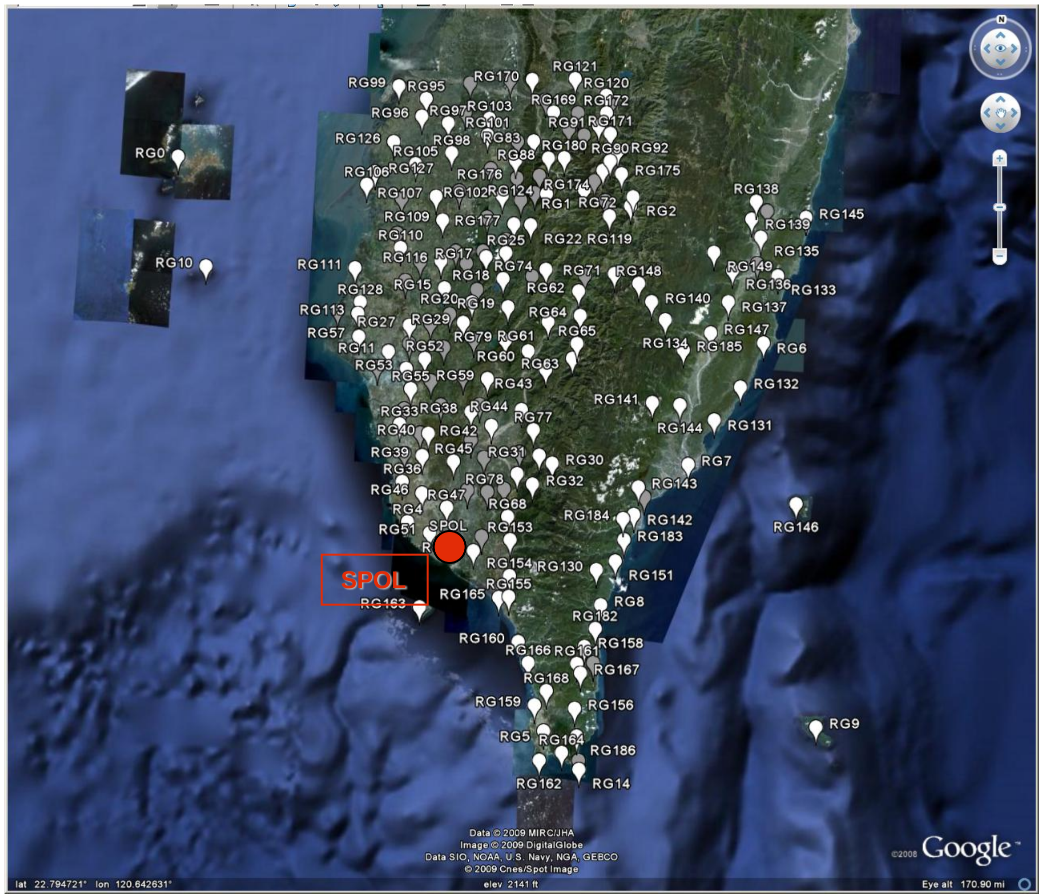
1. Investigation of the impact of complex terrain / partial beam blockage on the quality of polarimetric rainfall measurements using SPOL data collected in Taiwan

2. Brief summary of recent research efforts to improve polarimetric HCA and QPE

- Physical model-based polarimetric VPR
- Performance of the polarimetric QPE algorithm in the areas affected by ground clutter canceling
- Modification of HCA to discriminate between small and large hail
- Developing HCA module for transitional winter weather

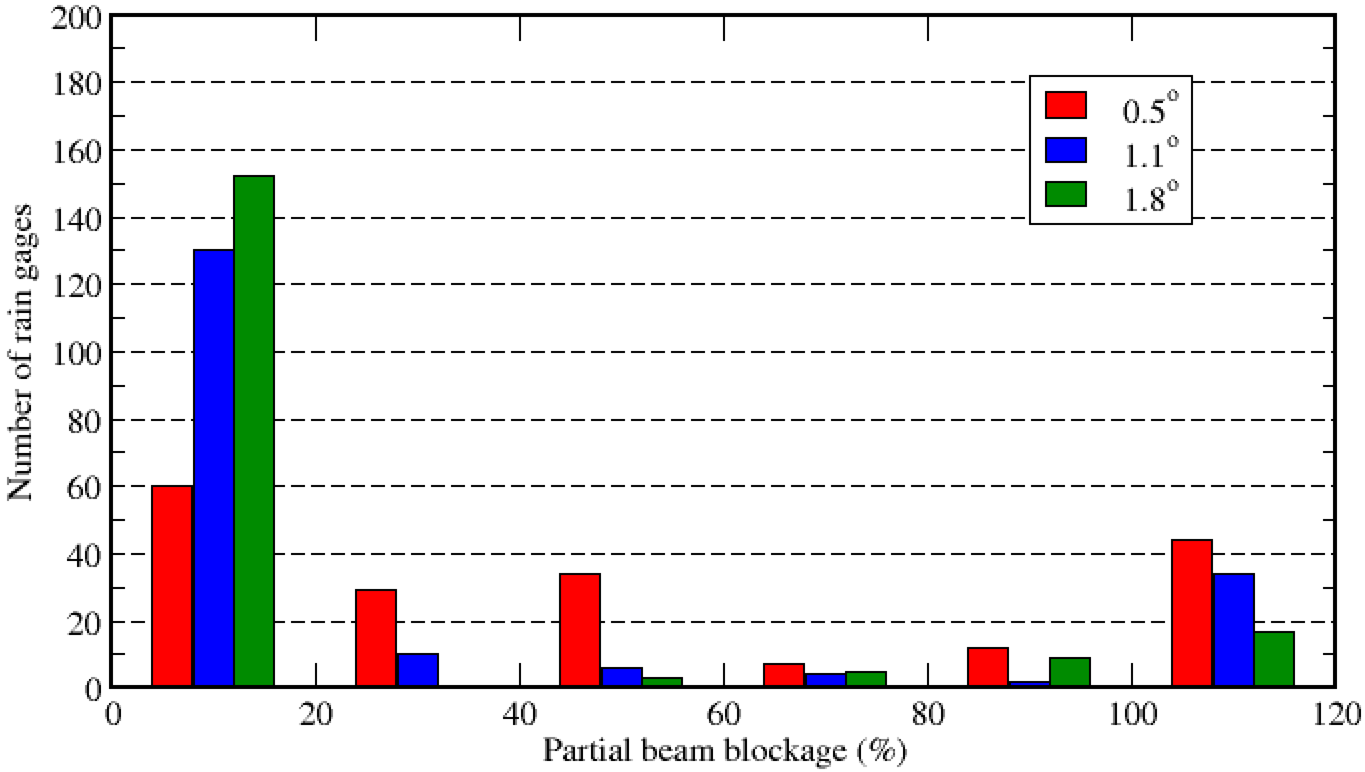
SoWMEX / TiMREX experiment in Taiwan, 2008.

Locations of Taiwan rain gages and SPOL radar

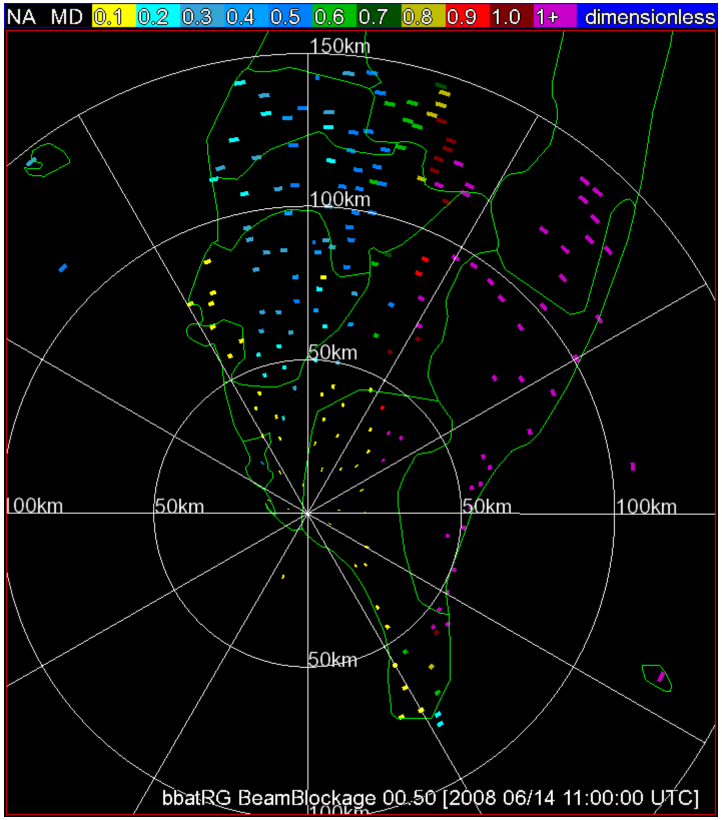


R < 150 km

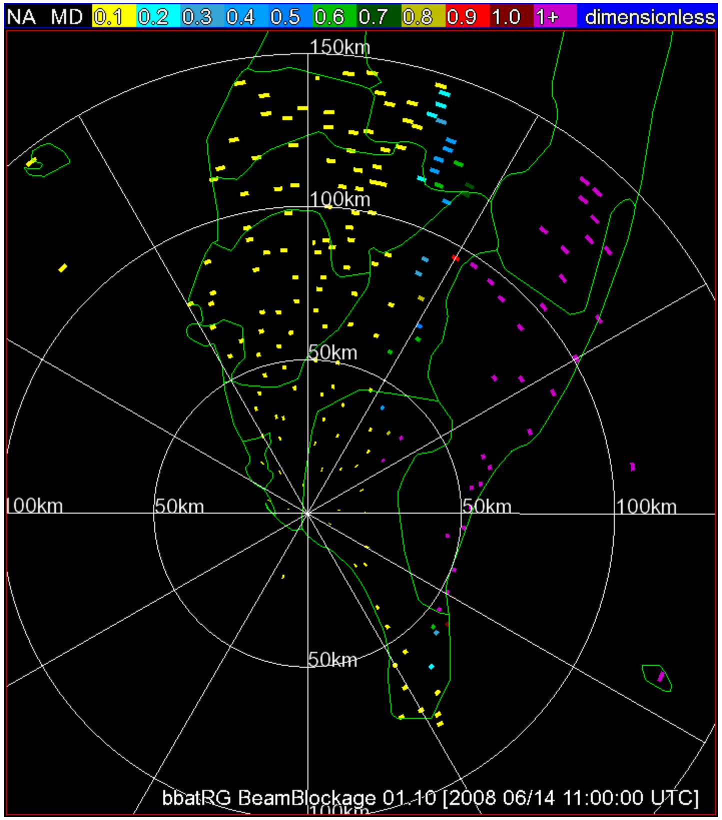
Degree of blockage at different elevations for raingage sites in Taiwan with respect to the SPOL radar



