Chapter I:

What do you need in order to use polarimetric information

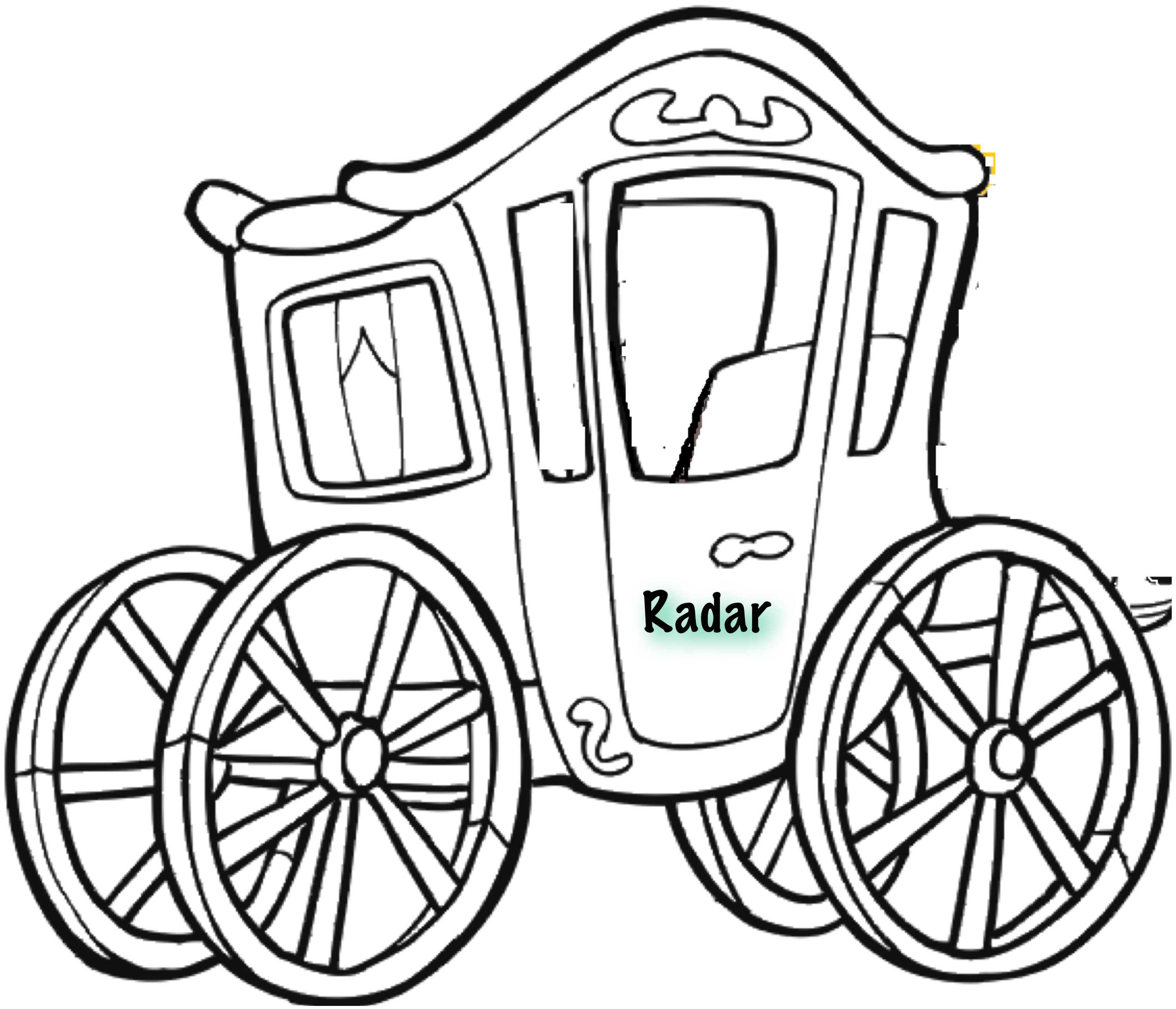
Radars

Infrastructure to operate then effectively

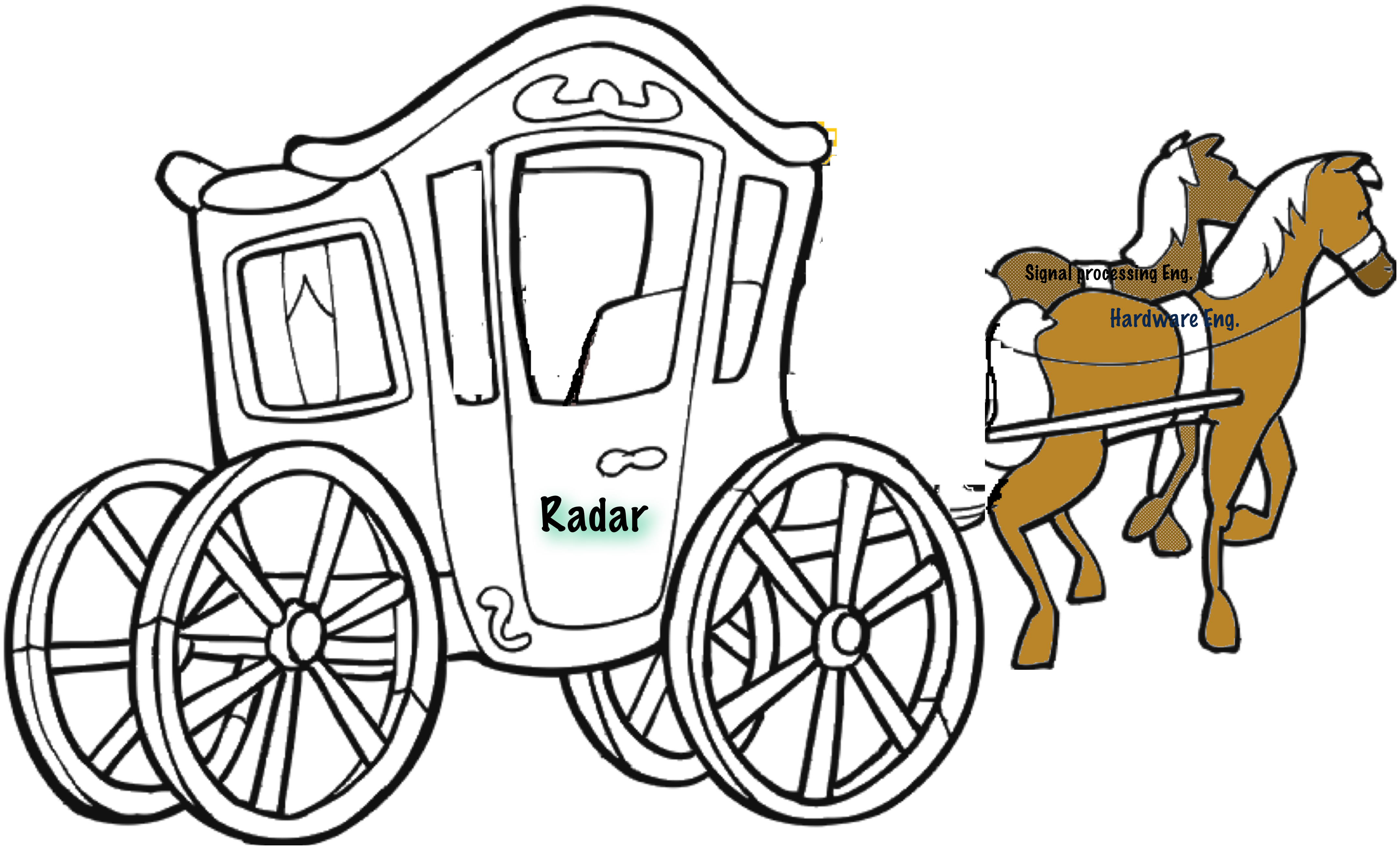
The more sophisticated are the radars the more sophisticated must be the infrastructure

