Nonuniform beam filling, attenuation, and their effects on dualpol data

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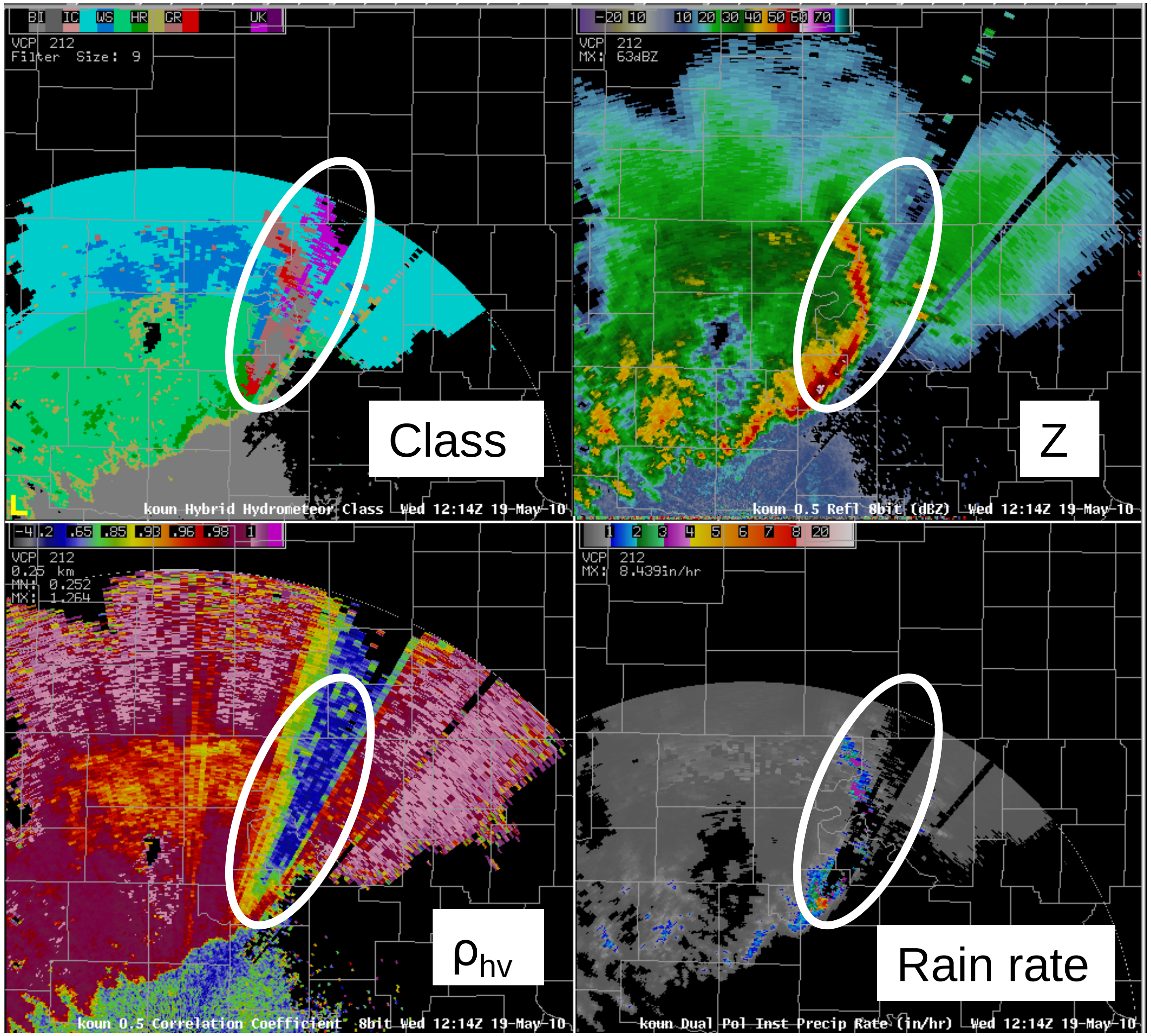
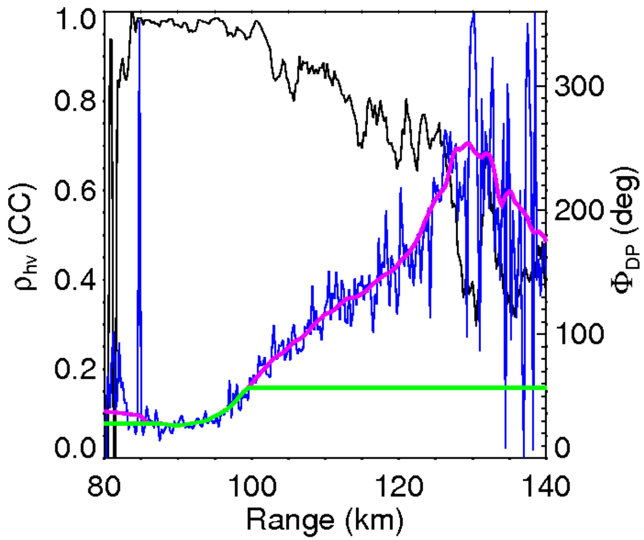
Squall line on May 19, 2010. What went wrong?