Partial Beam Blockage at Different Elevation Angles

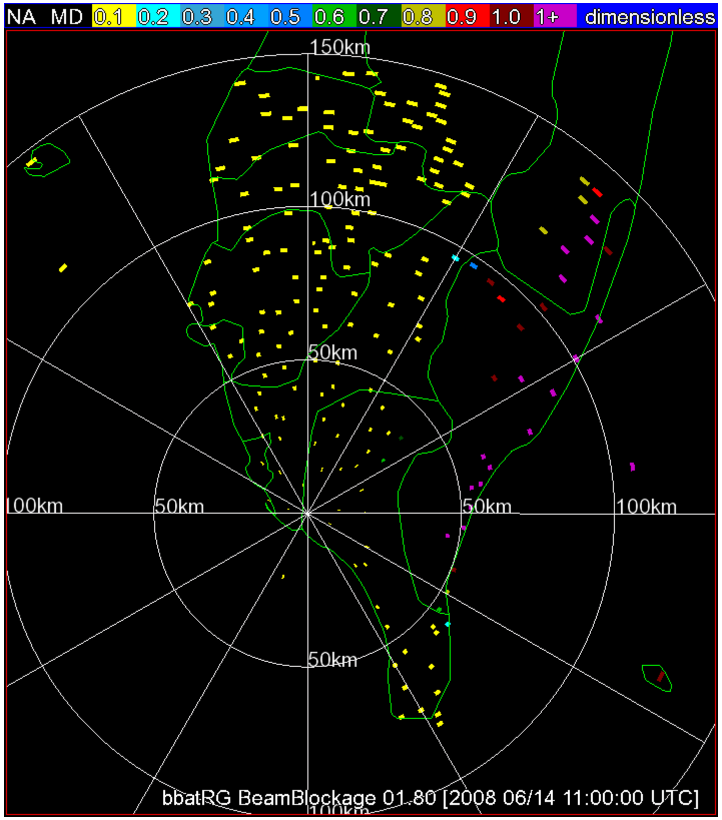


0.5

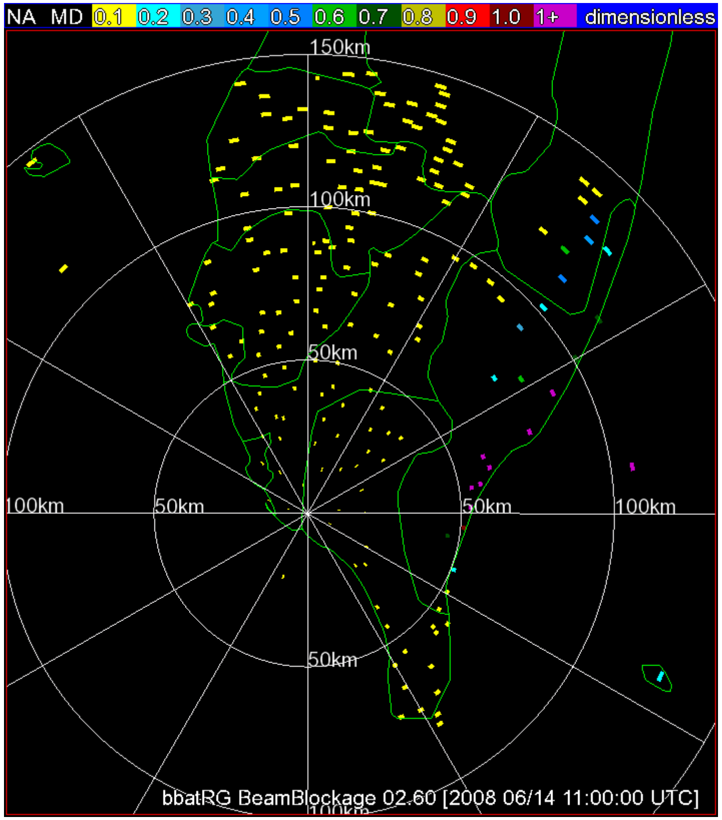


1.1

Partial Beam Blockage at Different Elevation Angles



1.8

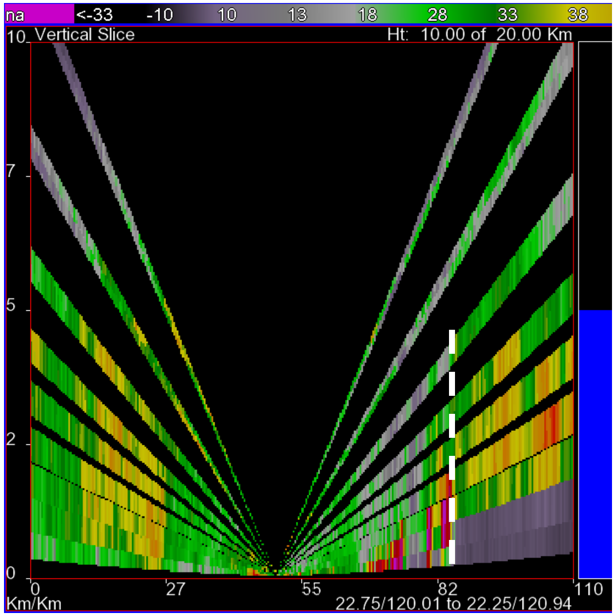


2.6

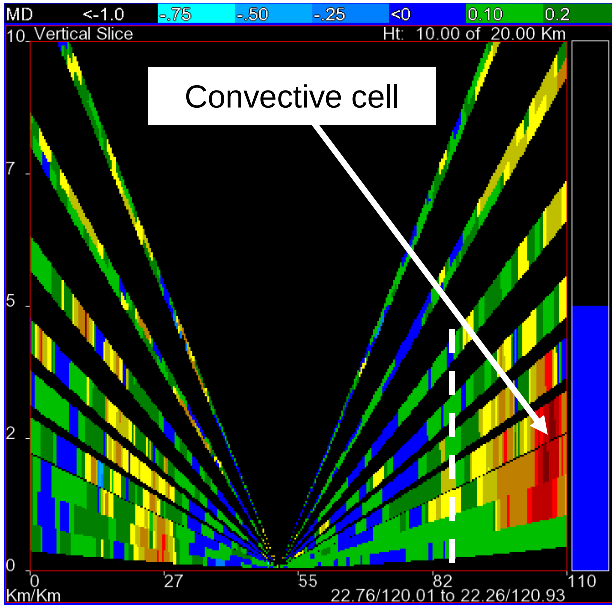
How can K_{DP} help?

RHI plots of Z and K_{DP} measured by the NCAR SPOL radar in Taiwan

Radar reflectivity Z



Specific differential phase K_{DP}



K_{DP} “senses” convective cell behind the mountain better than Z

List of rain events

1. 2008/06/02 21 – 22 UTC
2. 2008/06/05 01 – 03 UTC
3. 2008/06/14 10 – 13 UTC

Four different algorithms for rainfall estimation

$$R_1(Z) = 1.7010^{-2} 10^{0.0714Z}$$ Standard WSR-88D

$$R_2(Z) = R_1(Z) F^{-0.714}$$ Standard WSR-88D with geometrical blockage correction

$$F = 0.5 \tanh[0.0277(50 - b)] + 0.5$$

$$R_3(Z, Z_{DR}) = 1.33 R_2^{1.30}(Z) 10^{-0.343 Z_{DR}}$$ Bringi and Chandra, 2001

$$R_4(Z, Z_{DR}, K_{DP}) = \frac{R_2(Z)}{0.4 + 5.0 |Z_{dr} - 1|^{1.3}} \quad \text{if} \quad R_1(Z) < 6\,\text{mm/h}$$

$$R_4(Z, Z_{DR}, K_{DP}) = \frac{R(K_{DP})}{0.4 + 3.5 |Z_{dr} - 1|^{1.7}} \quad \text{if} \quad R_1(Z) > 6\,\text{mm/h}$$

$$R(K_{DP}) = 44.0 |K_{DP}|^{0.822} \operatorname{sign}(K_{DP})$$

Synthetic (Ryzhkov et al. 2005)

Correction of Z based on the geometry of obstruction

$$\alpha = 100\,\frac{\theta_b - \theta_0 + \Omega/2}{\Omega}$$

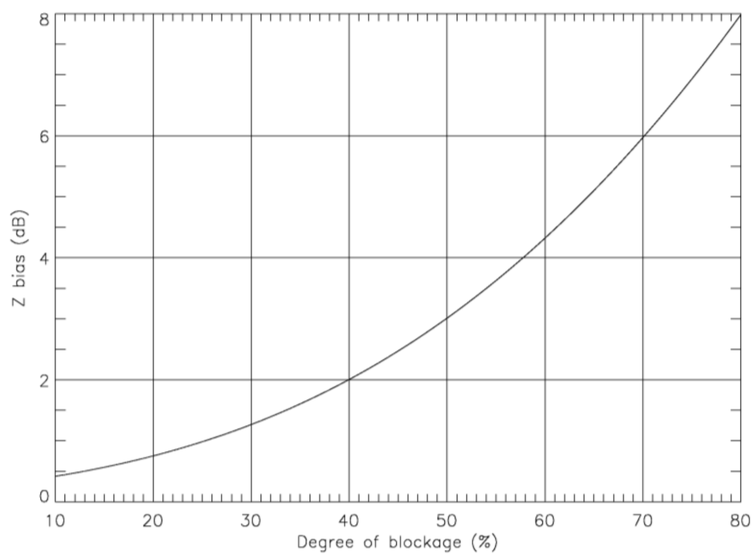
α is blockage degree (%)

Ω is radar beamwidth, θ_0 is elevation of the beam center, θ_b is blockage elevation

$$Z(dBZ) = Z_{blocked}(dBZ) + 10\log(F_{shield})$$

$$F_{shield} = 0.5\tanh[0.0277(50-\alpha)] + 0.5$$

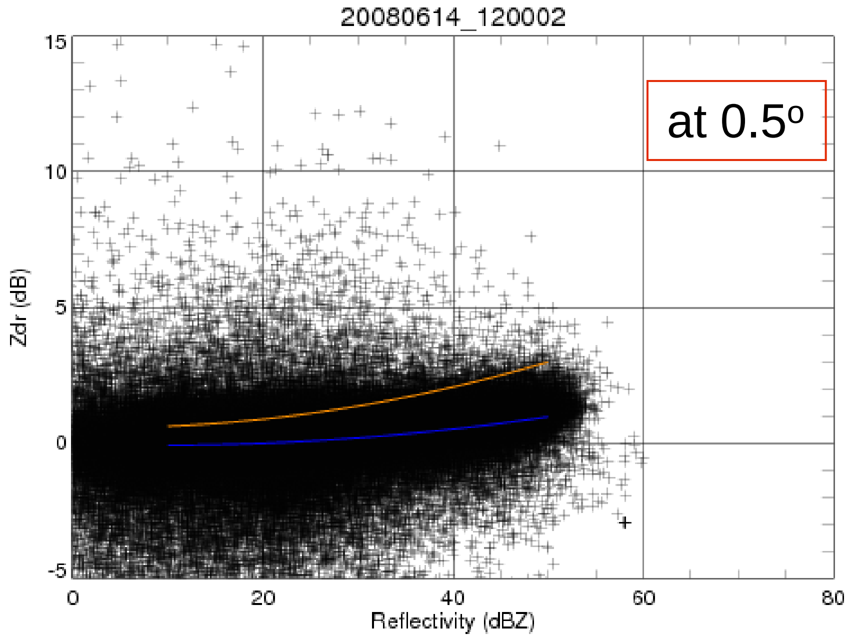
if Ω = 1.0

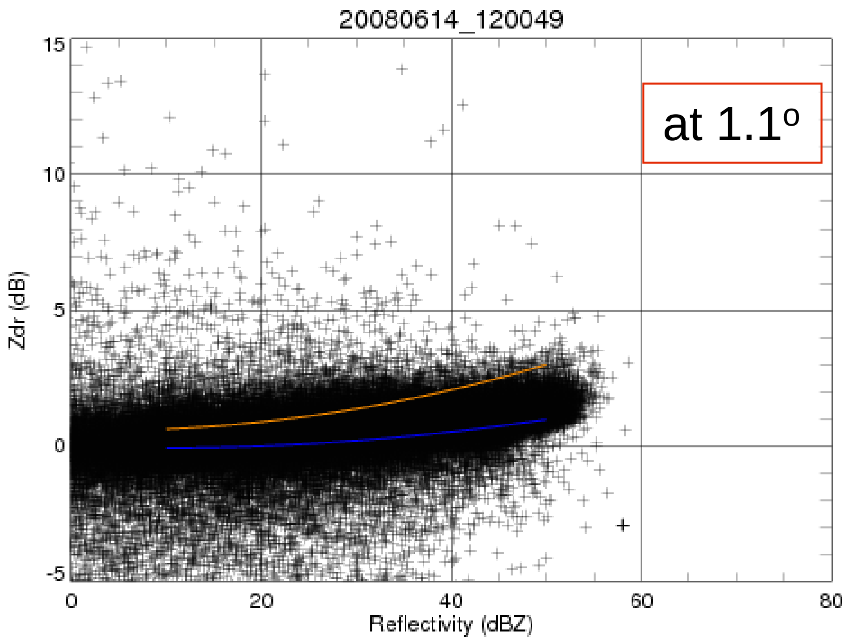


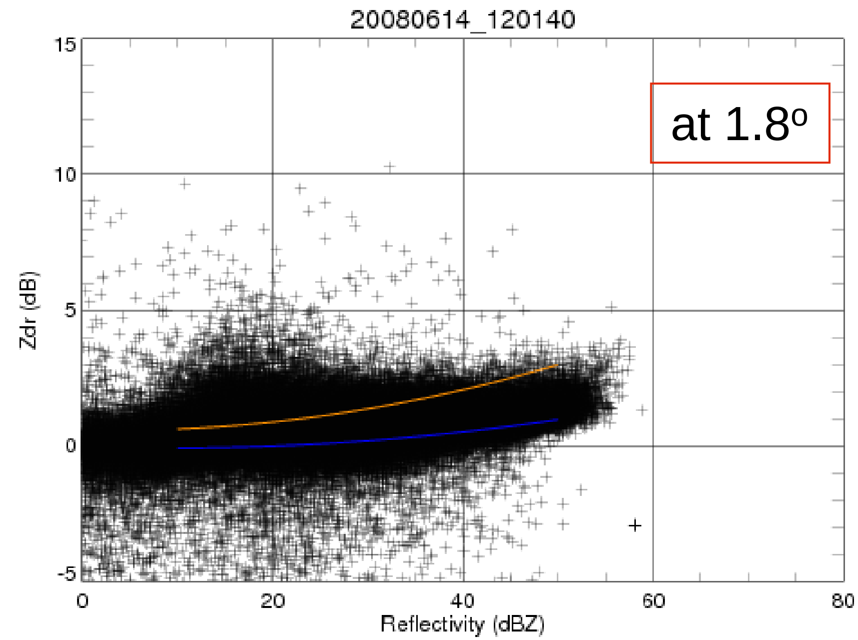
Z – Z_{DR} scatterplots at elevations 0.5°,1.1°, and 1.8°

Z_{DR} is negatively biased at lowest elevation due to contamination from ground clutter