People, not machines, are the key element

Absolute requirements for effective radar operations



Absolute requirements for effective radar operations



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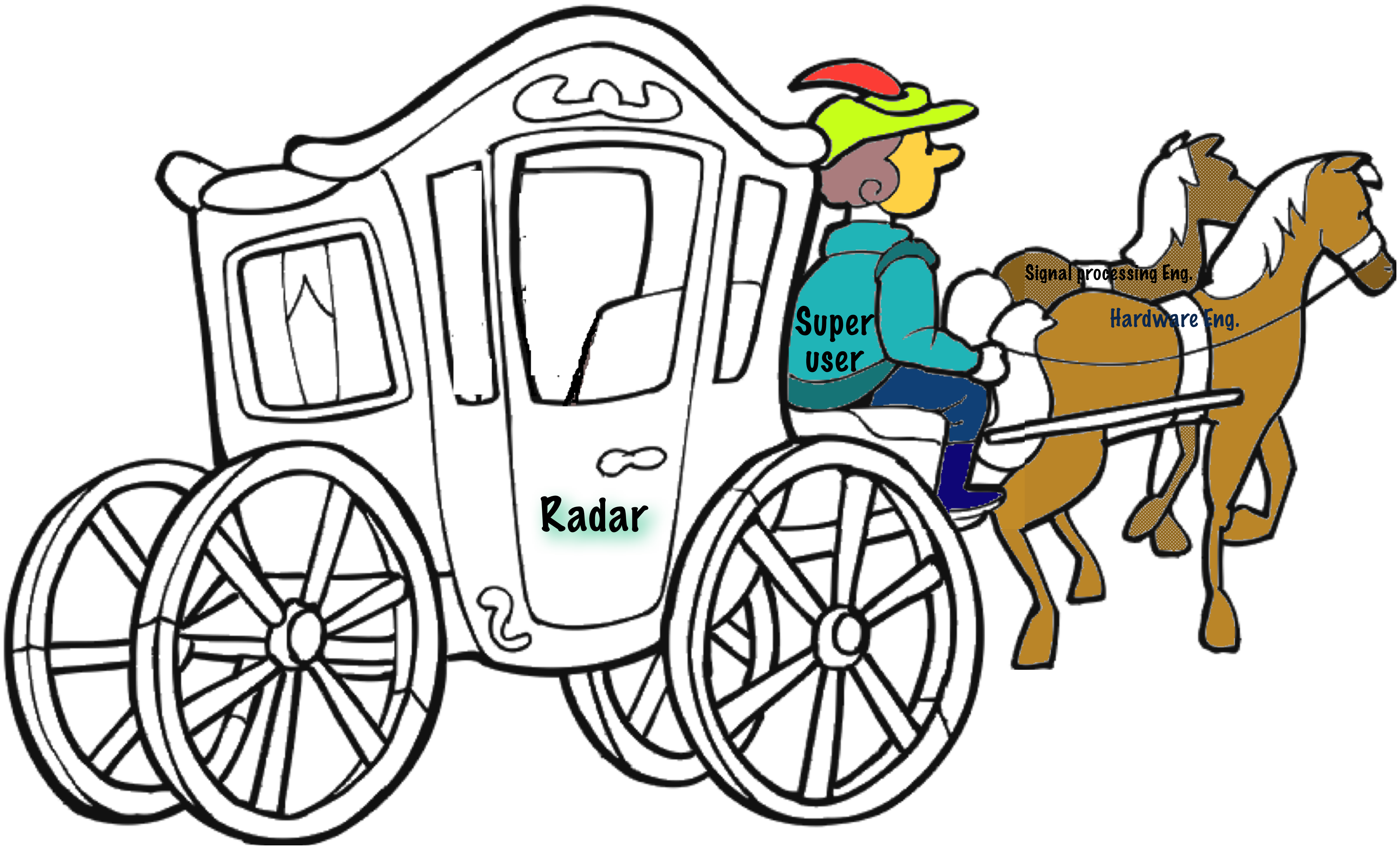

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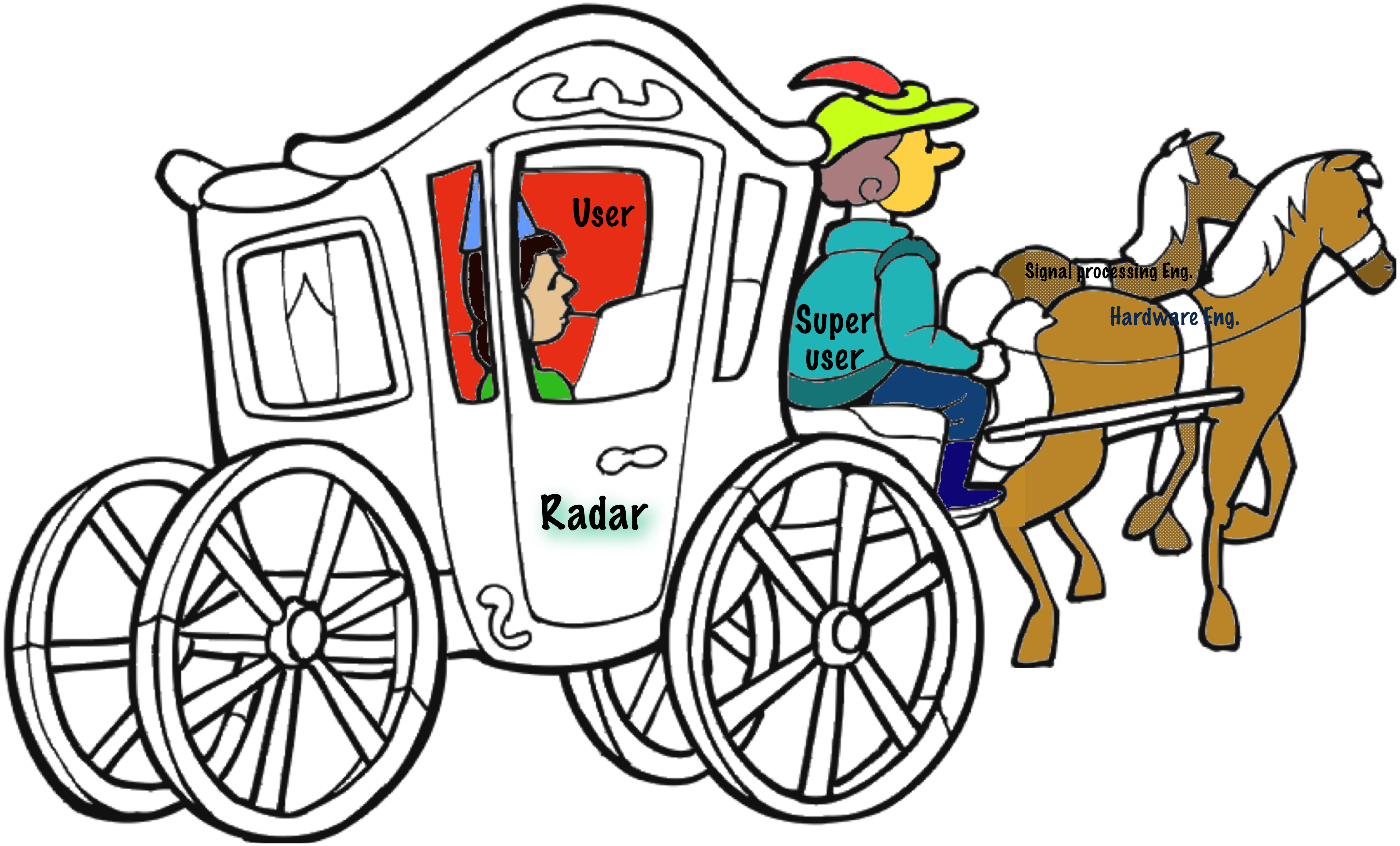