1214 Z

El = 0.5



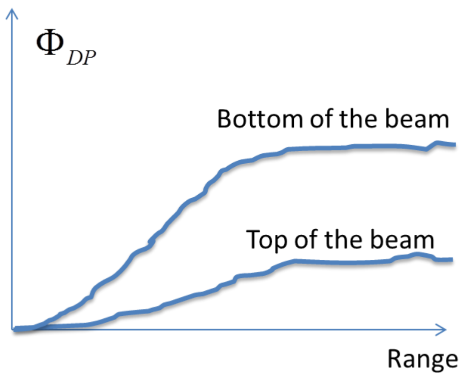
Anatomy of failure

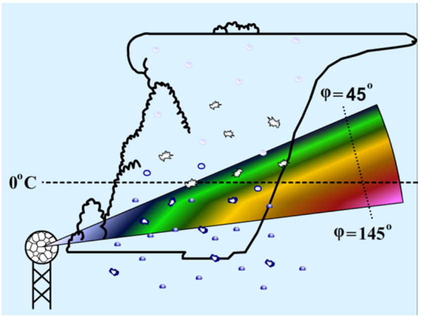


1. If CC drops below 0.9, then radar echo is considered nonmeteorological
2. Further differential phase processing along the beam stops after CC drops below 0.9
3. Φdp is underestimated and both Z and Zdr are undercorrected for attenuation
4. Low CC and Zdr point to nonmeteorological scatterers in HCA although Z is high
5. Rain rate is set to zero because the echo is classified as nonmeteorological

Why does CC drop?

How gradient of differential phase affects the magnitude of cross-correlation coefficient





Cross-correlation coefficient definition

$$\rho_{hv} = \frac{\overline{h^* v}}{\left(\overline{|h|^2}\,\overline{|v|^2}\right)^{1/2}}$$

$$h = a_{h1} e^{j\varphi_{h1}} + a_{h2} e^{j\varphi_{h2}}$$

$$v = a_{v1} e^{j\varphi_{v1}} + a_{v2} e^{j\varphi_{v2}}$$

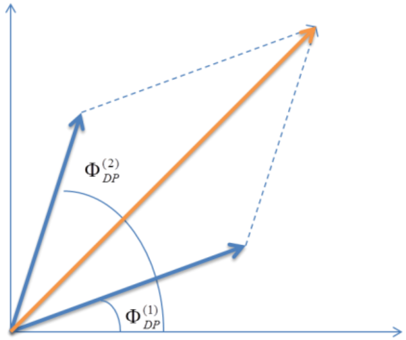
Only two spheroidal particles are in the radar resolution volume

$$\rho_{hv} \approx \frac{a_{h1}a_{v1}e^{j(\varphi_{v1}-\varphi_{h1})} + a_{h2}a_{v2}e^{j(\varphi_{v2}-\varphi_{h2})}}{\left[(a_{h1}^2 + a_{h2}^2)(a_{v1}^2 + a_{v2}^2)\right]^{1/2}} = \frac{a_{h1}a_{v1}e^{j\Phi_{DP}^{(1)}} + a_{h2}a_{v2}e^{j\Phi_{DP}^{(2)}}}{\left[(a_{h1}^2 + a_{h2}^2)(a_{v1}^2 + a_{v2}^2)\right]^{1/2}}$$

Two identical spherical raindrops

$$a_{h1} = a_{v1} = a_{h2} = a_{v2} = a$$

$$|\rho_{hv}| = \frac{1}{2} \left| e^{j\Phi_{DP}^{(1)}} + e^{j\Phi_{DP}^{(2)}} \right|$$



More rigorous analysis (Ryzhkov 2007)

$$\frac{\rho_{hv}^{(m)}}{\rho_{hv}} = \xi = \exp\left\{-1.37\,10^{-5}\,\Omega^2\left[\left(\frac{d\Phi_{DP}}{d\theta}\right)^2 + \left(\frac{d\Phi_{DP}}{d\varphi}\right)^2\right]\right\}$$