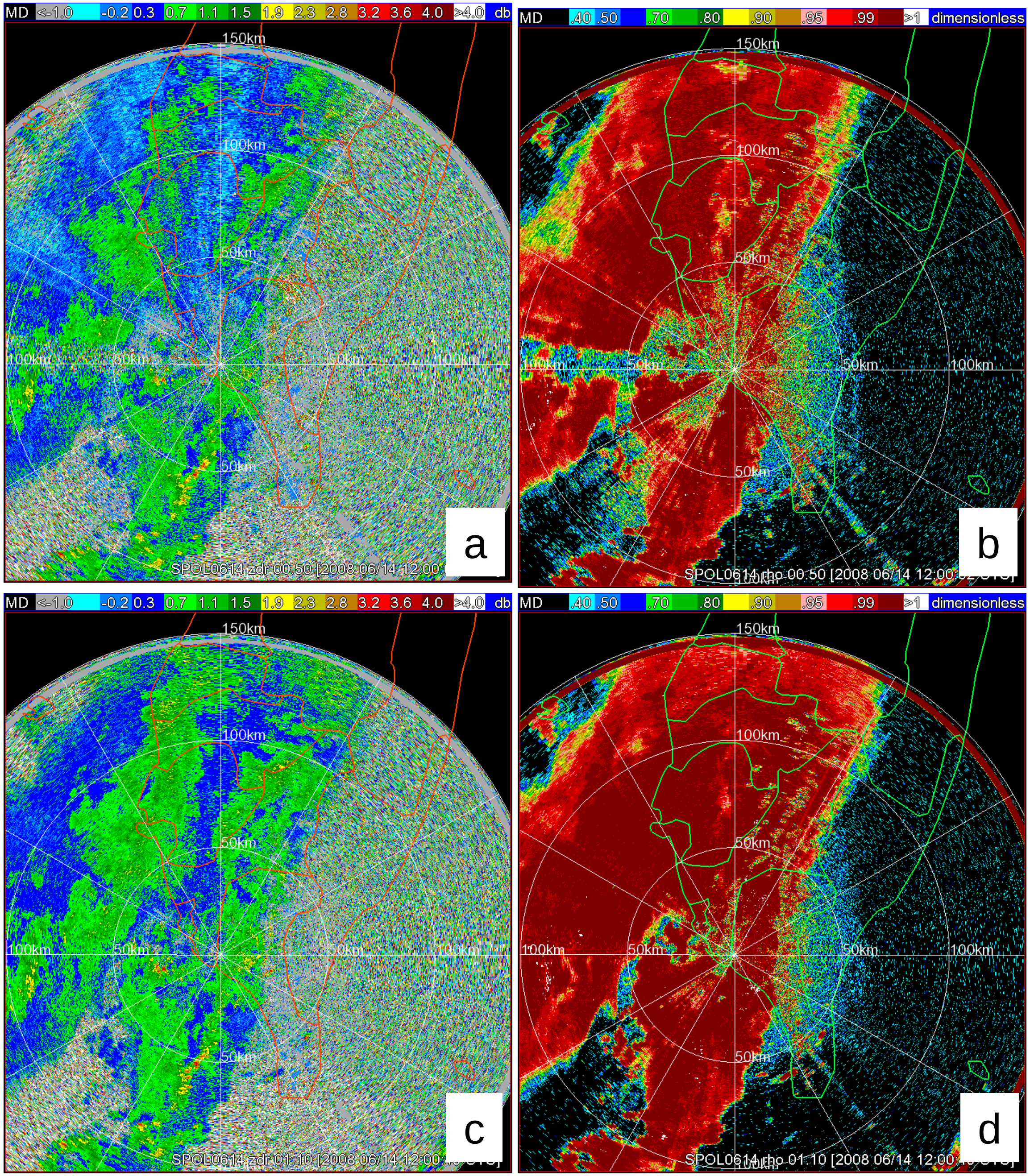
With ρ_{hv} > 0.8, r < 140 km







$\mathbf{Z_{dr}}$ $\rho_{\mathbf{hv}}$



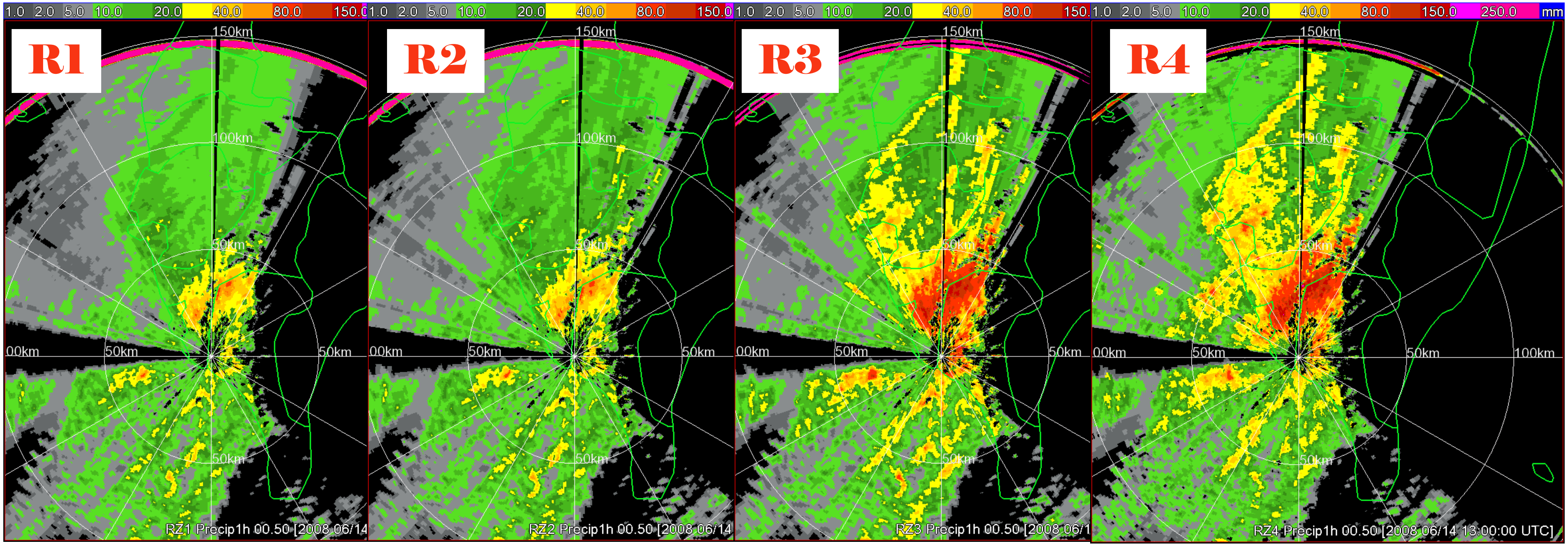
Z_{DR} and ρ_{hv} are lower at lower elevation

At 0.5^{o}

At 1.1^{o}

3 hour rain totals computed using 4 algorithms at elevation 0.5

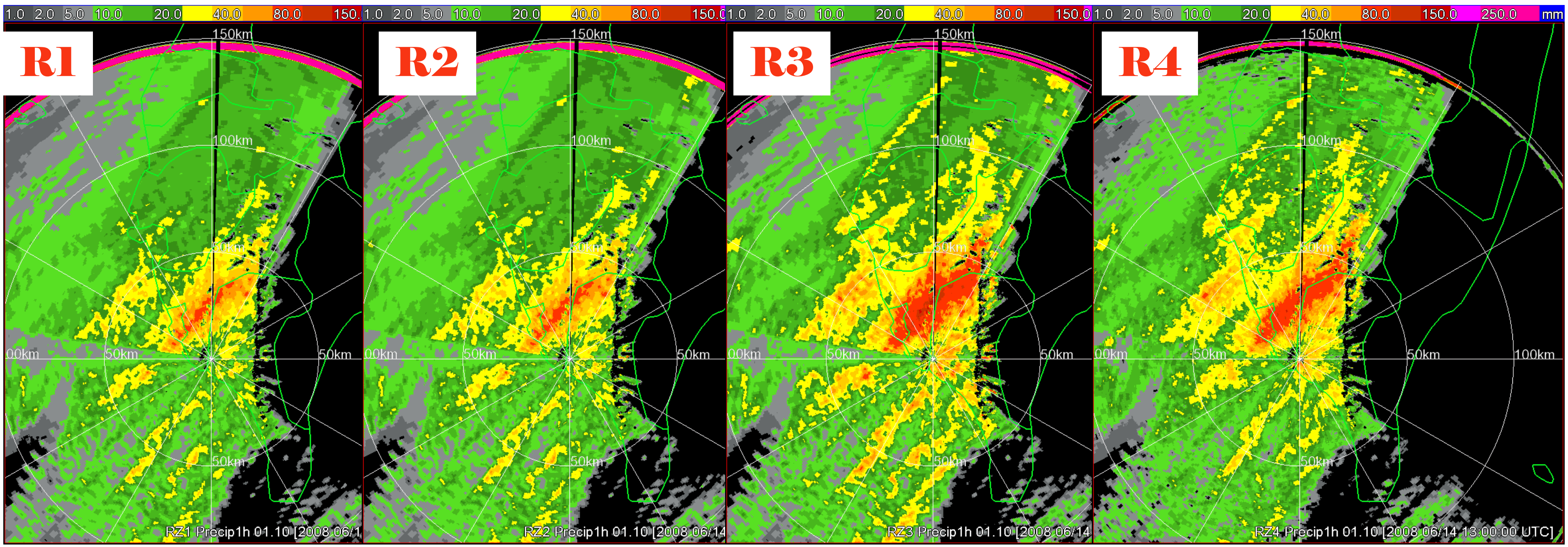
2008/06/14, 10 – 13 UTC



R_1 and R_2 – conventional relations, R_3 and R_4 – polarimetric relations

3 hour rain totals computed using 4 algorithms at elevation 1.1

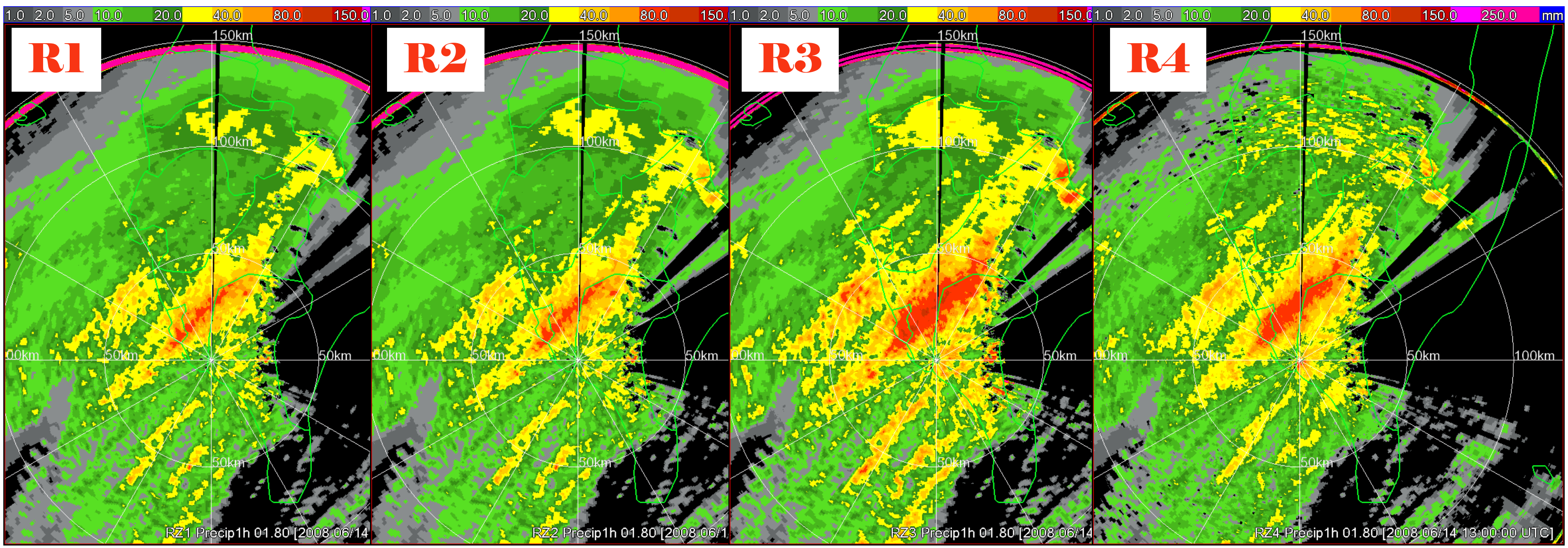
2008/06/14, 10 – 13 UTC



R_1 and R_2 – conventional relations, R_3 and R_4 – polarimetric relations

3 hour rain totals computed using 4 algorithms at elevation 1.8

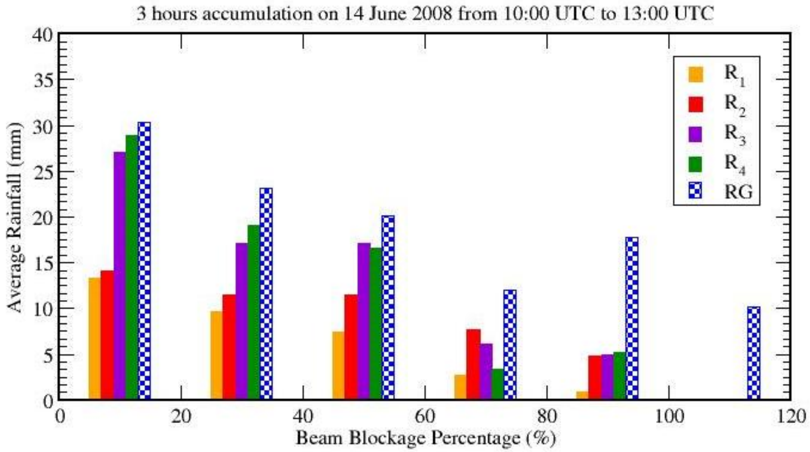
2008/06/14, 10 – 13 UTC



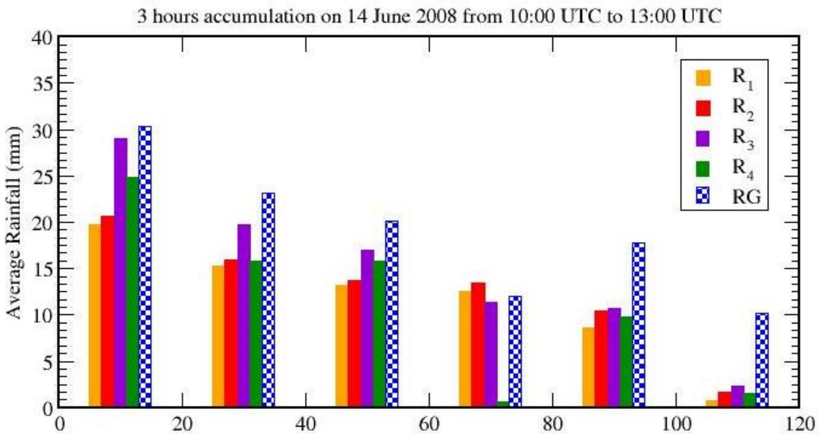
R_1 and R_2 – conventional relations, R_3 and R_4 – polarimetric relations

Average rain 3 hr total (mm)