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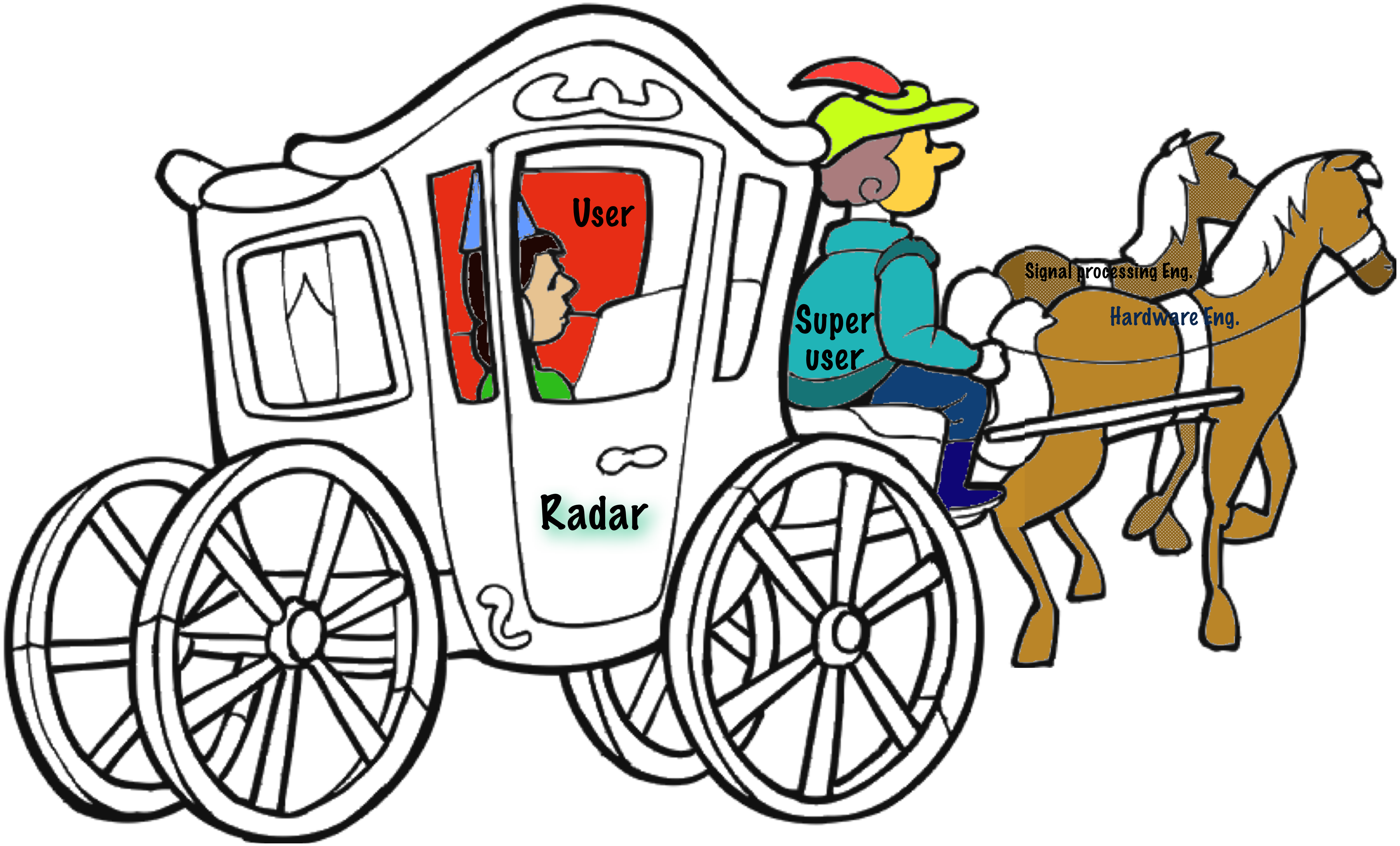
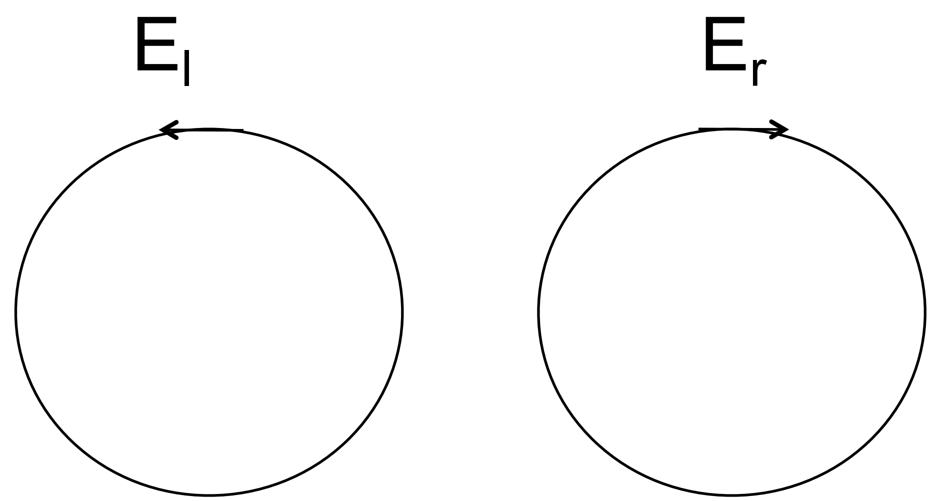


The engineers can be external, but the Super-User, the user that understands data quality, monitors data regularly and has a common language with the engineers, must be in-house.