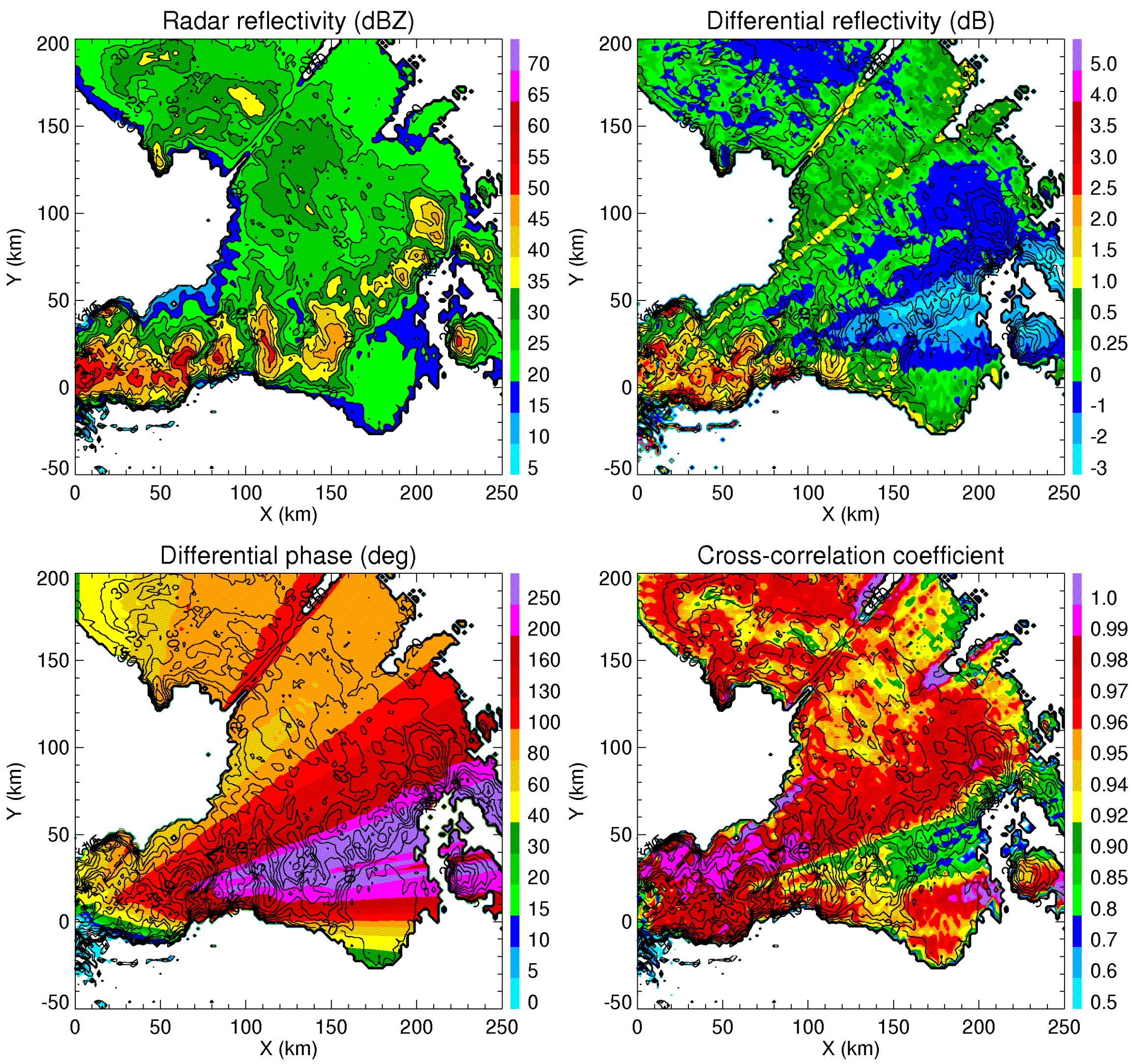
ρ_{hv} - intrinsic CC

$\rho_{hv}^{(m)}$ - measured CC

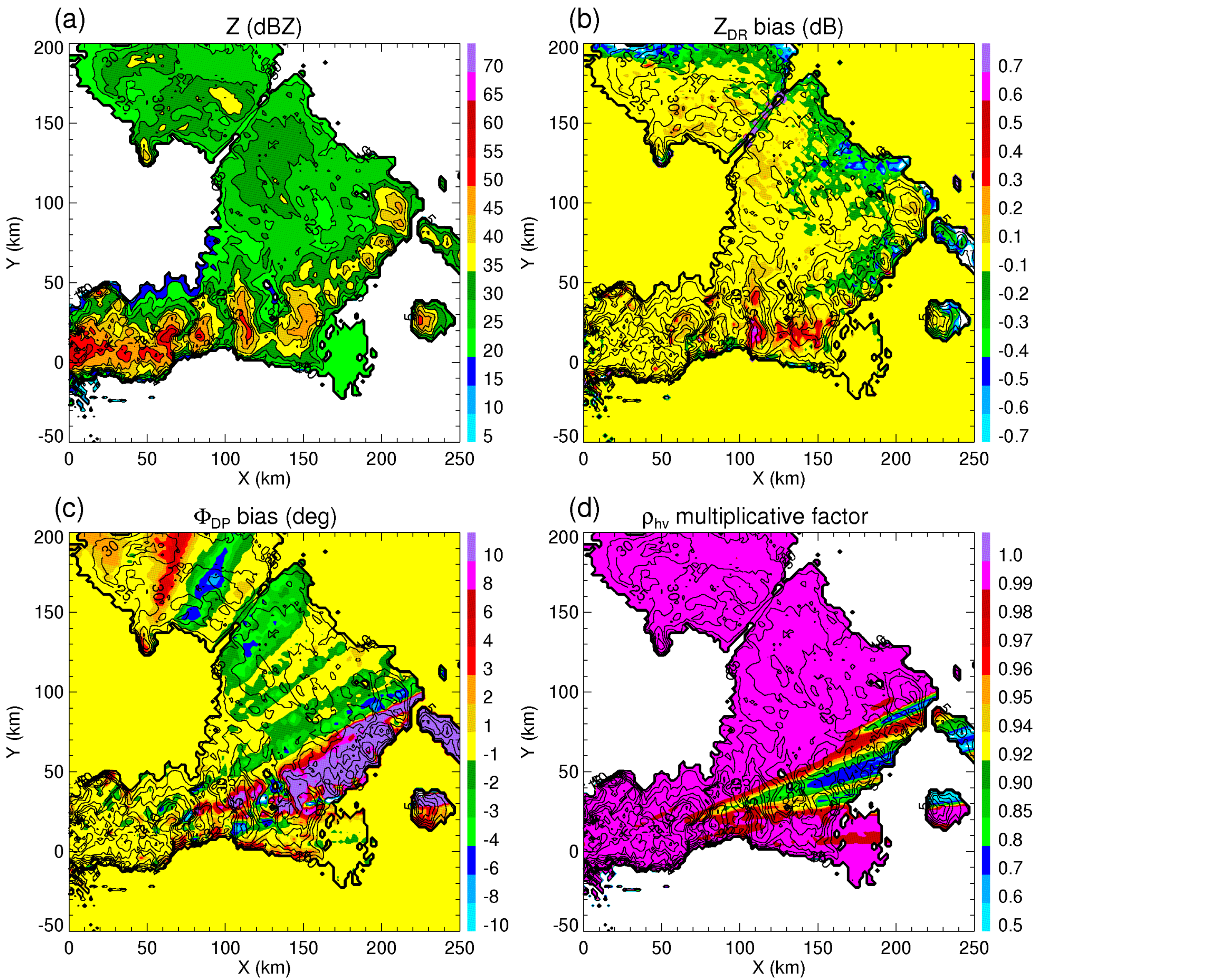
Ω - one-way 3-dB antenna pattern width

The drop in CC is more pronounced for wider antenna beams and shorter wavelengths

Another example of NBF case. June 2, 2004. KOUN



Theoretical estimates of the NBF- related biases in polarimetric variables. June 2 2004, KOUN.

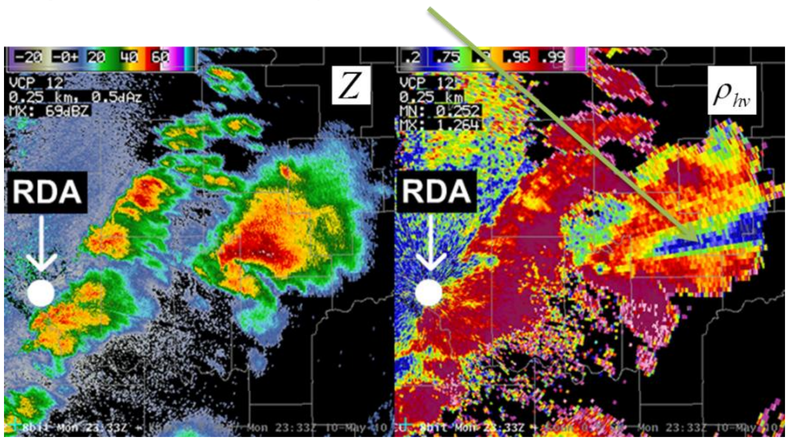


Cross-correlation coefficient is directly affected by the *gradient* of differential phase within the radar resolution volume, not total differential phase which is proportional to path-integrated attenuation

This is similar to the drop of autocorrelation coefficient (or increase of the spectrum width) in the presence of strong gradients of Doppler velocity (wind shear)

Very often (but not always!) the gradient of Φdp is well correlated with the magnitude of Φdp, therefore, radial “valleys” of reduced CC are commonly observed in the directions of stronger attenuation