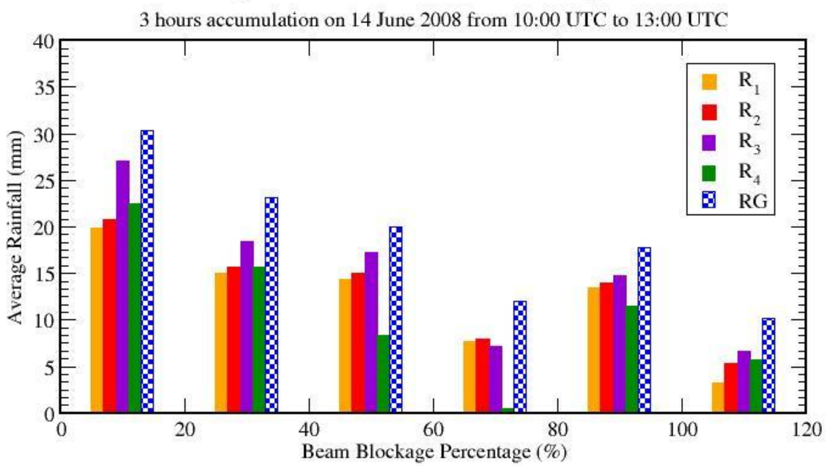
2008/06/14 10 – 13 UTC



El = 0.5



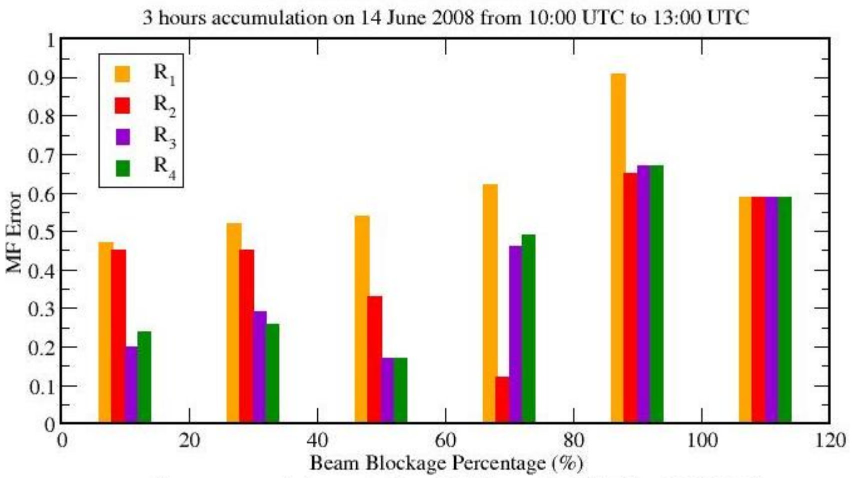
El = 1.1



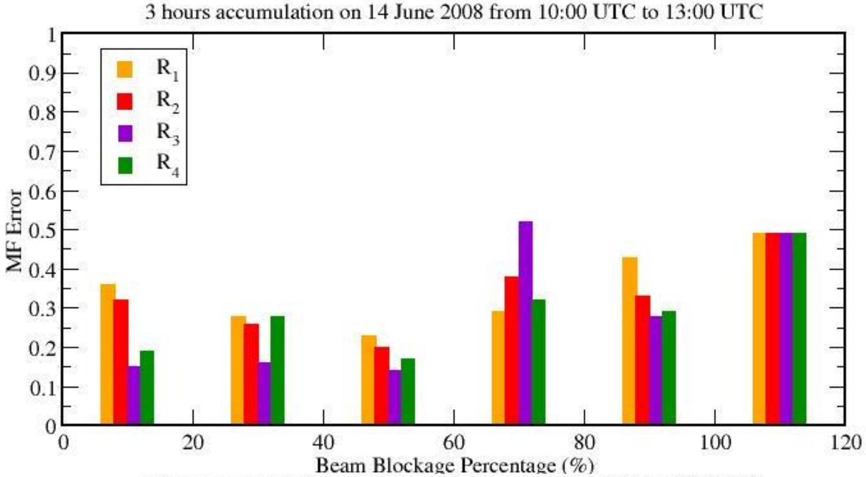
El = 1.8

Median fractional error

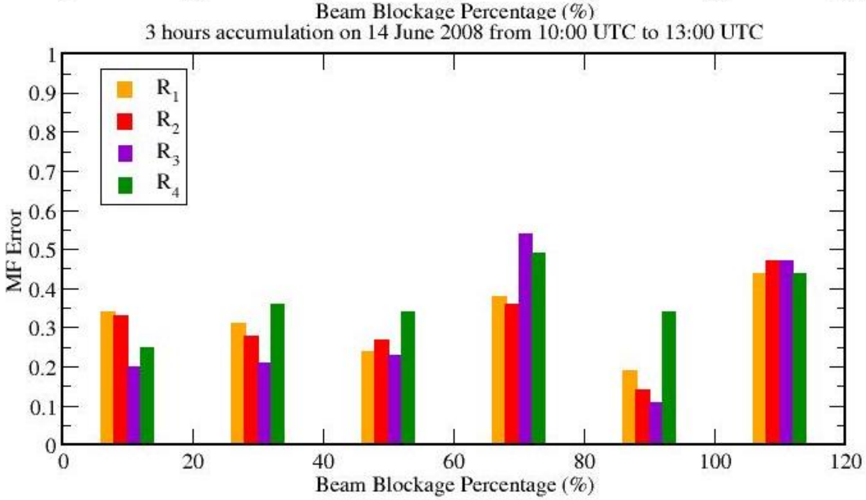
2008/06/14 10 – 13 UTC



El = 0.5



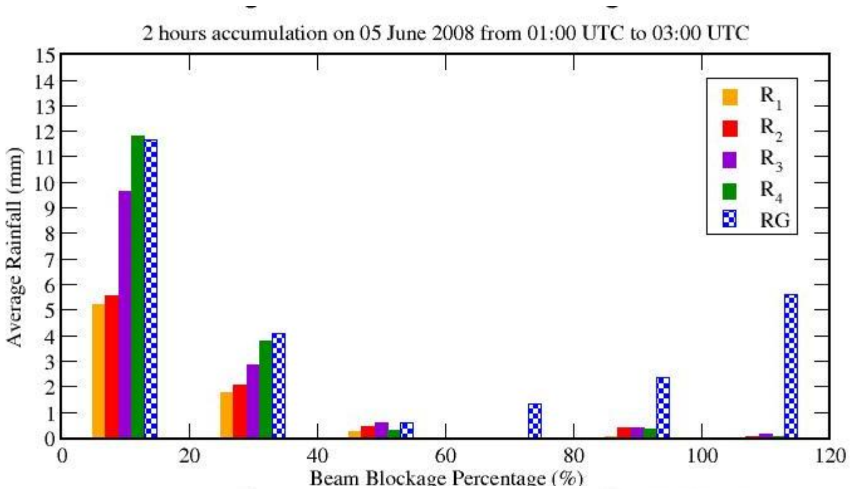
El = 1.1



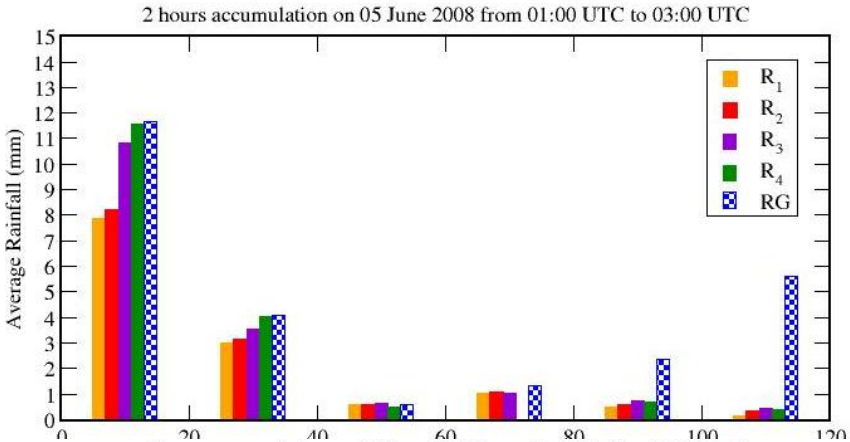
El = 1.8

Average rain 3 hr total (mm)

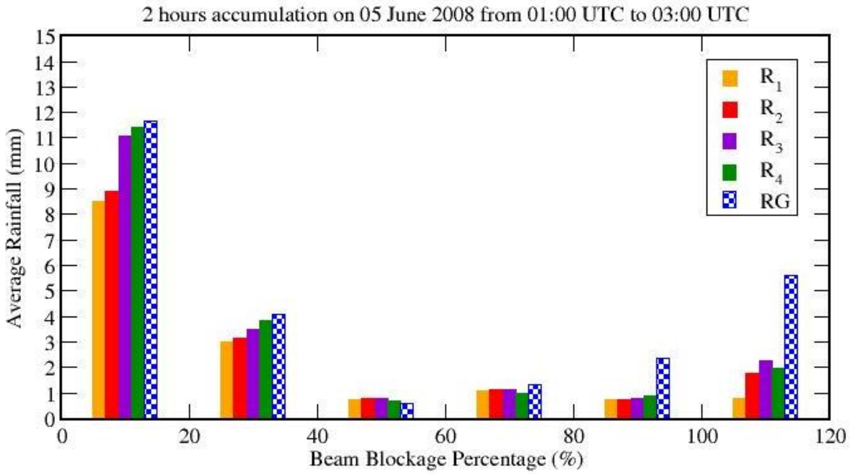
2008/06/05 1 – 3 UTC



El = 0.5



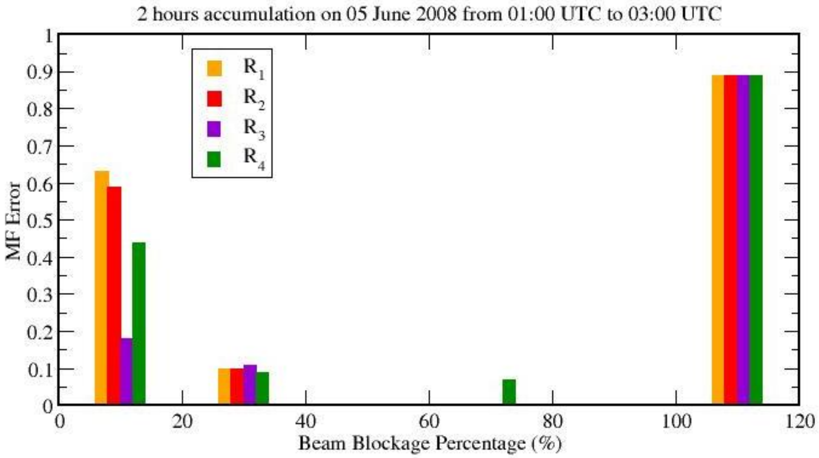
El = 1.1



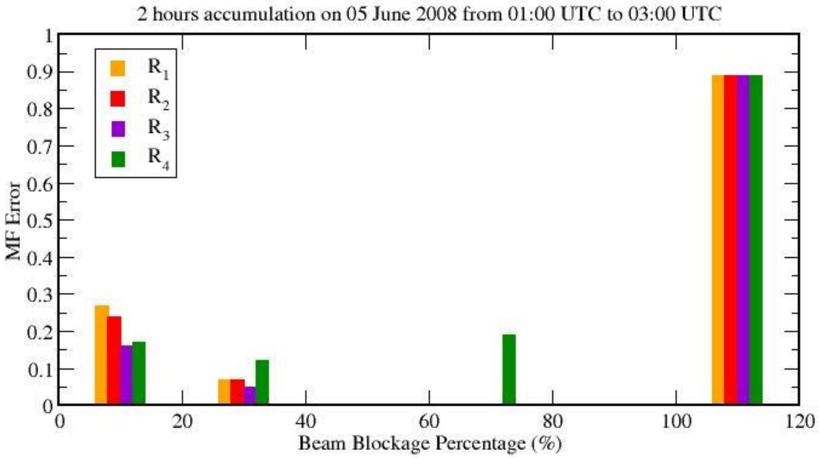
El = 1.8

Median fractional error

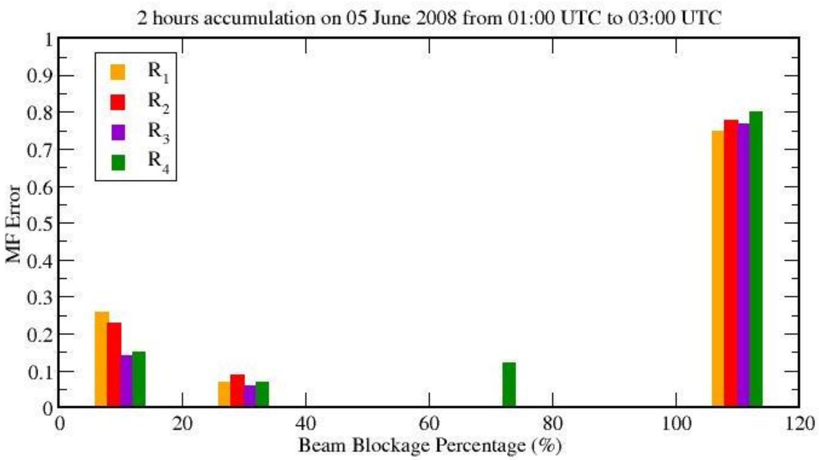
2008/06/05 1 – 3 UTC



El = 0.5



El = 1.1



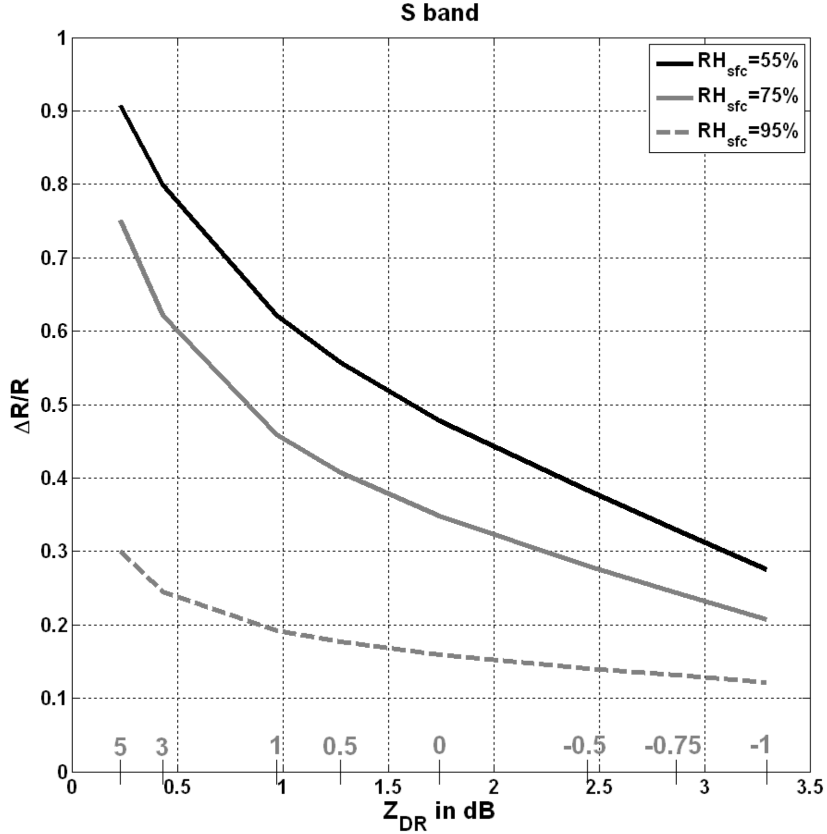
El = 1.8

Retrieval of vertical profile of rain rate using microphysical models

Impact of evaporation

R < 5 mm/h

Relative change in rain rate due to evaporation as a function of Z_{DR} aloft and surface relative humidity