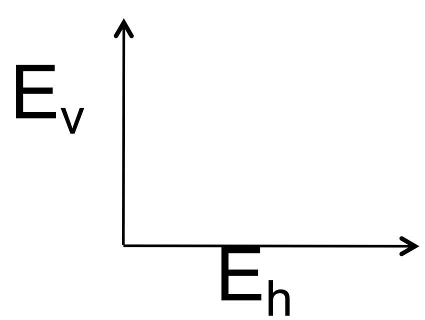
Polarimetric Radar

Isztar Zawadzki

Polarimetric implementations



Circular polarization

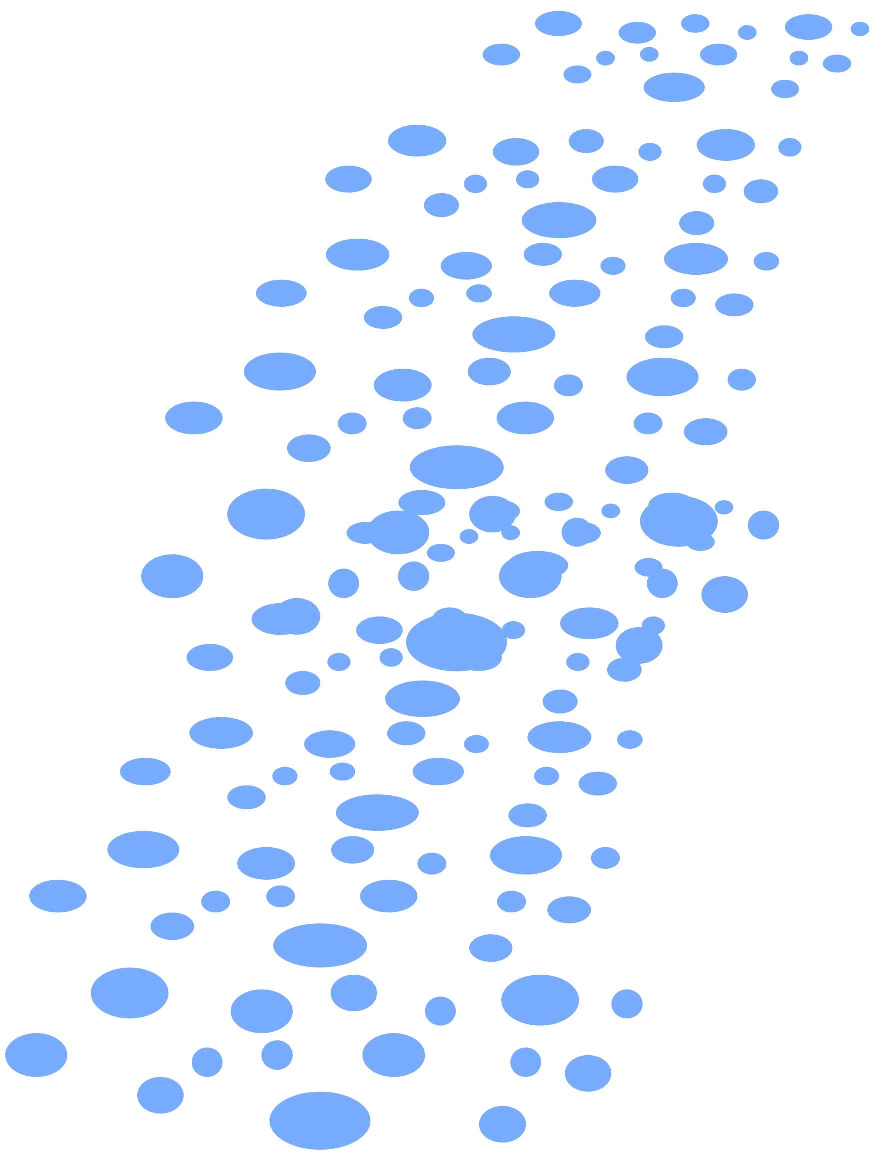


Linear polarization

Alternate H and V
(older systems)

Simultaneous H and V
on transmission and reception
(research radars)

Polarimetric implementation



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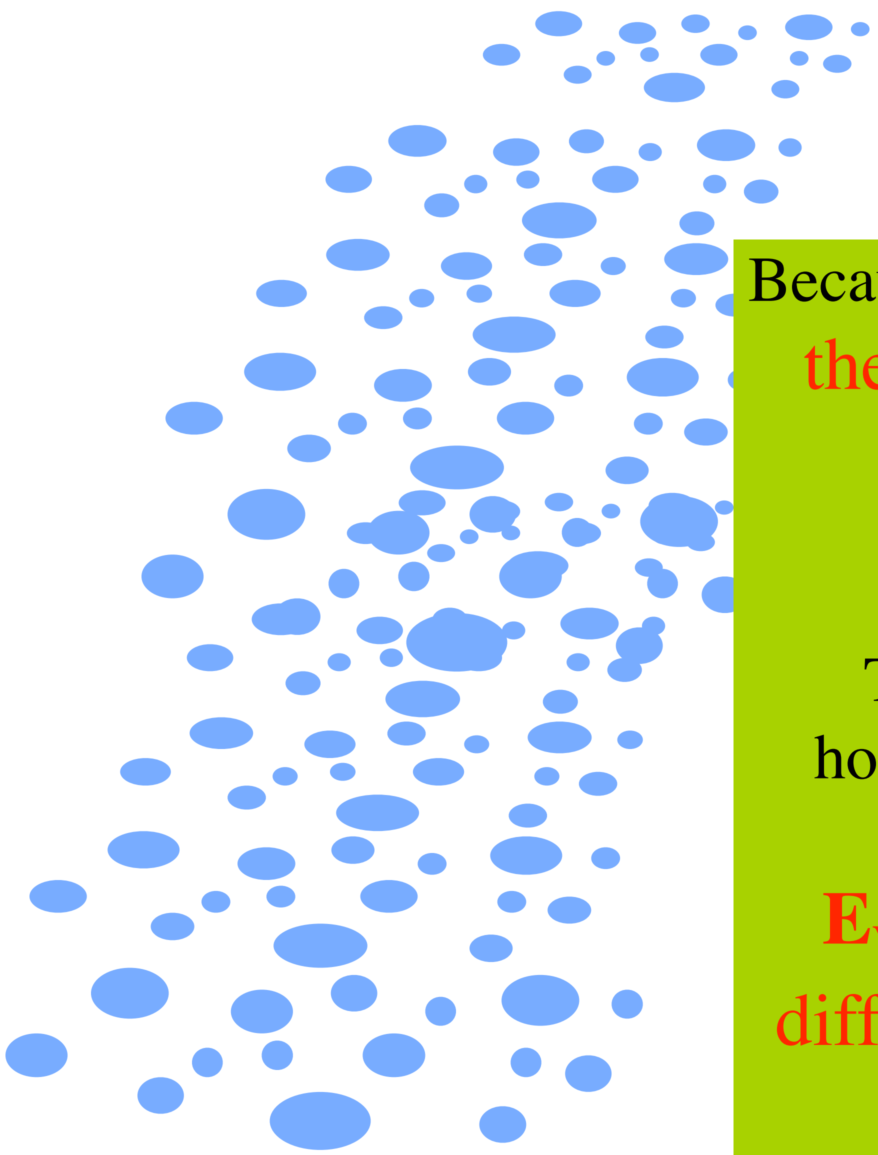
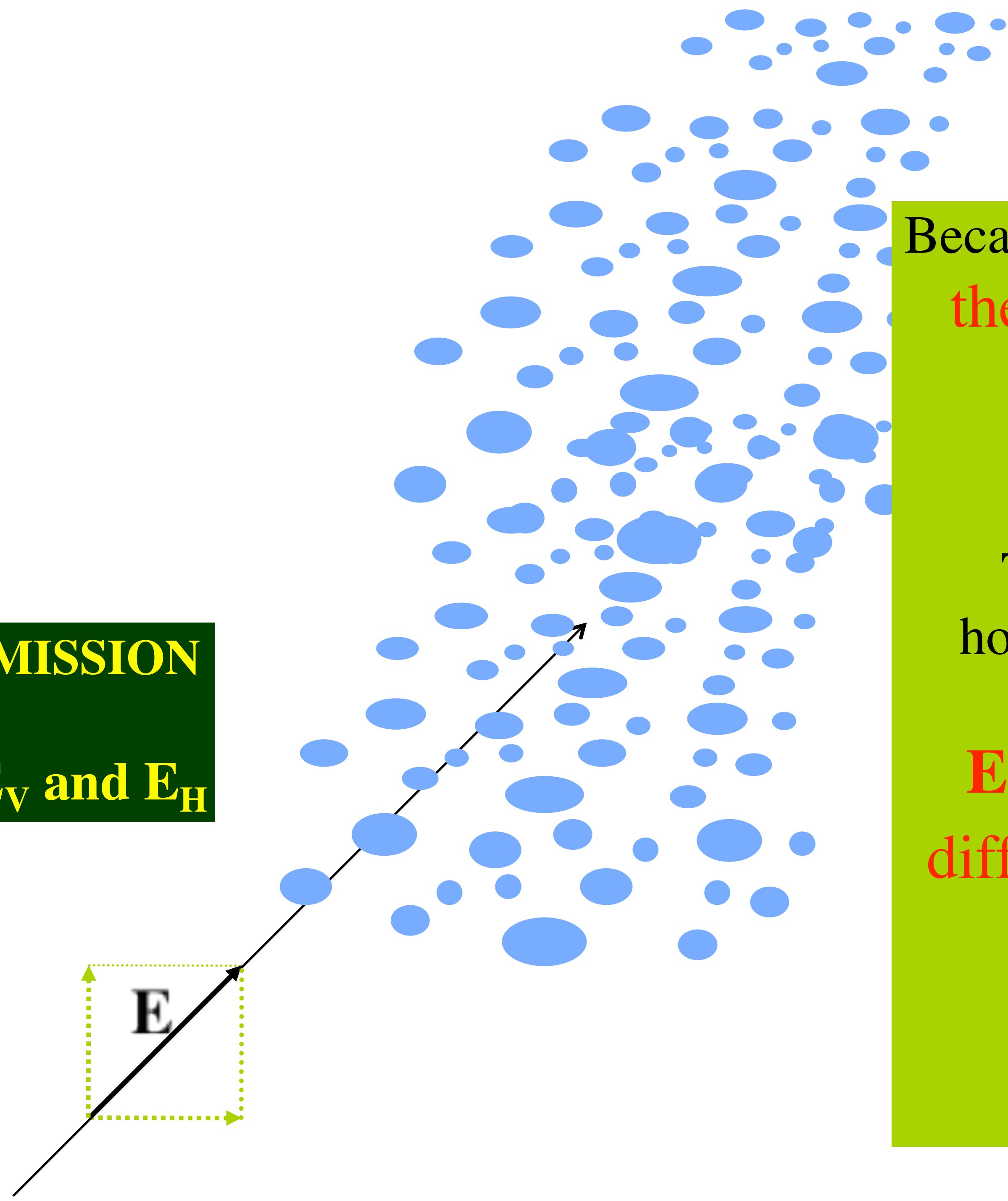