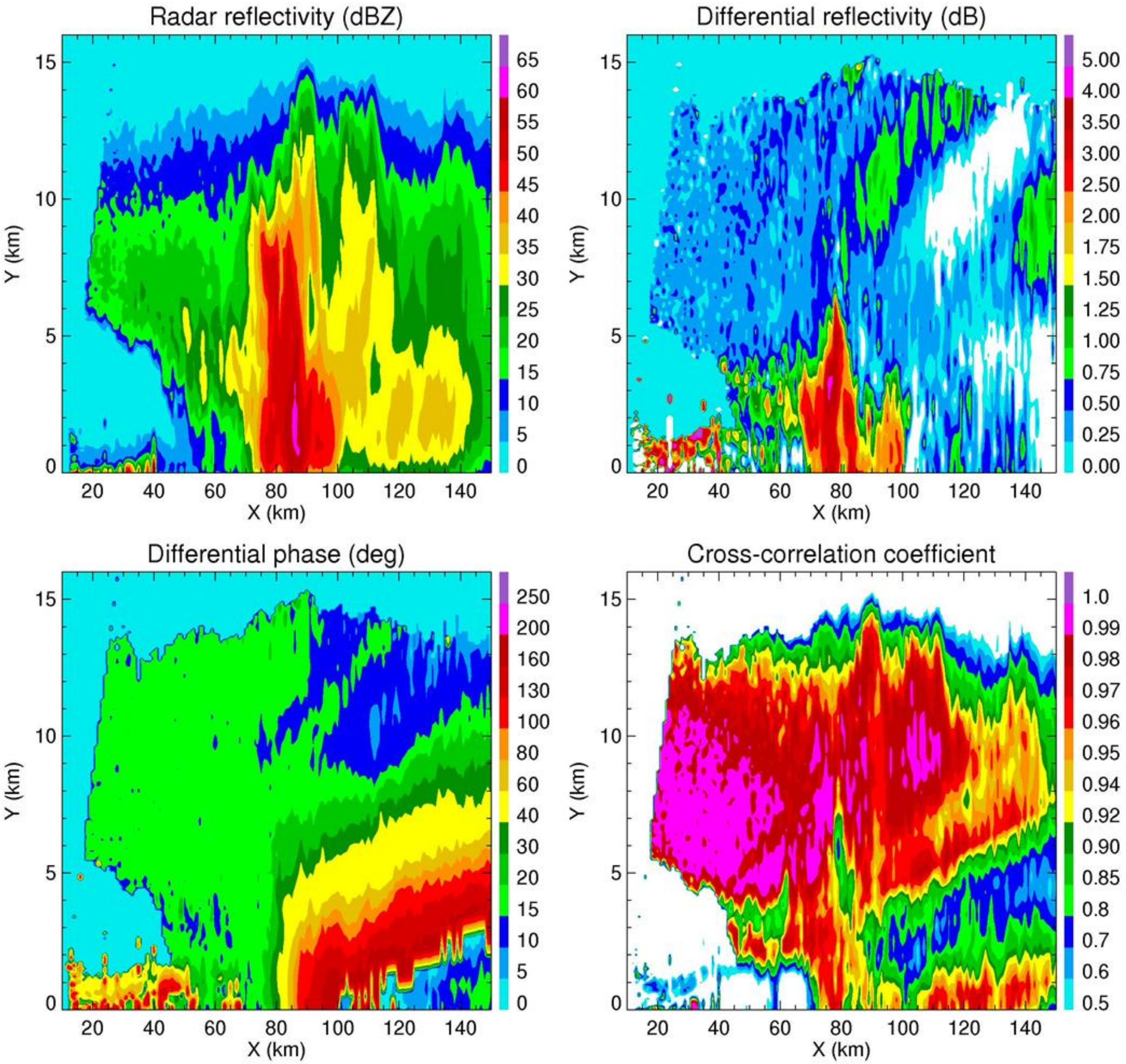
Radial drop of the cross-correlation coefficient due to high gradient of differential phase within the radar beam