Input parameters:

Z and Z_{DR} at lowest unobscured height H and relative humidity RH

Methodology:

1. Rain rate R aloft is estimated using the $R(Z,Z_{DR})$ relation
2. Rain rate at the surface is estimated using lookup tables computed for different combinations of Z_{DR}, RH, and H

M. Kumjian and **A. Ryzhkov**, 2009: The impact of evaporation on polarimetric characteristics of rain. Theoretical model and practical implications. Submitted to *Journal of Applied Meteorology.*

Summary of Taiwan tests

1. Polarimetric algorithms perform better than the conventional R(Z) (optimized for US) because they are less affected by DSD variability and ground clutter contamination

2. Geometrical correction of partial beam blockage based on DEM leads to incremental improvement

3. The performance of rainfall algorithms (especially of R(Z)) is worse at lowest elevation (even in lightly blocked areas) due to contamination from ground clutter

4. Statistically, the K_{DP} – based algorithm didn't show apparent improvement compared to $R(Z,Z_{DR})$ at S band for examined rain events

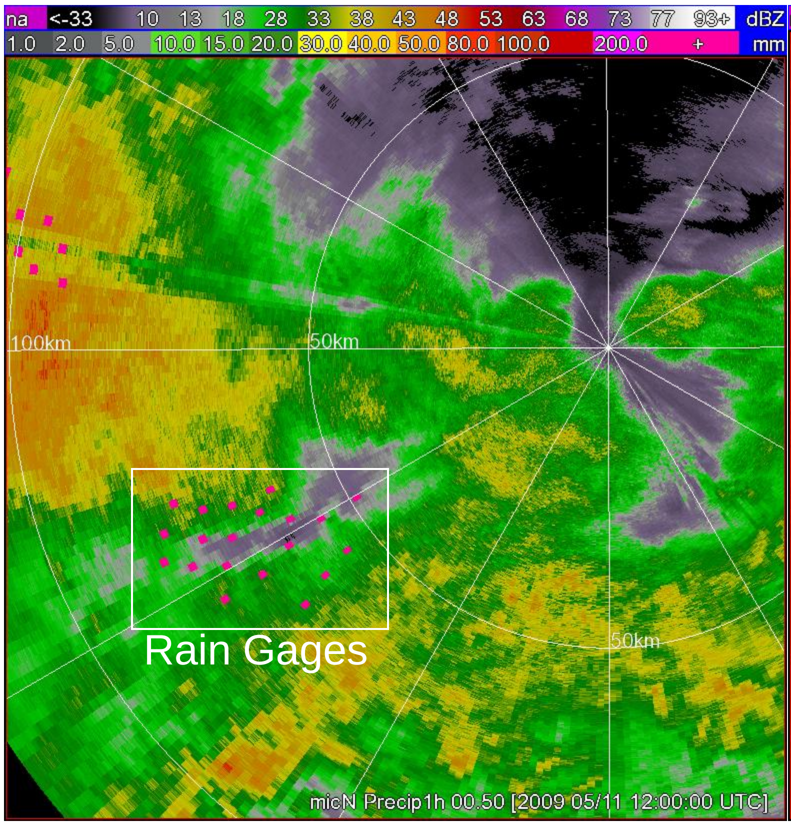
Suggestions for decision-makers

1. The Taiwan dataset is too small for comprehensive validation of the procedure for rainfall estimation in the presence of beam blockage, hence, no decision on operational implementation of such a procedure can be made at the moment
2. Nevertheless, one of the modules of this procedure, namely, geometrical correction of radar reflectivity factor based on DEM can be recommended for operational implementation
3. More validation studies are required in the complex terrain areas containing dense and well calibrated raingage networks. Possible venues are:

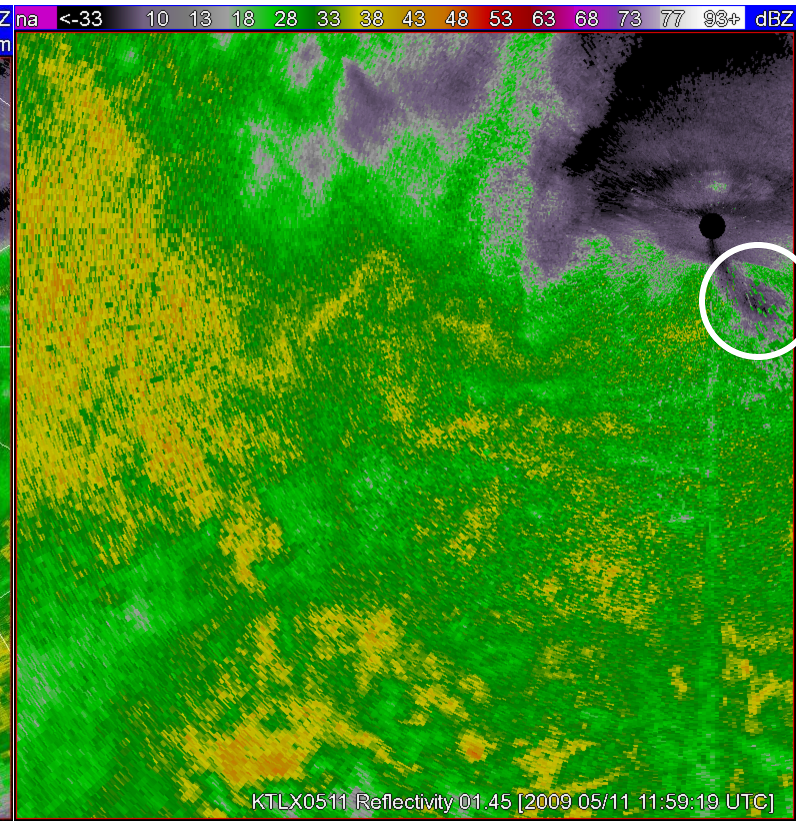
- utilization of mobile X-band polarimetric radars in Western US (HMT)
- utilization of operational C-band polarimetric radars and gage network in Taiwan via collaboration between NSSL and TWB

III. Polarimetric rainfall estimation in the areas affected by ground clutter filtering

Effect of ground clutter filtering in the OU PRIME field of radar reflectivity



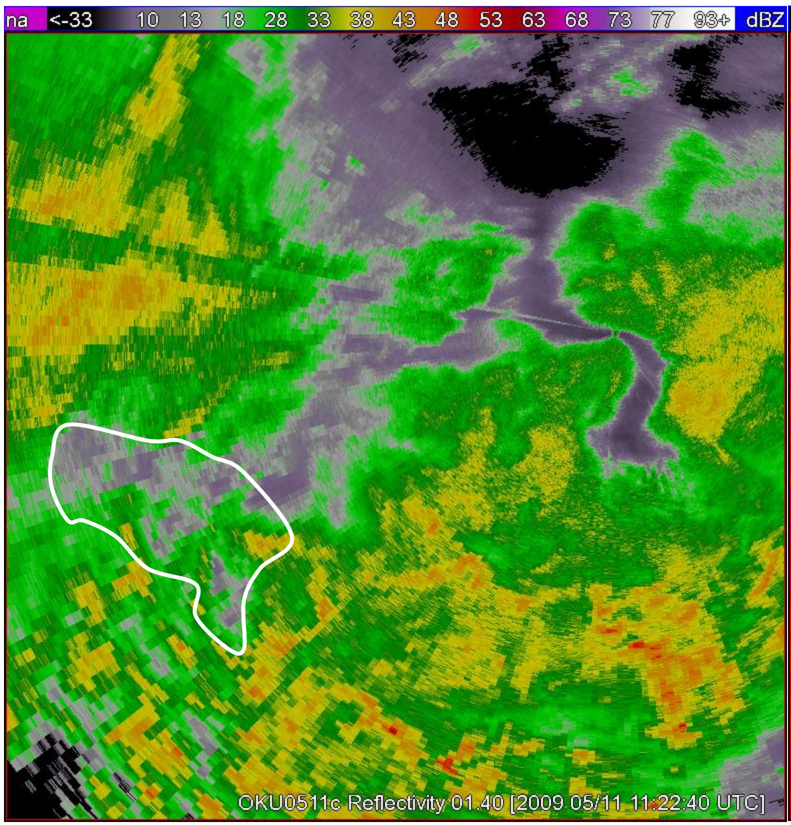
OU’



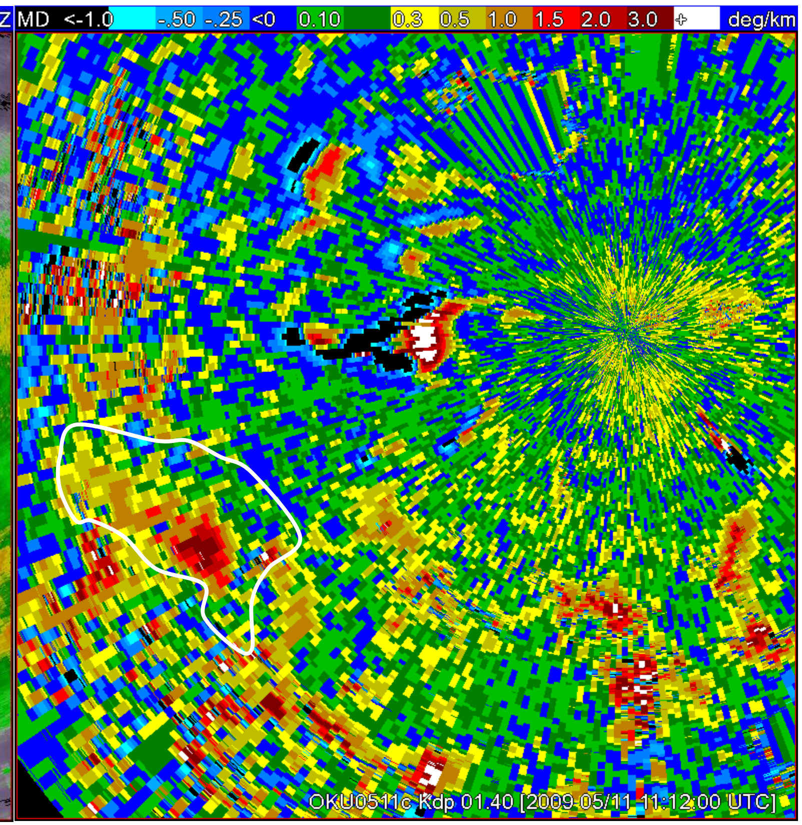
KTLX

K_{DP} is not affected by ground clutter filtering and exhibits maximum where Z is reduced due to application of clutter filter at V ≈ 0 m/s