Because of the drops' deformation
the medium is anisotropic
for EM propagation
and scattering.

Thus, the vertical and the horizontal components of the electric vector,
$\mathbf{E_V}$ and $\mathbf{E_H}$, are scattered differently and propagate at different speeds.

Polarimetric implementation



CONSIDER A TRANSMISSION AT 45 DEGREES:
EQUAL POWER IN. E_V and E_H

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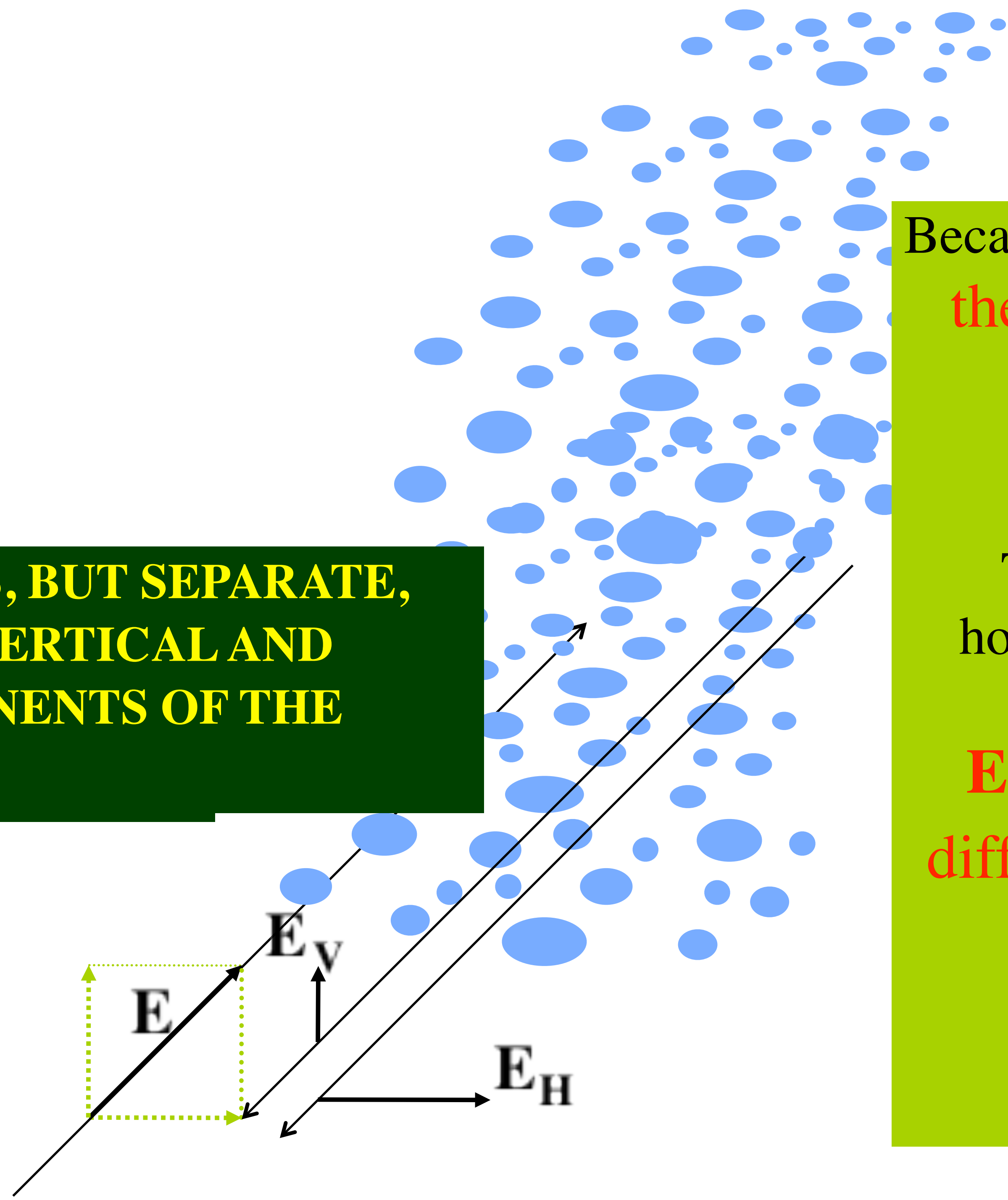
Polarimetric implementation



AND A SIMULTANEOUS, BUT SEPARATE, RECEPTION OF THE VERTICAL AND HORIZONTAL COMPONENTS OF THE ELECTRIC VECTOR.