Example of CC drop in RHI due to high vertical gradient of Φdp

KOUN

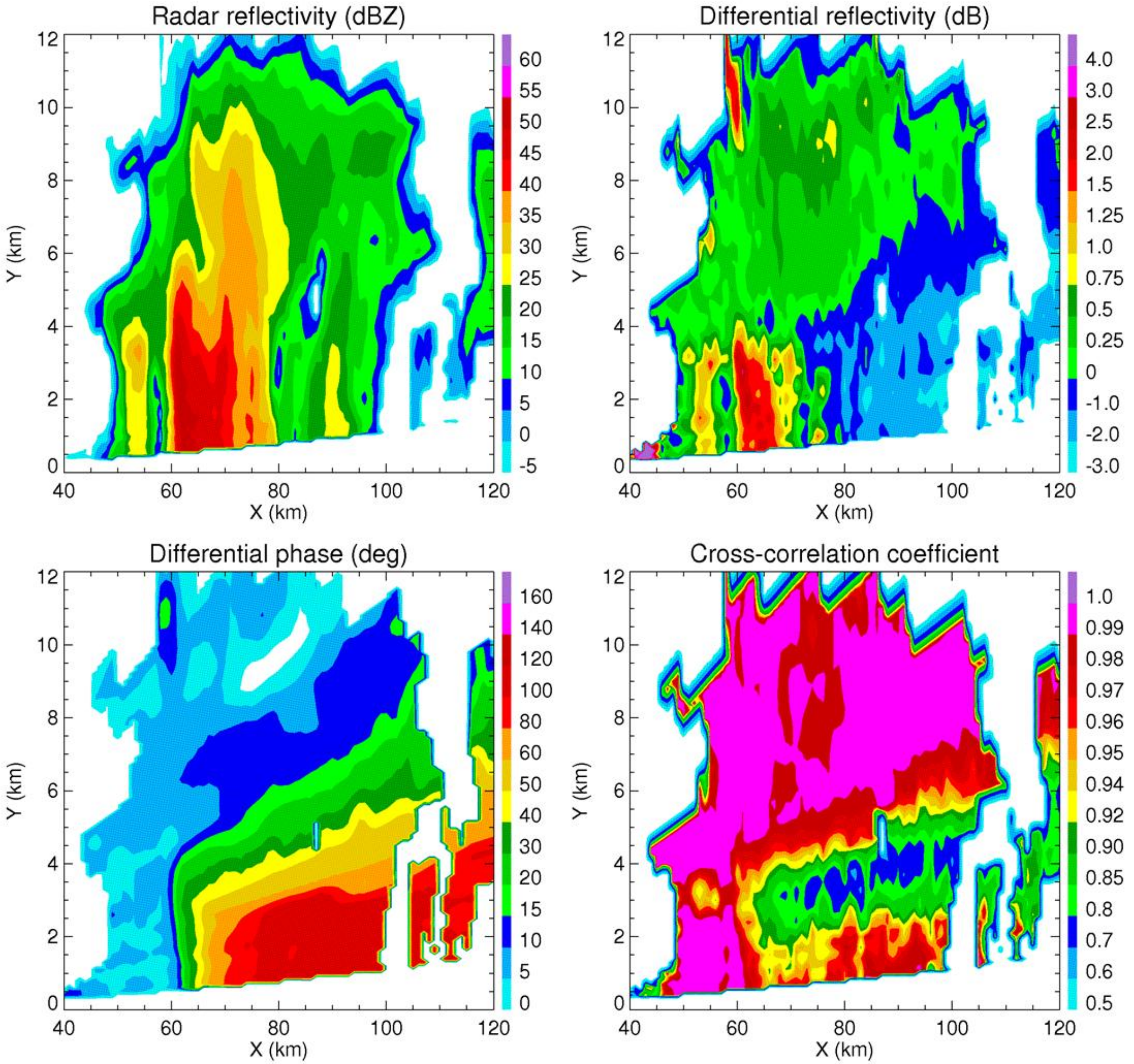
S band



Example of CC drop in RHI due to high vertical gradient of Φdp

King radar

C band



How to fix the problem?

1. Identify the rays where potential problem can exist:

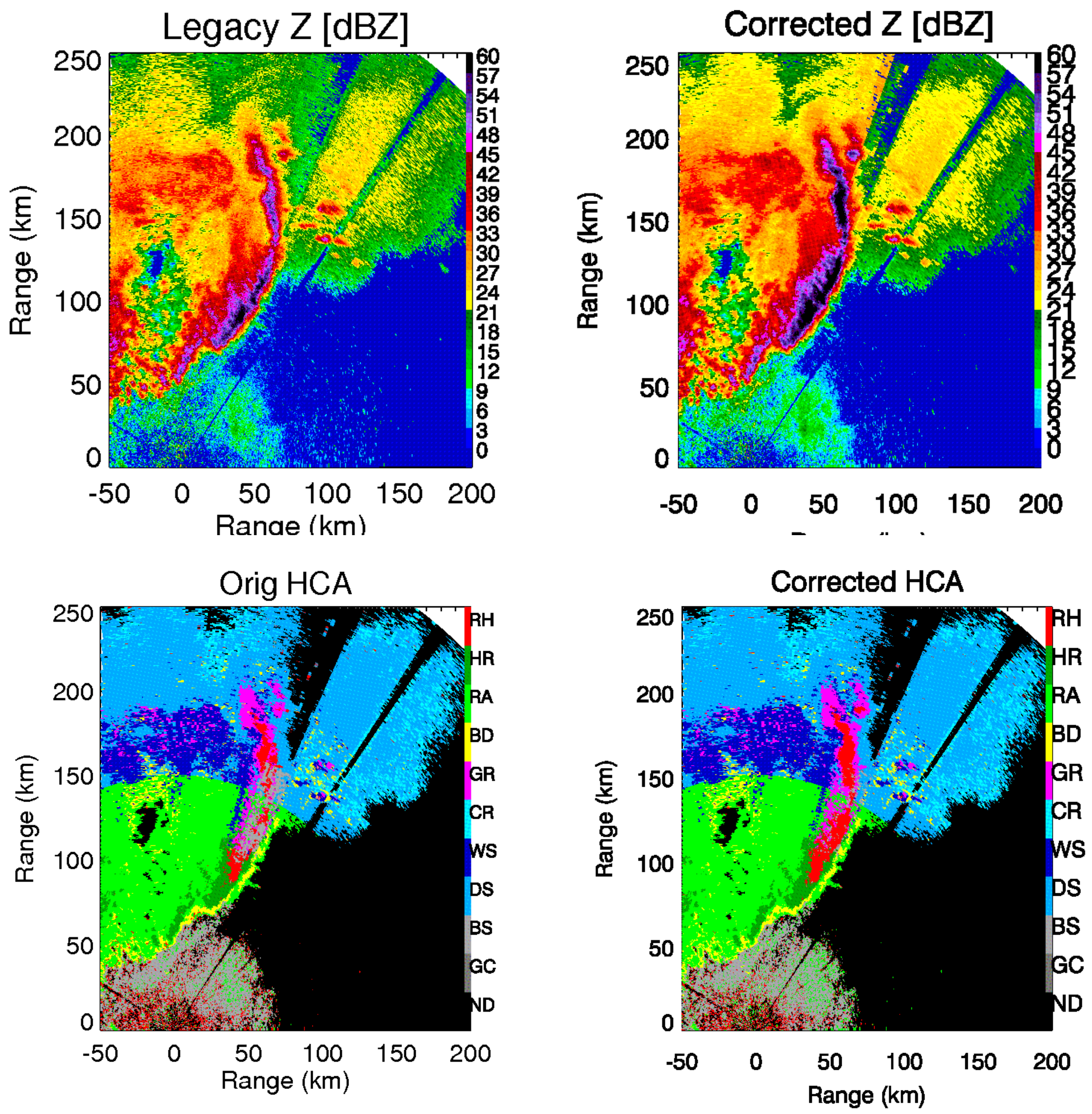
   Starting 160 gates away from the radar, count the number of gates where (a) 30 < Z < 50 dBZ, (b) |V| > 1 m/s, (c) CC < 0.7