Z

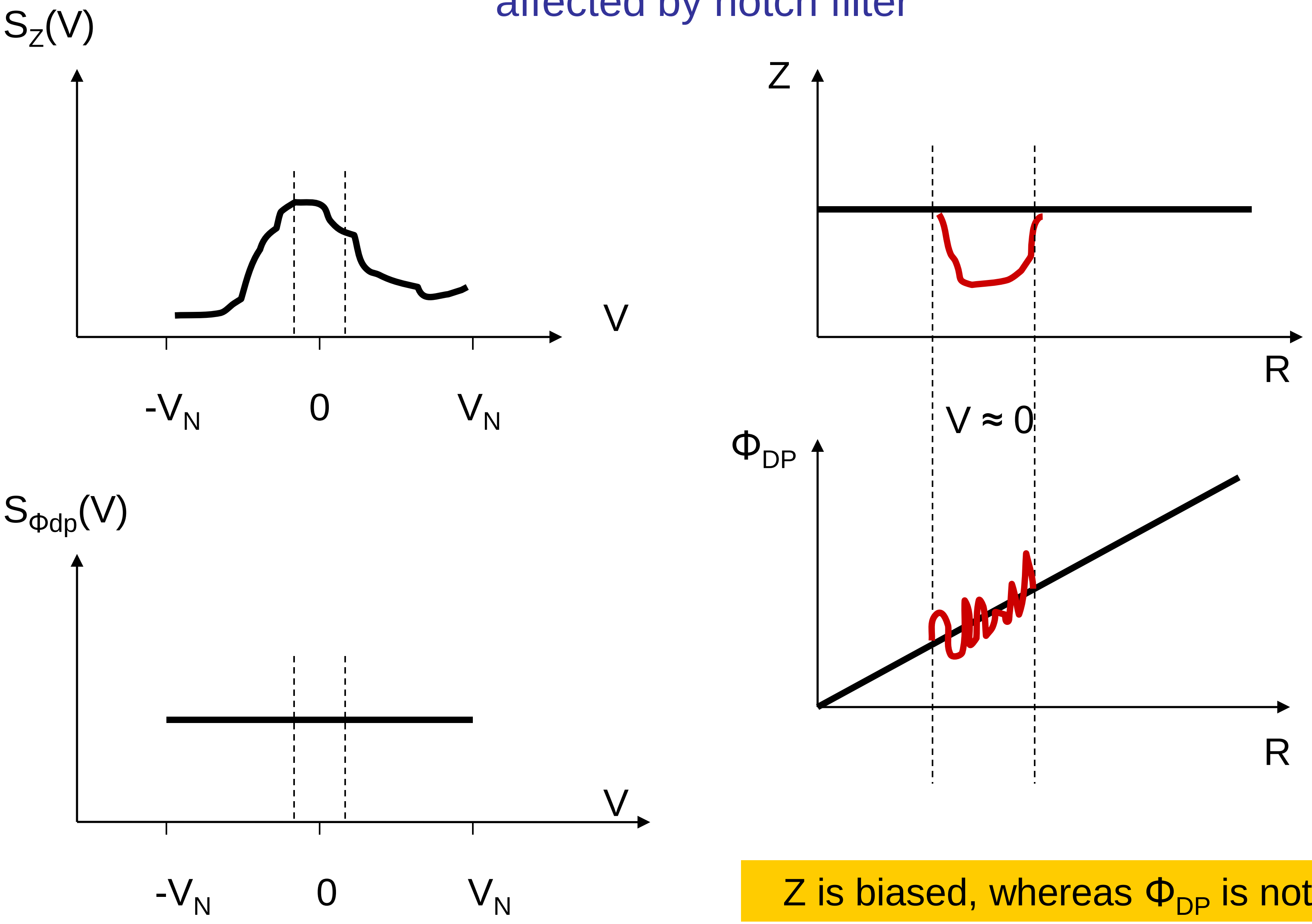


K_{DP}



Elev. Angle=1.4°

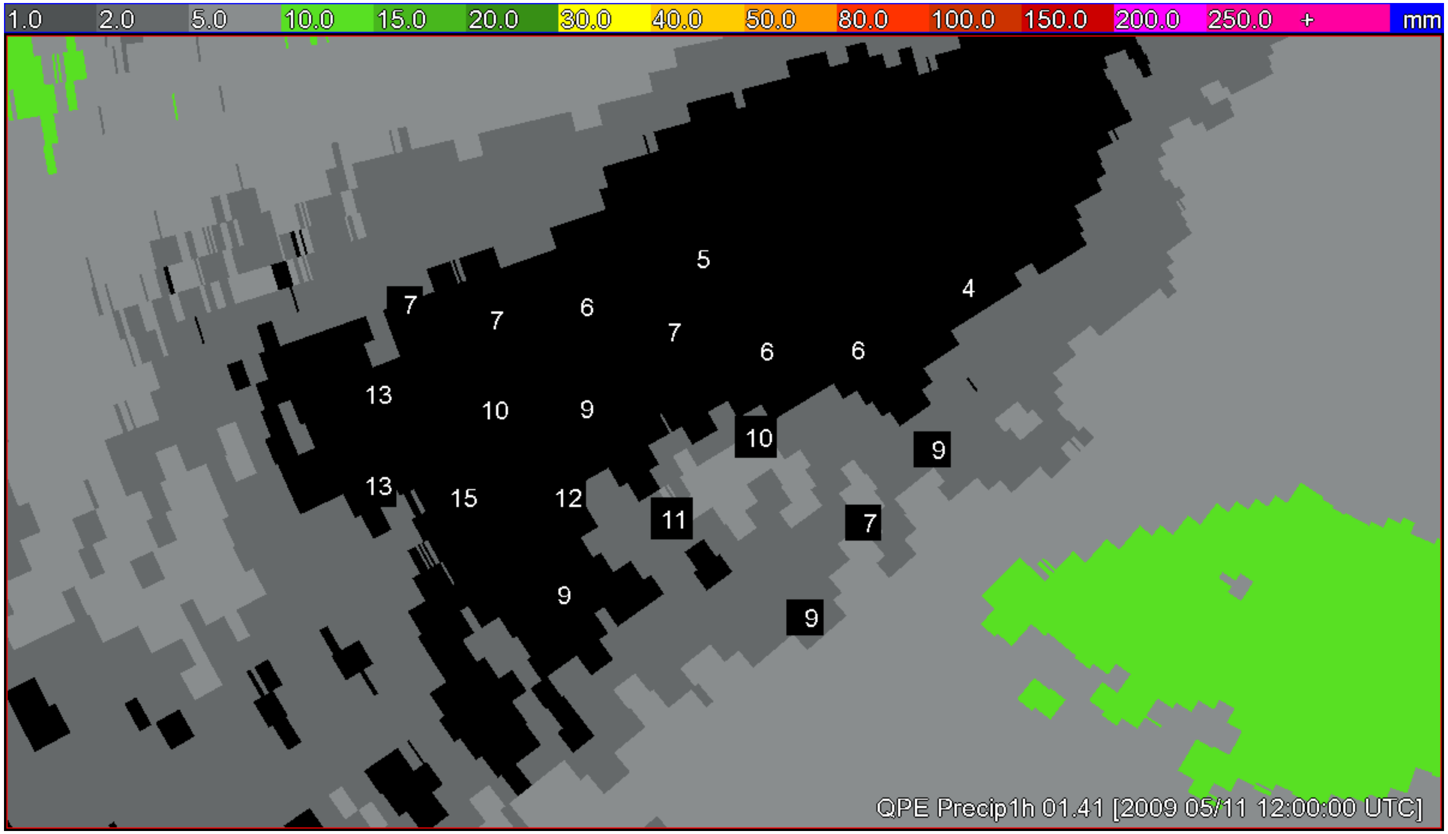
Radar reflectivity and differential phase are differently affected by notch filter



Z is biased, whereas Φ_{DP} is not

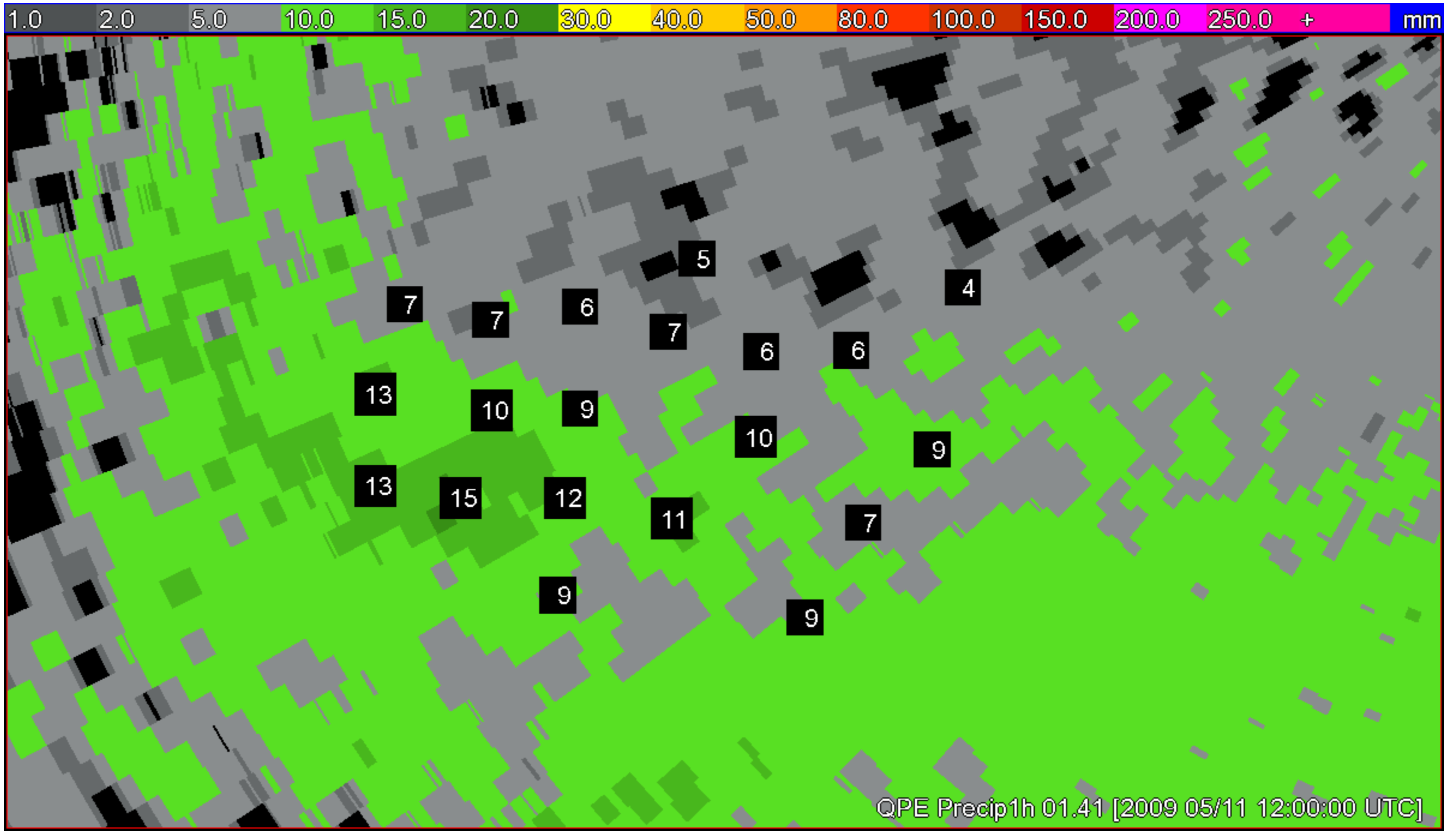
R(Z) vs rain gages

20090511-12:00 UTC



$R(K_{DP})$ vs rain gages

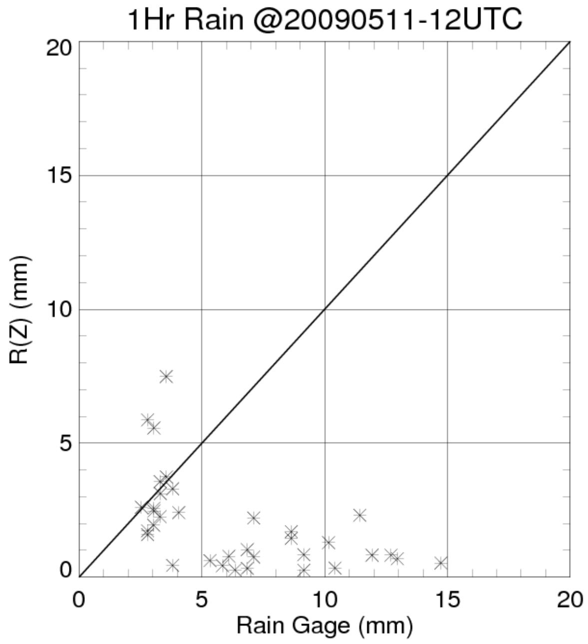
20090511-12:00 UTC



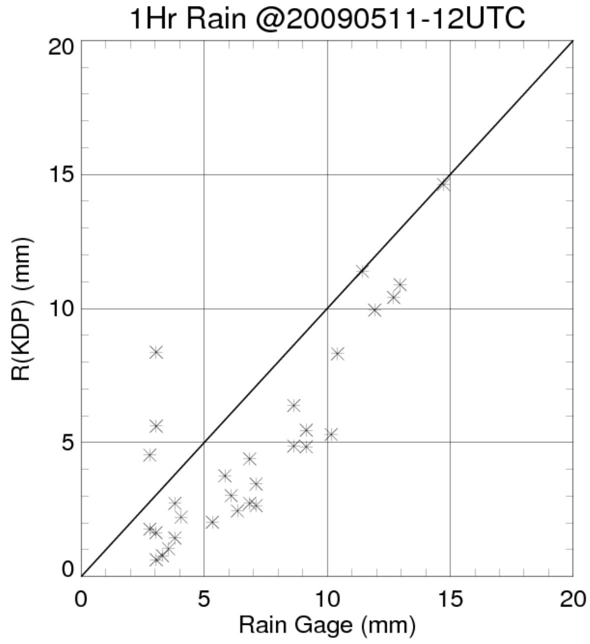
Hourly radar totals versus gage totals for R(Z) and R(K_{DP})

2009/05 11-12:00 UTC

R(Z)

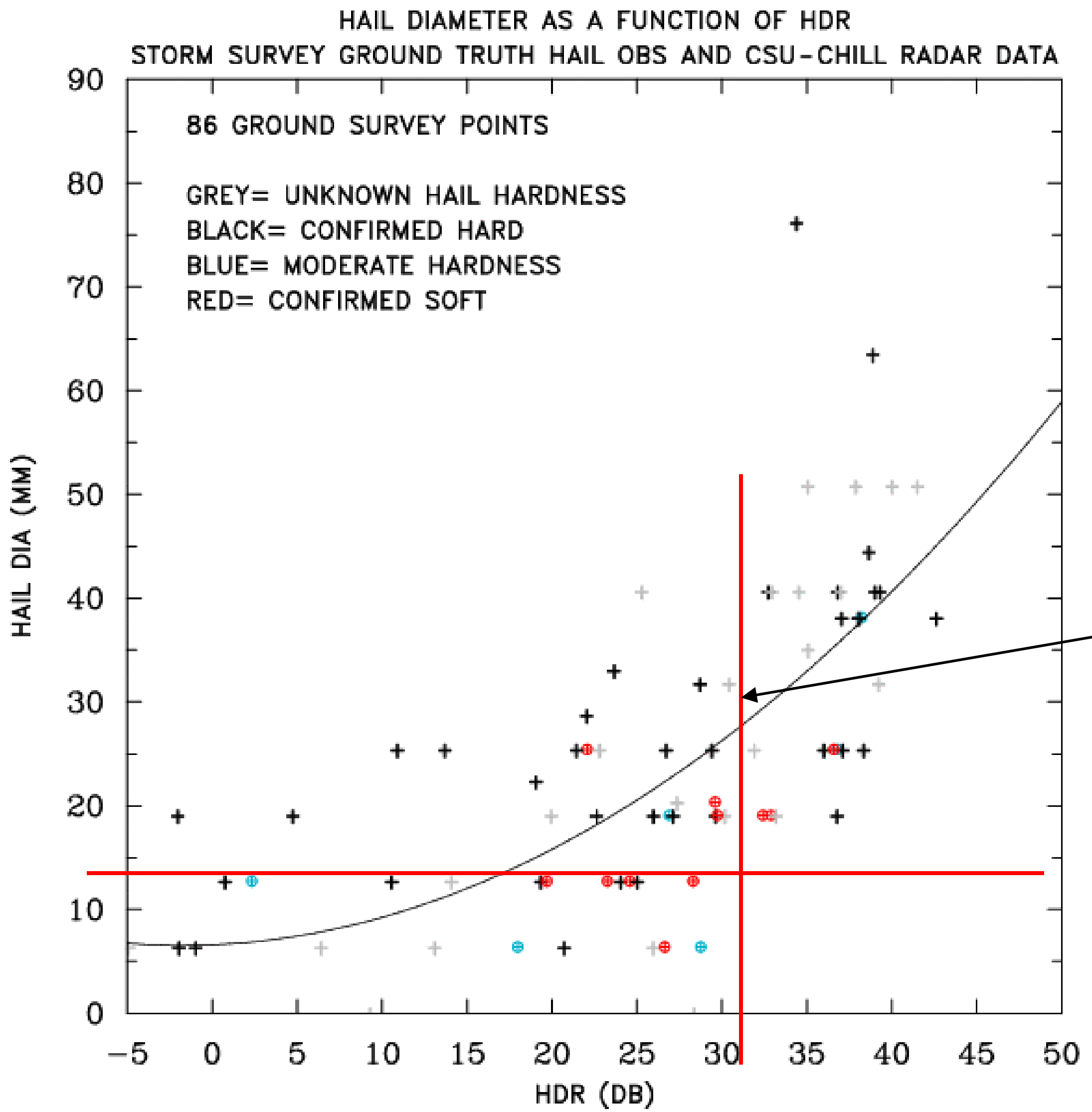


R(K_{DP})