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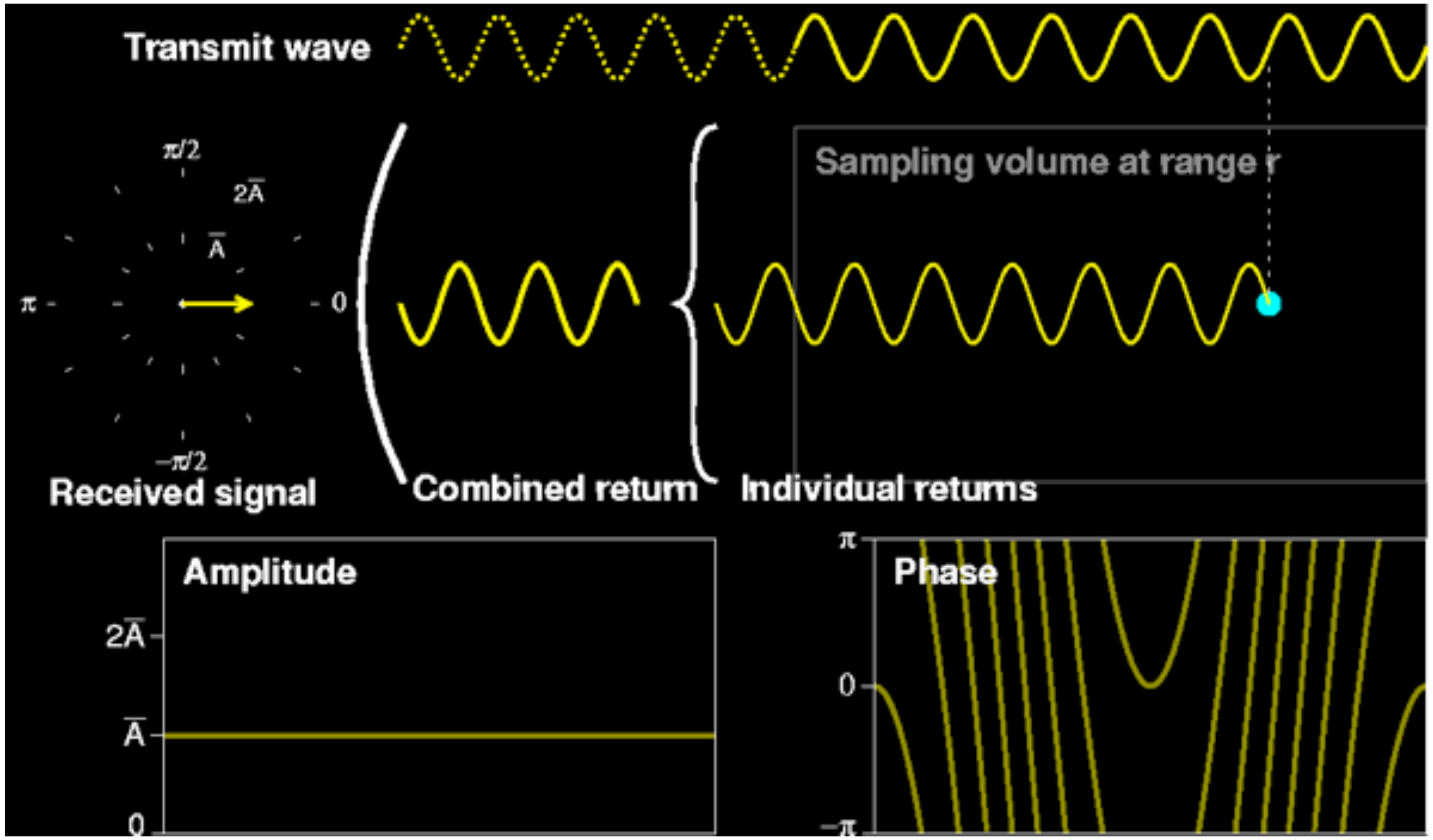
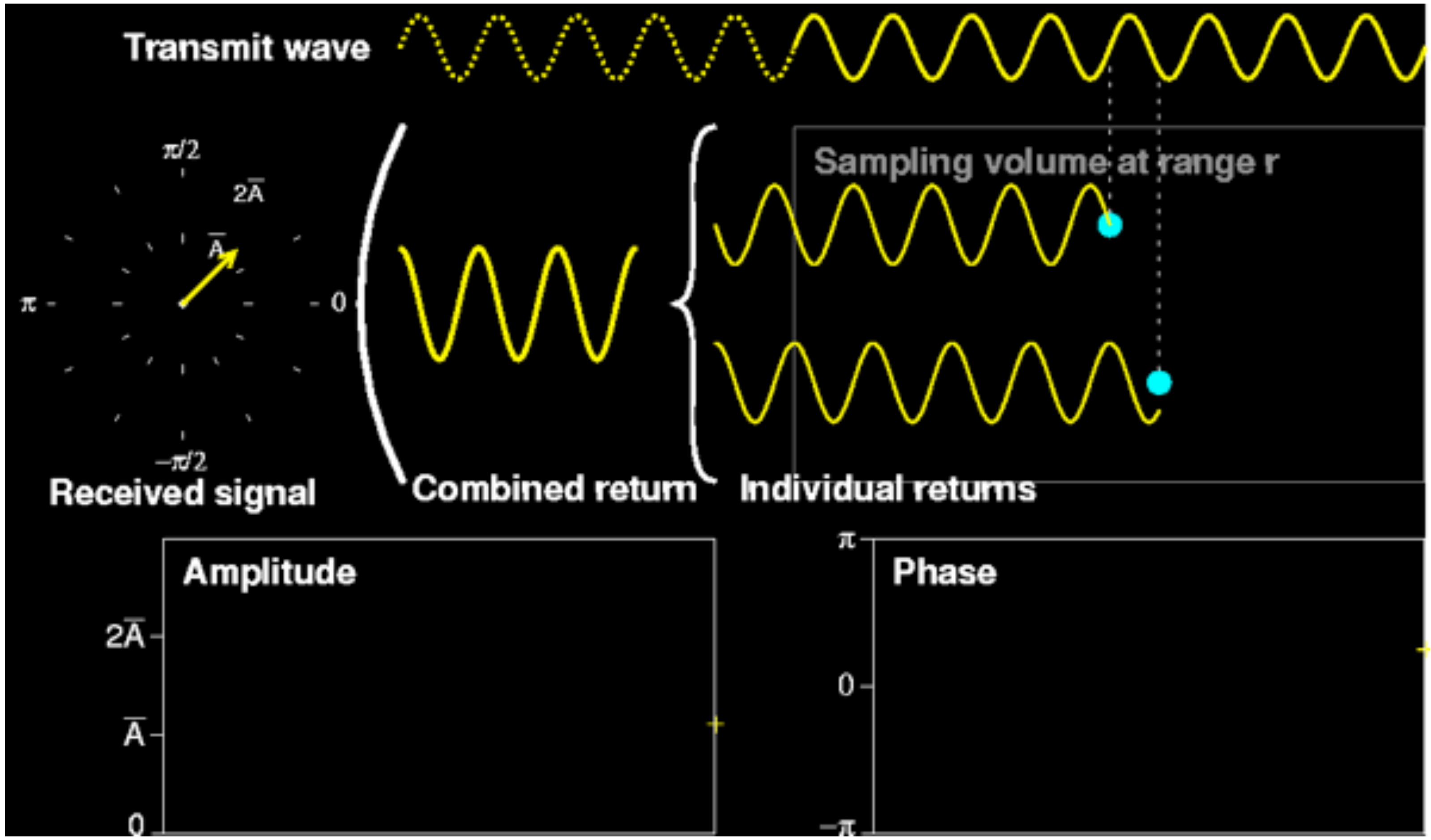
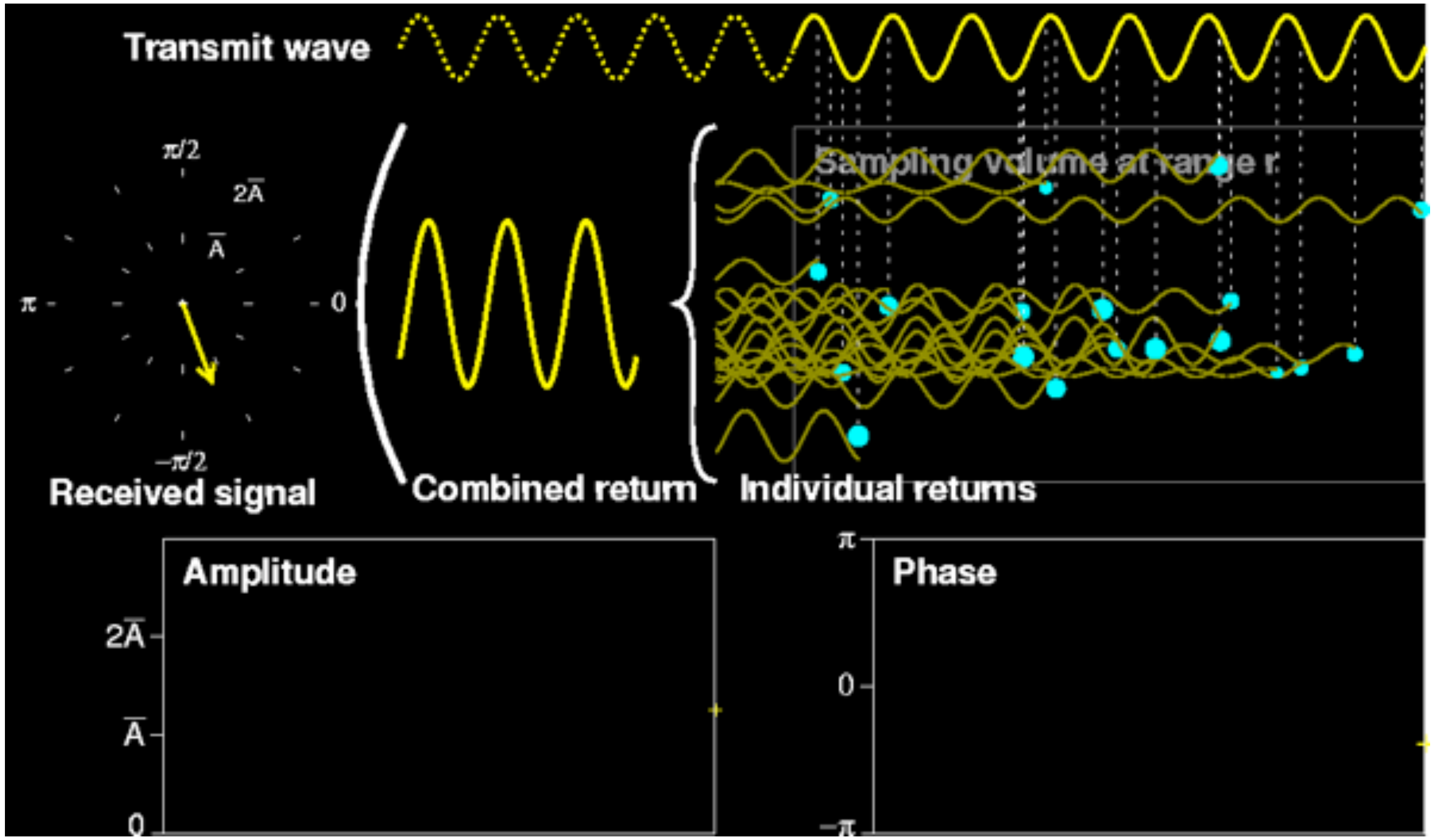
Return from a single drop