   If total count exceeds 10 then the radial is considered highly impacted and differential phase should be processed differently from unaffected radials

2. In the affected ray, utilize SNR threshold (usually 5 dB) rather than CC threshold to distinguish between weather and nonweather gates and proceed with Φ_{dp} processing

3. In the classification routine, decrease weights for Zdr, Kdp, CC, and SD(Φ_{dp}) so that classification is performed primarily using Z and SD(Z). This will prevent nonmeteorlogical echo to be designated in the areas of weather echo.

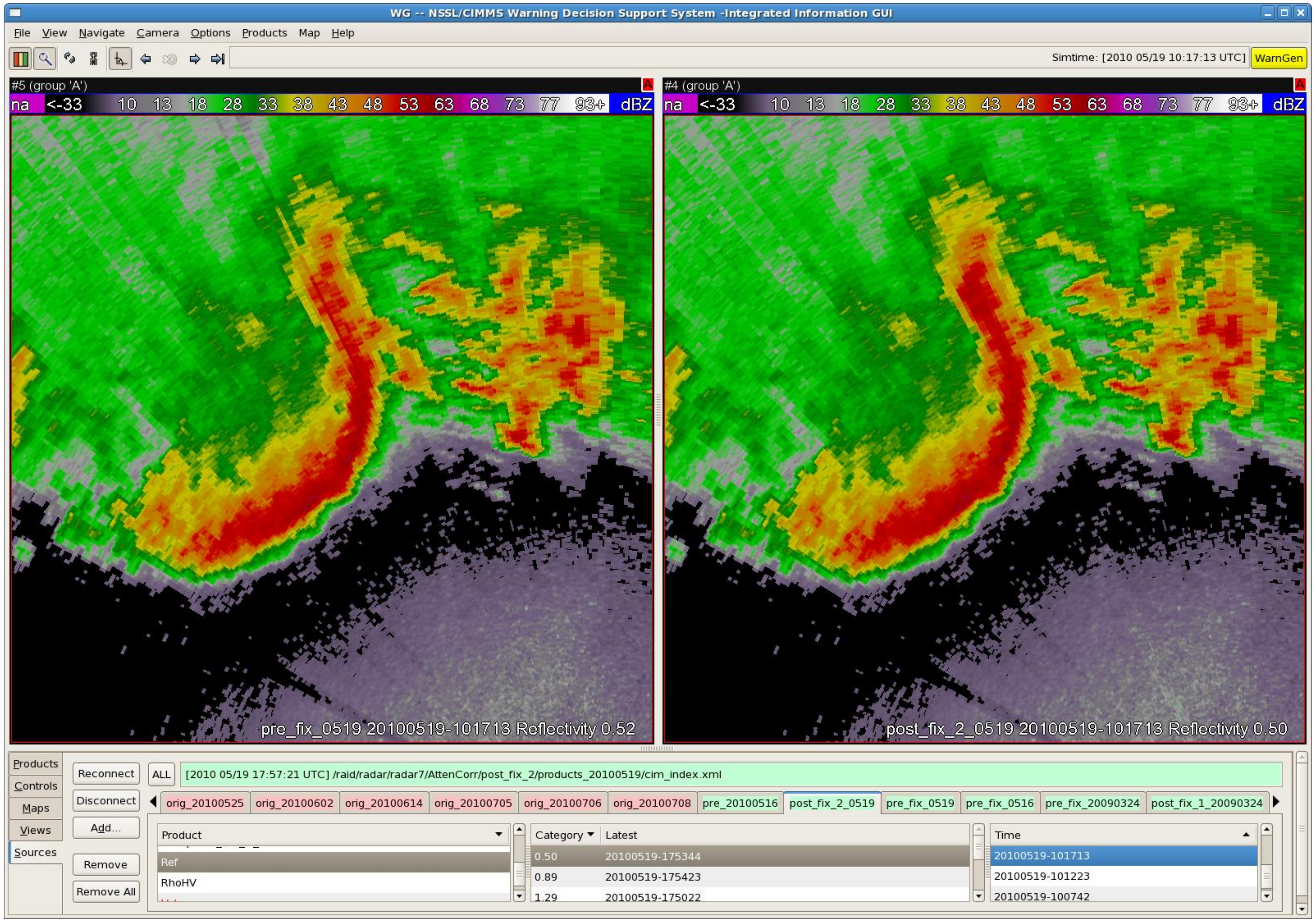
Comparison of contaminated and corrected data