Elev=1.41°

Modification of HCA to discriminate between small and large hail

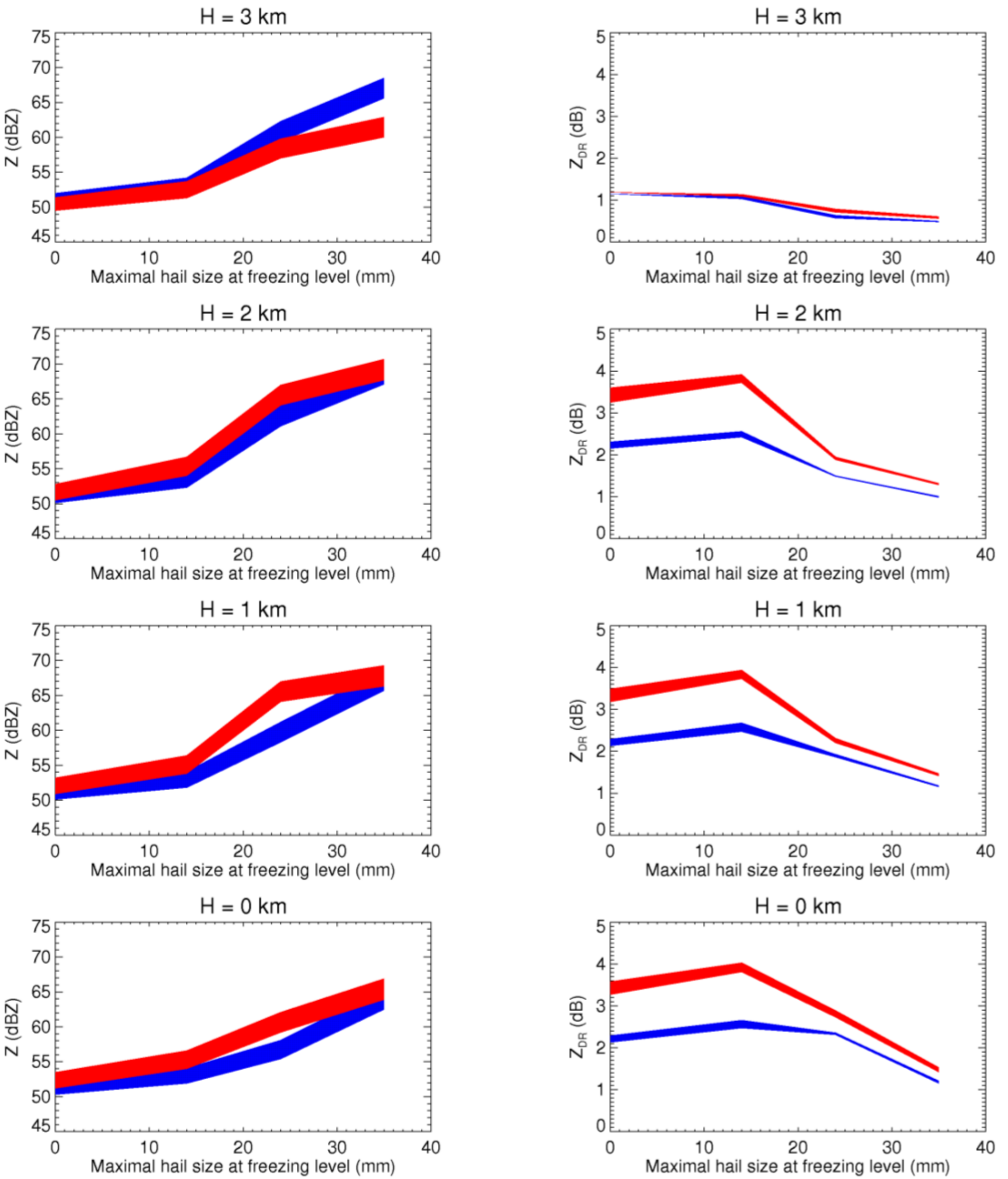


Hdr = Z – f(Zdr)

If Hdr > 30 dB
Hail size > 20 mm
this gave best detection of verified structural damage

Dupue et al 2006
CSU

Dependencies of Z and Z_{DR} on maximal hail size at the freezing level for various parameters of size distribution of ice aloft



S band

C band

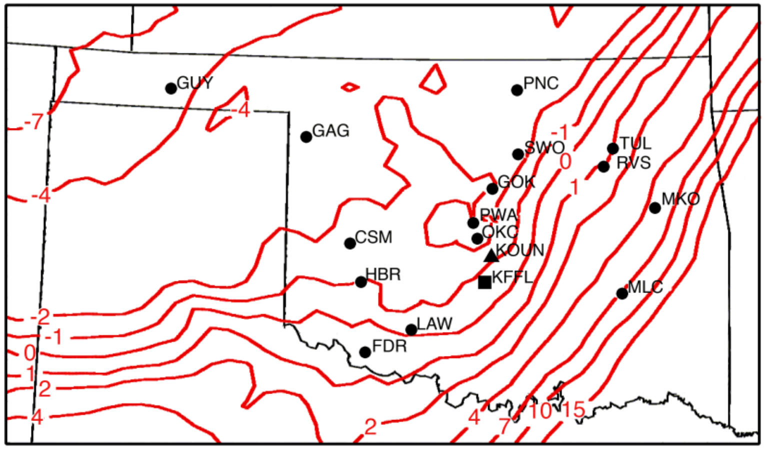
These dependencies are strong functions of height

Z(C) can be higher or lower than Z(S) depending on hail size and height

$$Z_{DR}(C) > Z_{DR}(S)$$

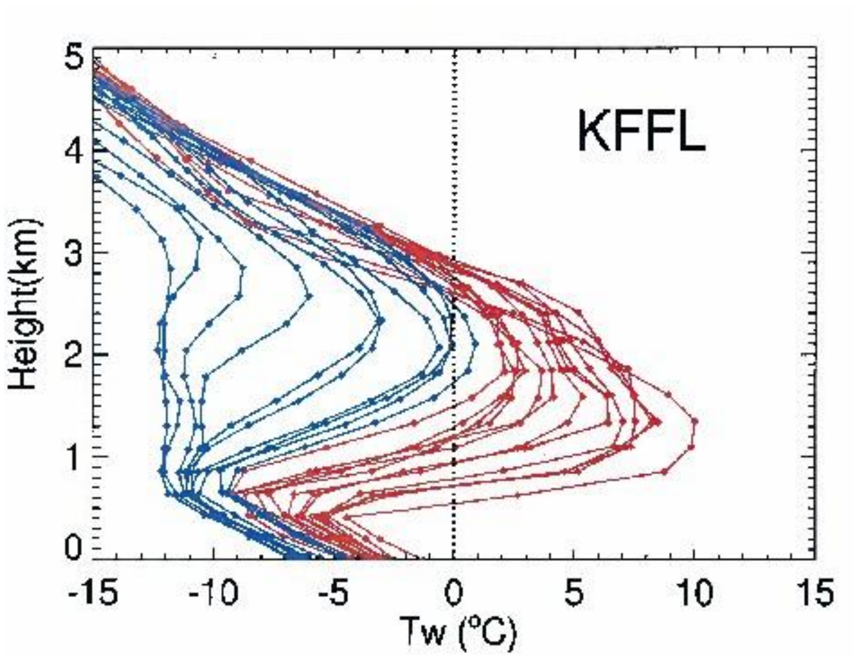
The presence of smaller hail tends to increase Z_{DR} at both radar wavelengths

Developing HCA for transitional winter weather



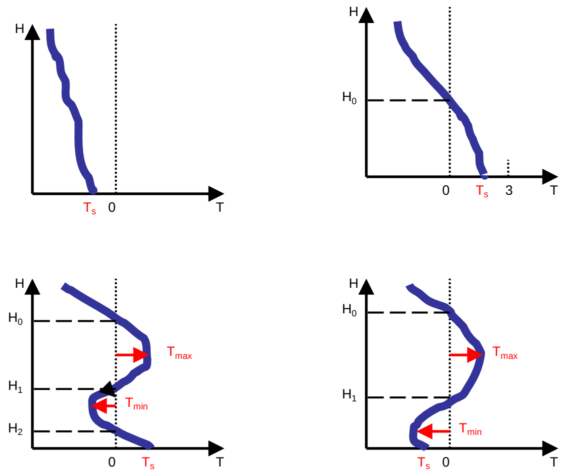
11/30/2006

Surface isotherms during passage of cold front



Evolution of the vertical profile of wet bulb temperature

“Background” hydrometeor classification using vertical profile of wet bulb temperature