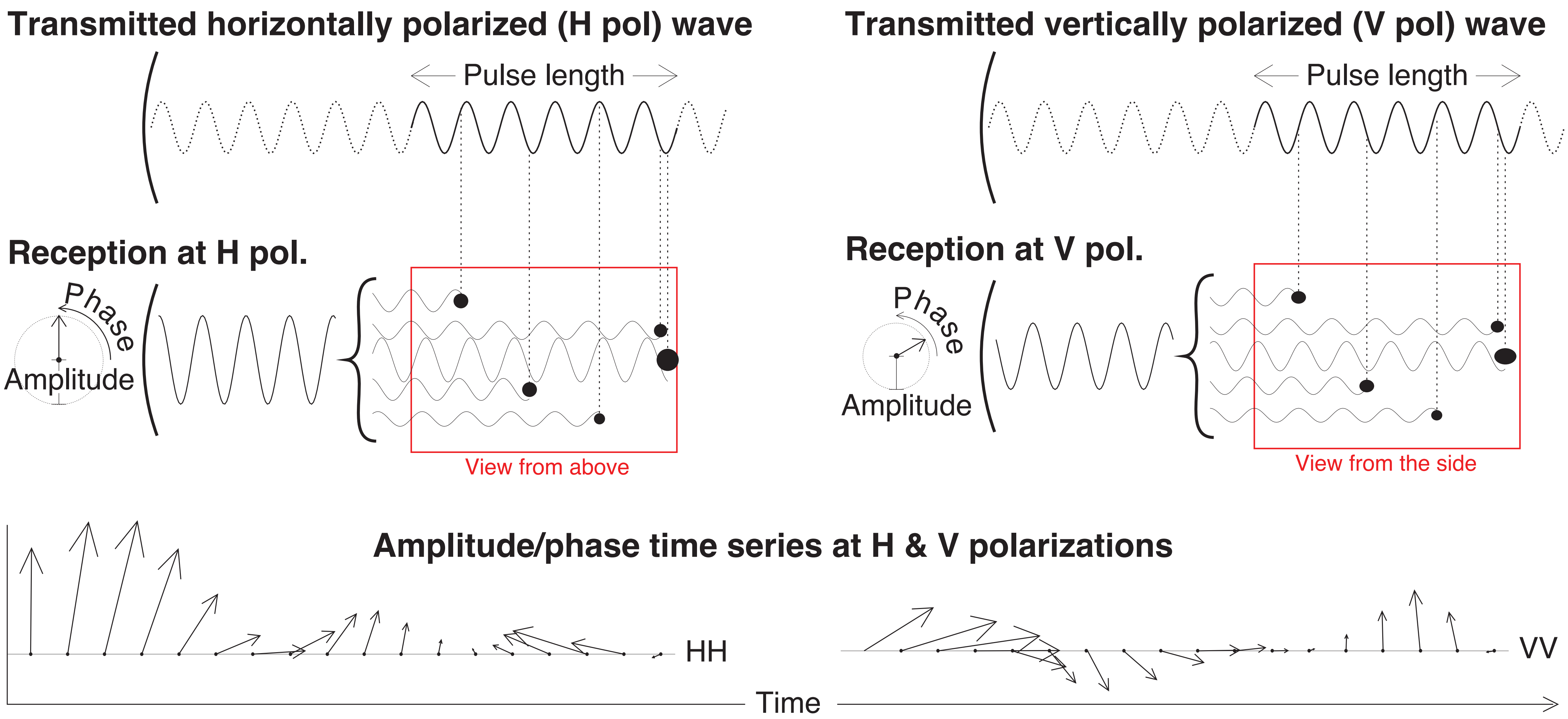
Return from two drops moving relatively to each other