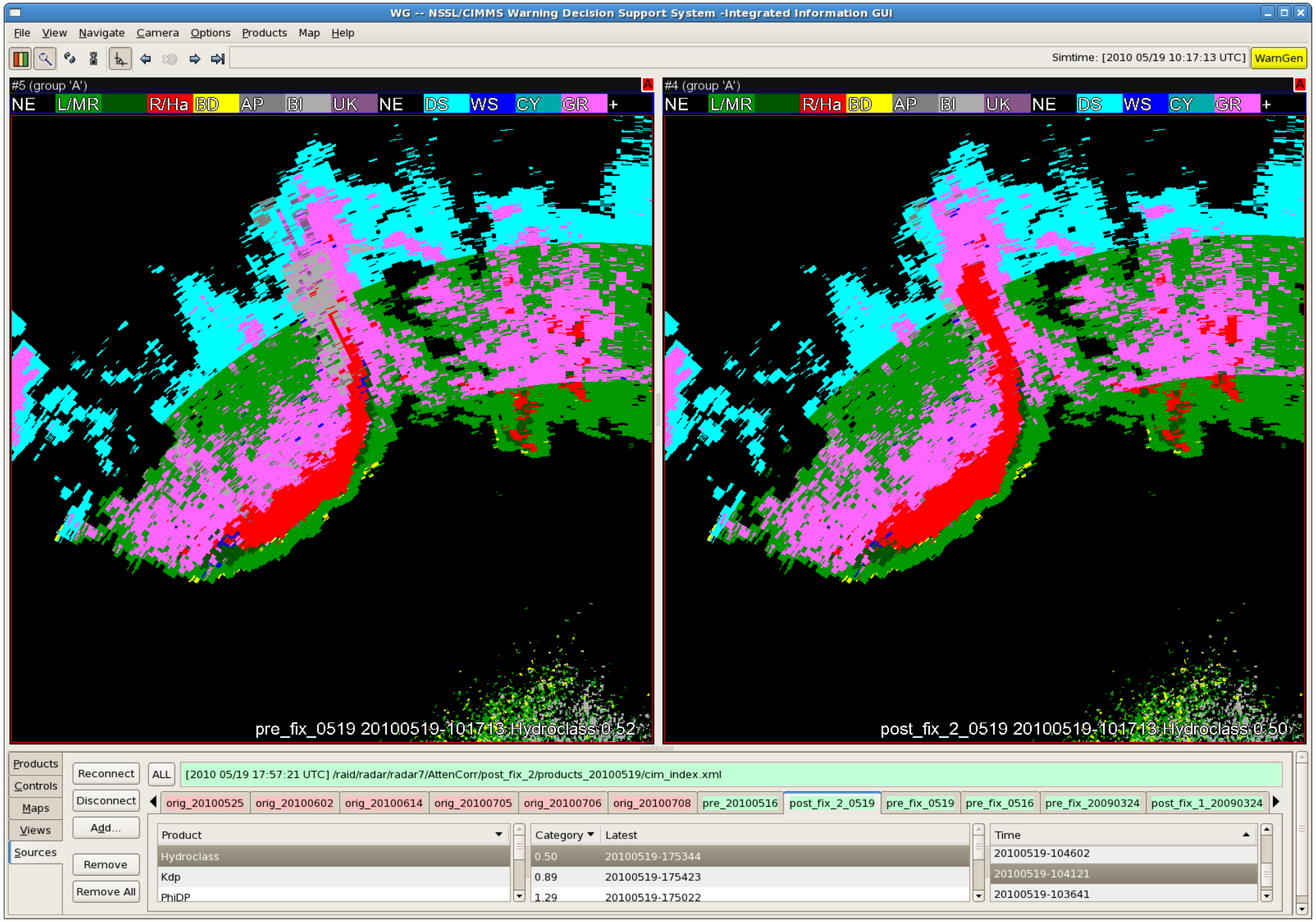
Attenuation correction of Z. 05/19/2010. KOUN

Before correction

After correction



Classification before (left) and after correction (right). 05/19/2010, KOUN



Conclusions

The drop in the cross-correlation coefficient due to large gradient of differential phase in the radar resolution volume may have strong impact on the quality of radar echo classification and on rainfall estimation

The nature of this phenomenon is well understood and necessary changes in the routines for processing of differential phase and classification were suggested and tested.

Extensive testing of the suggested software patch demonstrated that it is sufficiently robust and can be recommended for operational implementation