Four types of vertical profiles of wet bulb temperature

List of classes

HR – heavy rain

RA – light / moderate rain

WS – wet snow

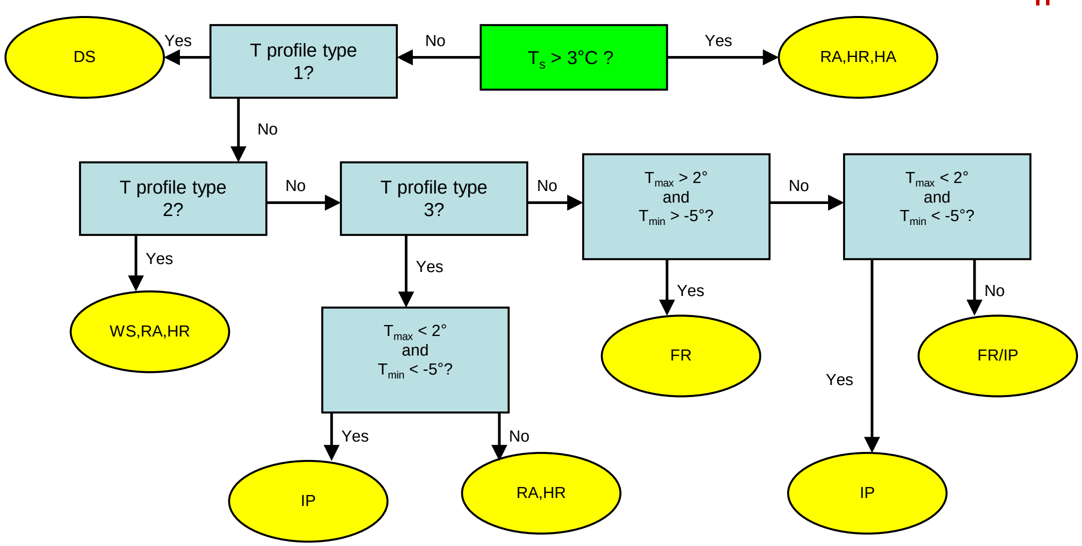
DS – dry snow

CR – crystals

FR – freezing rain

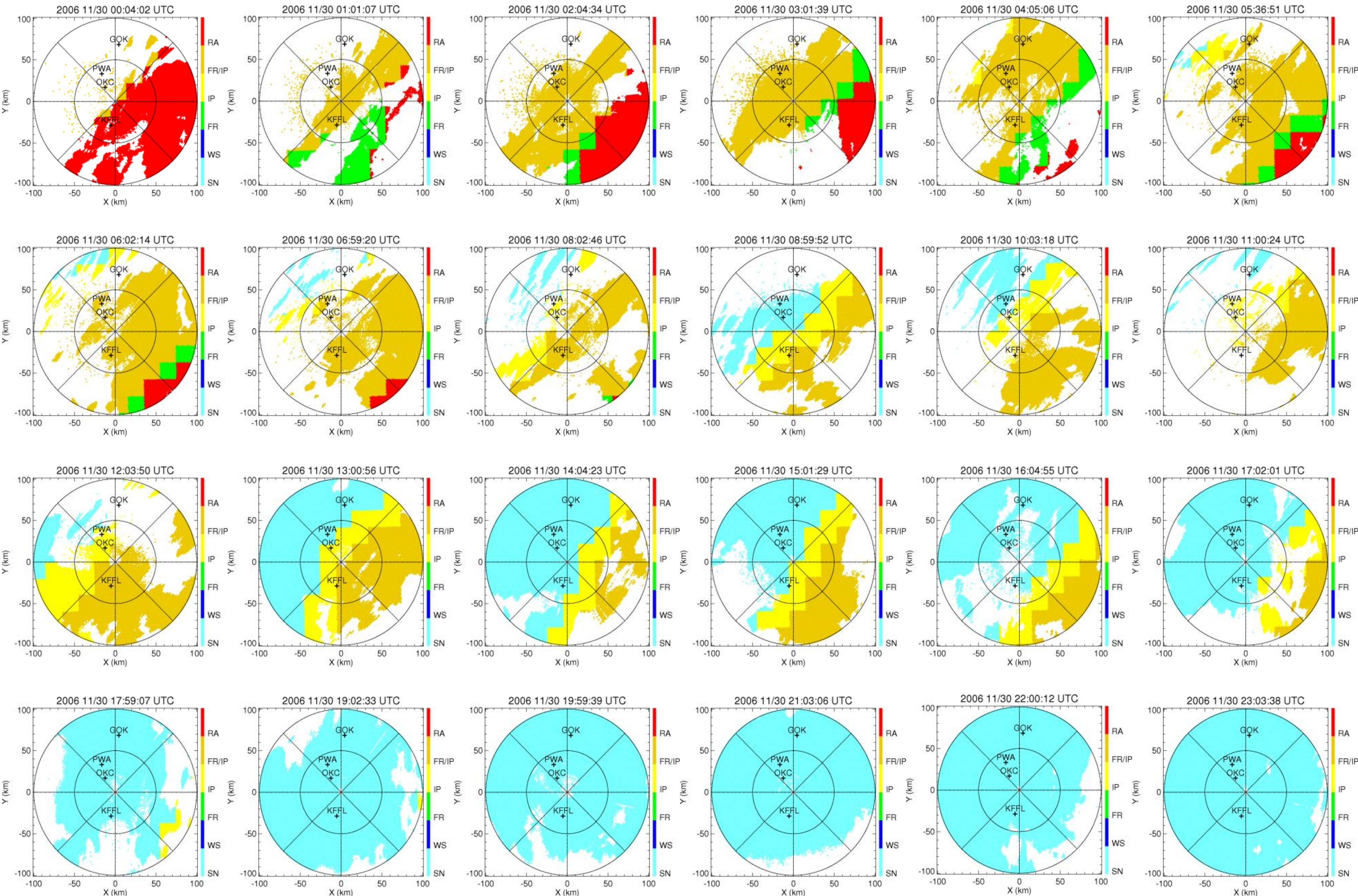
FR/IP – freezing rain / ice pellets

IP – ice pellets



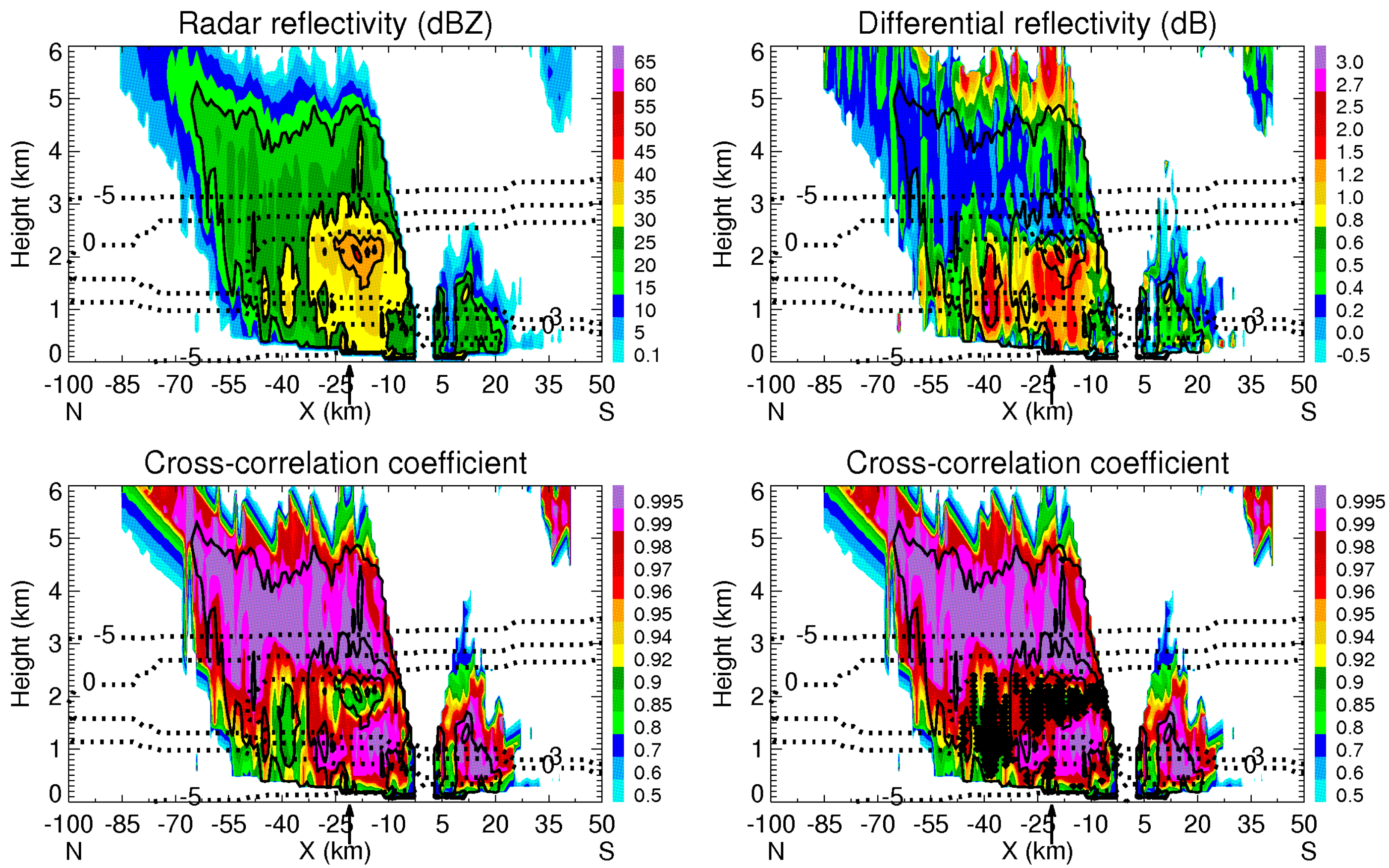
Logistic for determination of precipitation types

Background classification



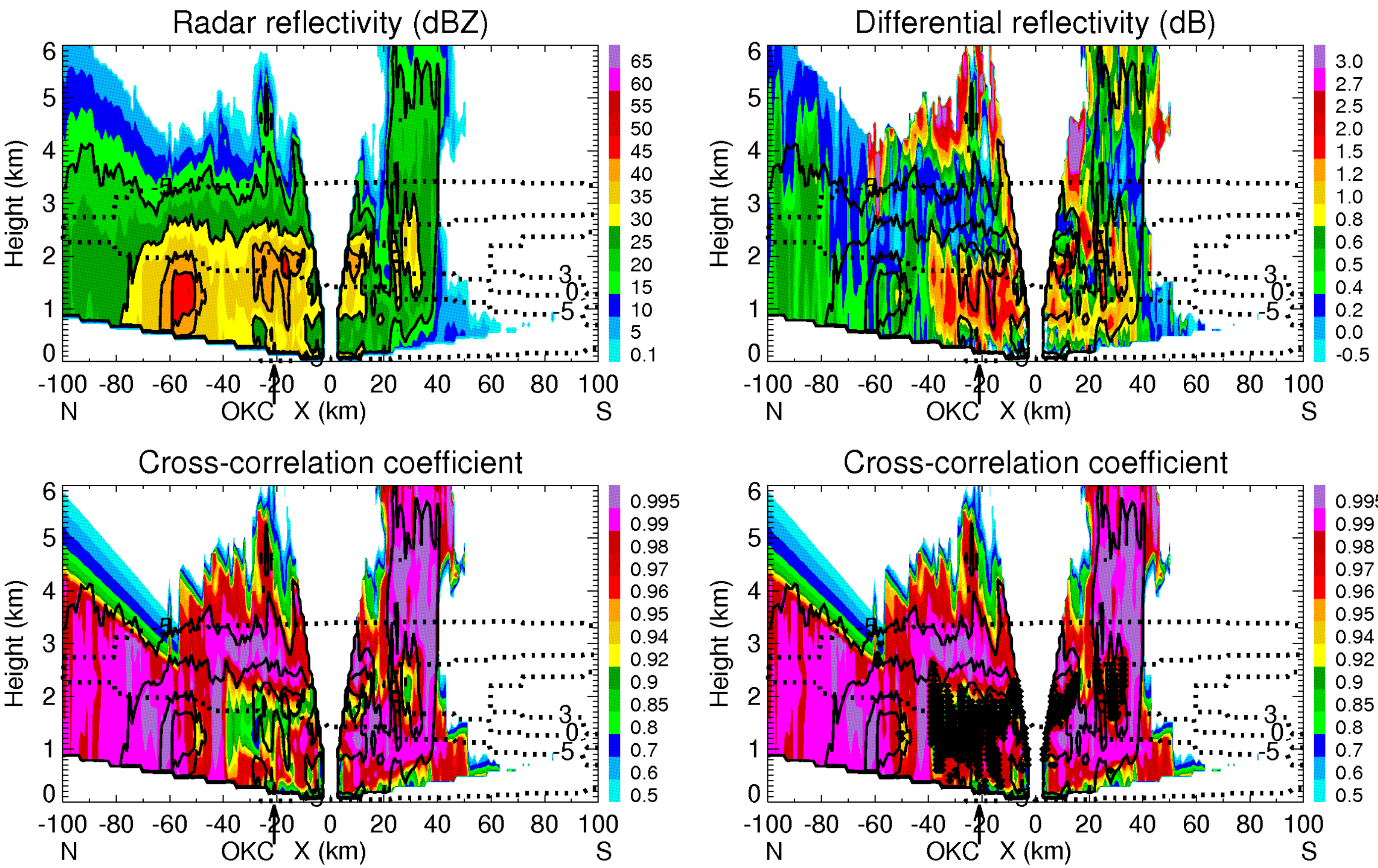
Example 1

Radar and RUC model outputs are consistent

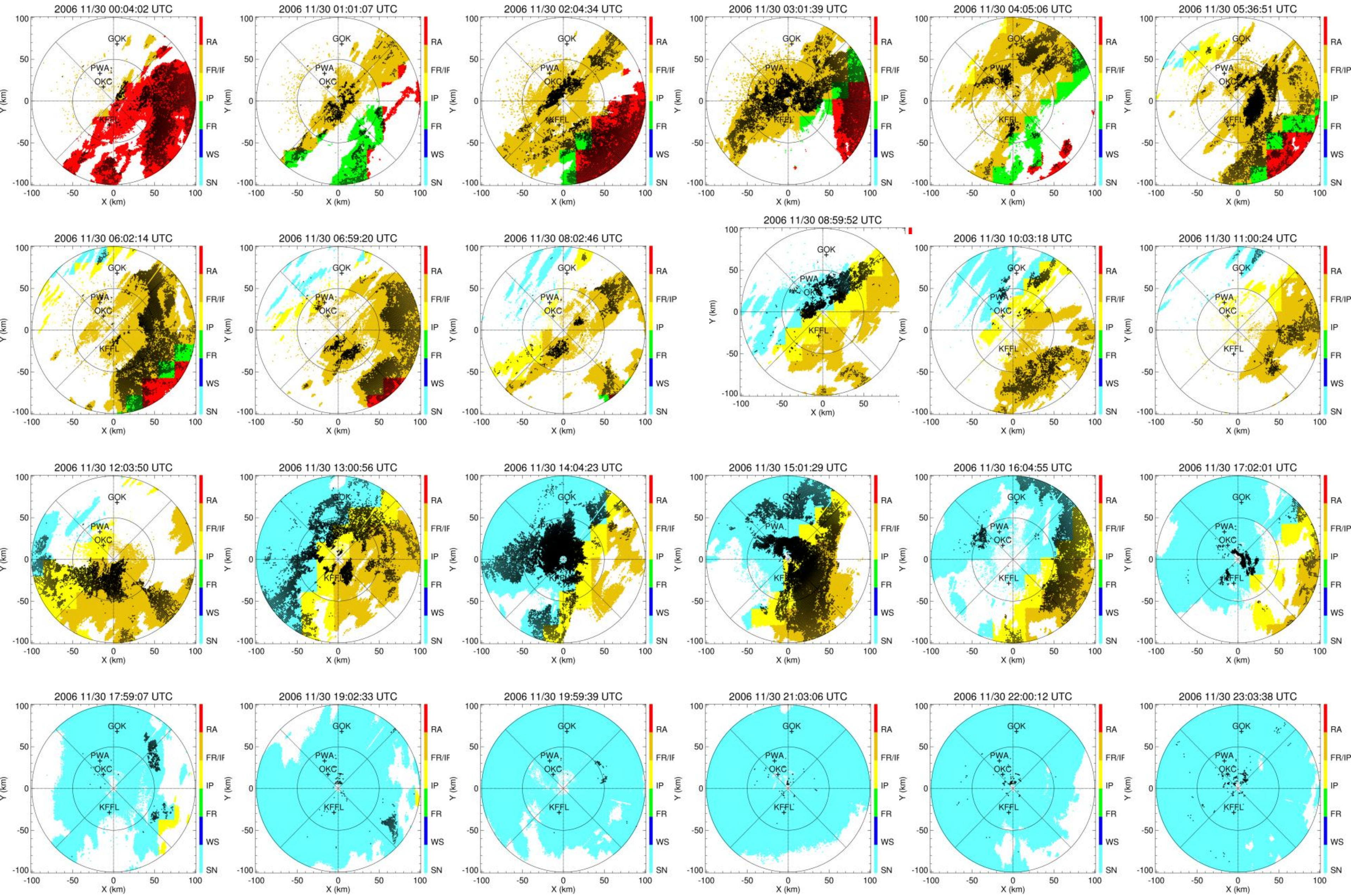


Example 2

Radar and RUC model outputs are inconsistent



Background classification with radar signatures of the melting layer overlaid



Ground validation of winter HCA