Return from many drops moving relatively to each other



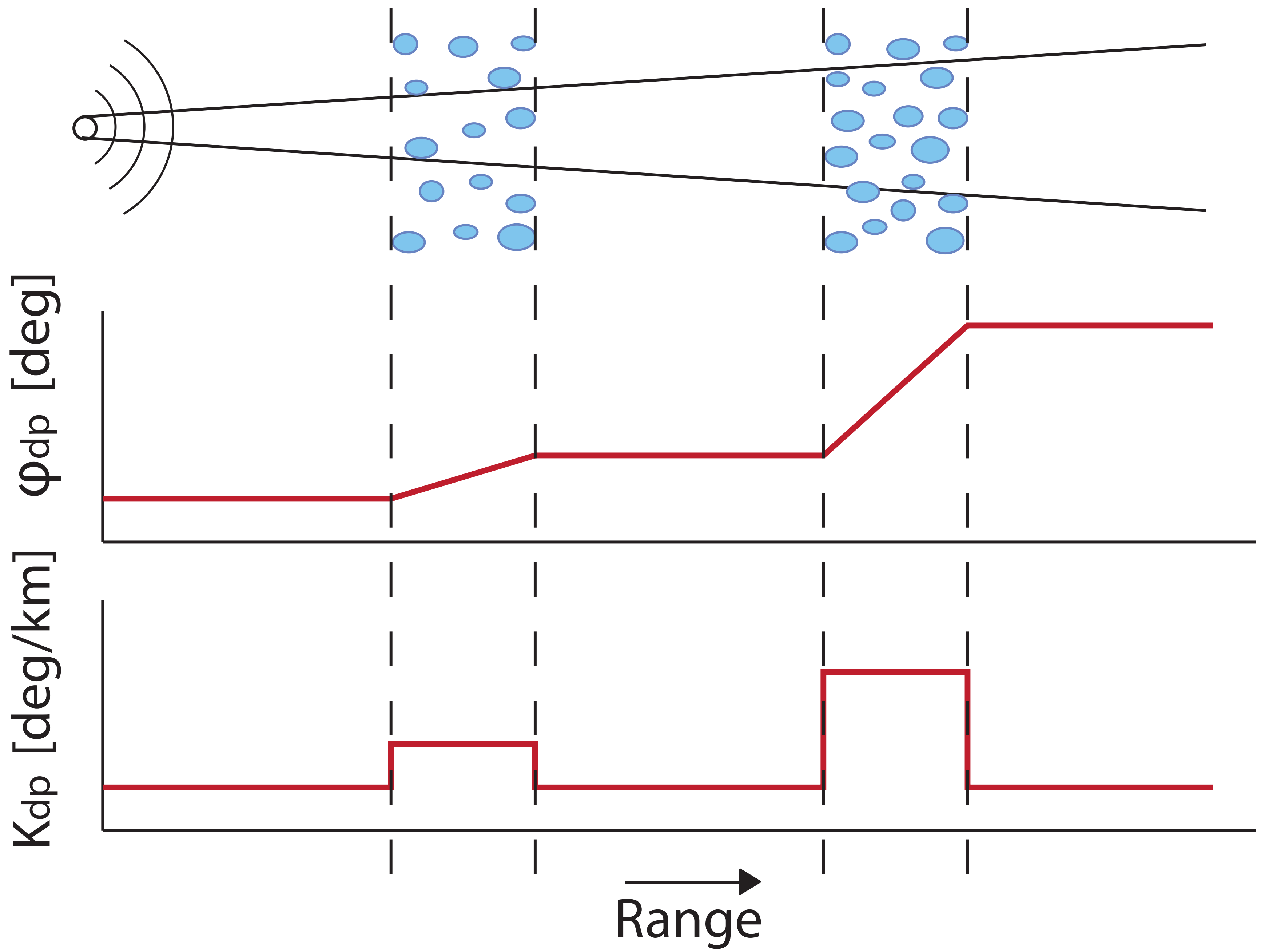
Returns from dual-pol from many drops moving relatively to each other



$$Z_{DR} = \frac{Z_H}{Z_V} = \frac{P_{HH}}{P_{VV}}$$

$$\begin{pmatrix}\text{Complex} \\ \text{correl.}\end{pmatrix}_{HH,VV} = (P_{HH}P_{VV})^{.5}\rho_{co}\exp(2j\phi_{DP})$$

KDP and $\Phi_{dp}=\Phi_h-\Phi_v$



What information do we obtain from polarization diversity at 45^0 transmission and simultaneous reception of Z_H and Z_V?

M
E
A
S
U
R
A
B
L
E
S

Z_e • Equivalent reflectivity (horizontal and vertical).

What information do we obtain from polarization diversity at 45^0 transmission and simultaneous reception of Z_H and Z_V?

MEASURABLES

Z_e • Equivalent reflectivity (horizontal and vertical).

$$Z_{DR} = 10\log\left(\frac{Z_H}{Z_V}\right)$$

• It is zero for spherical particles; positive (negative) for oblate (prolate) particles. Measures the average deformation of targets.

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$$\phi_{DP} = \phi_V - \phi_H$$

• Phase difference between E_H and E_V produced by the anisotropy of the optical density of the propagation medium. It is zero for spherical particles; positive for oblate, and negative for prolate, particles. Measures mass*deformation It is independent of radar calibration.

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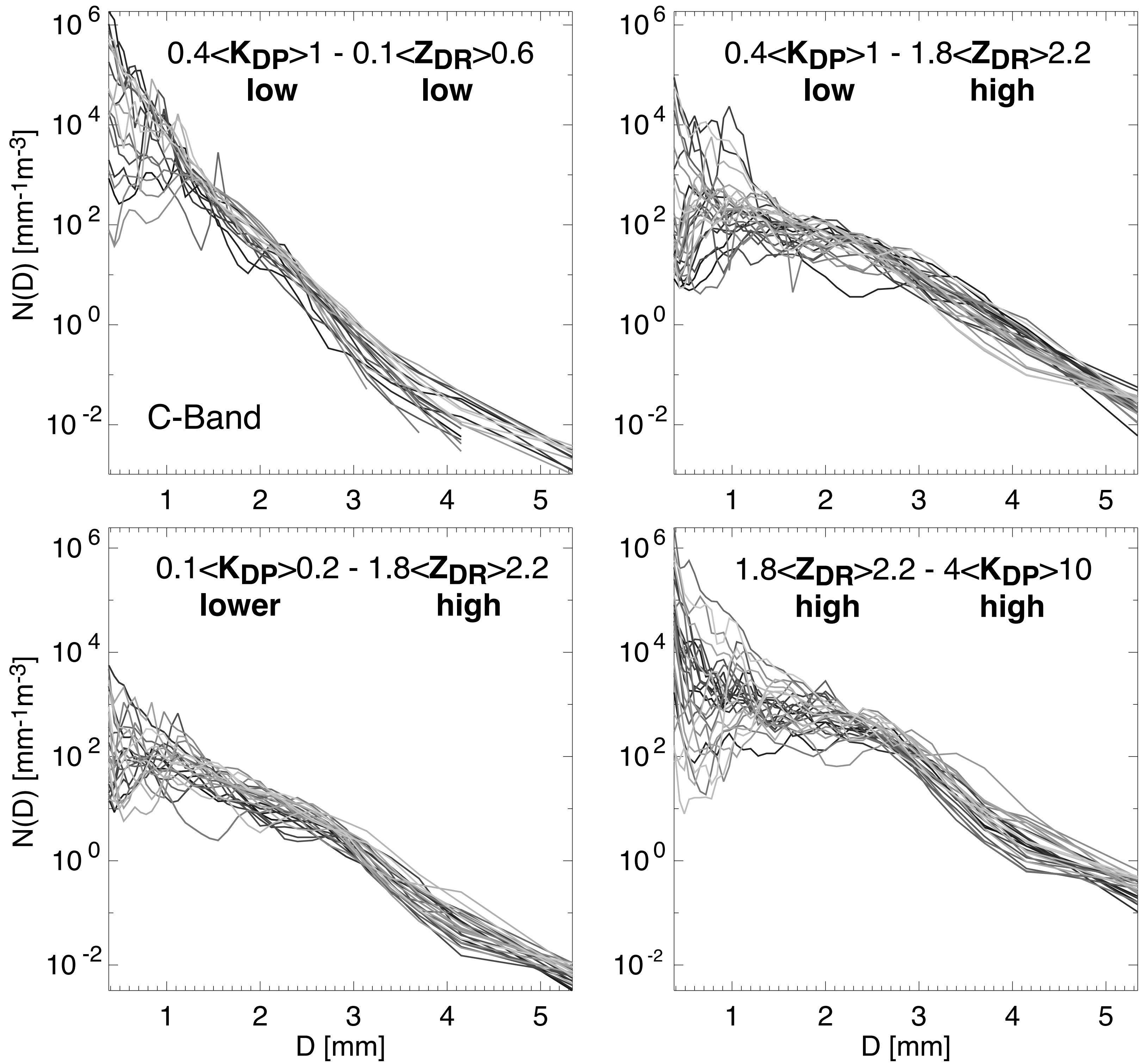
$$\rho_{HV} = \overline{\left(Z_H - \overline{Z_H}\right) * \left(Z_V - \overline{Z_V}\right)}$$

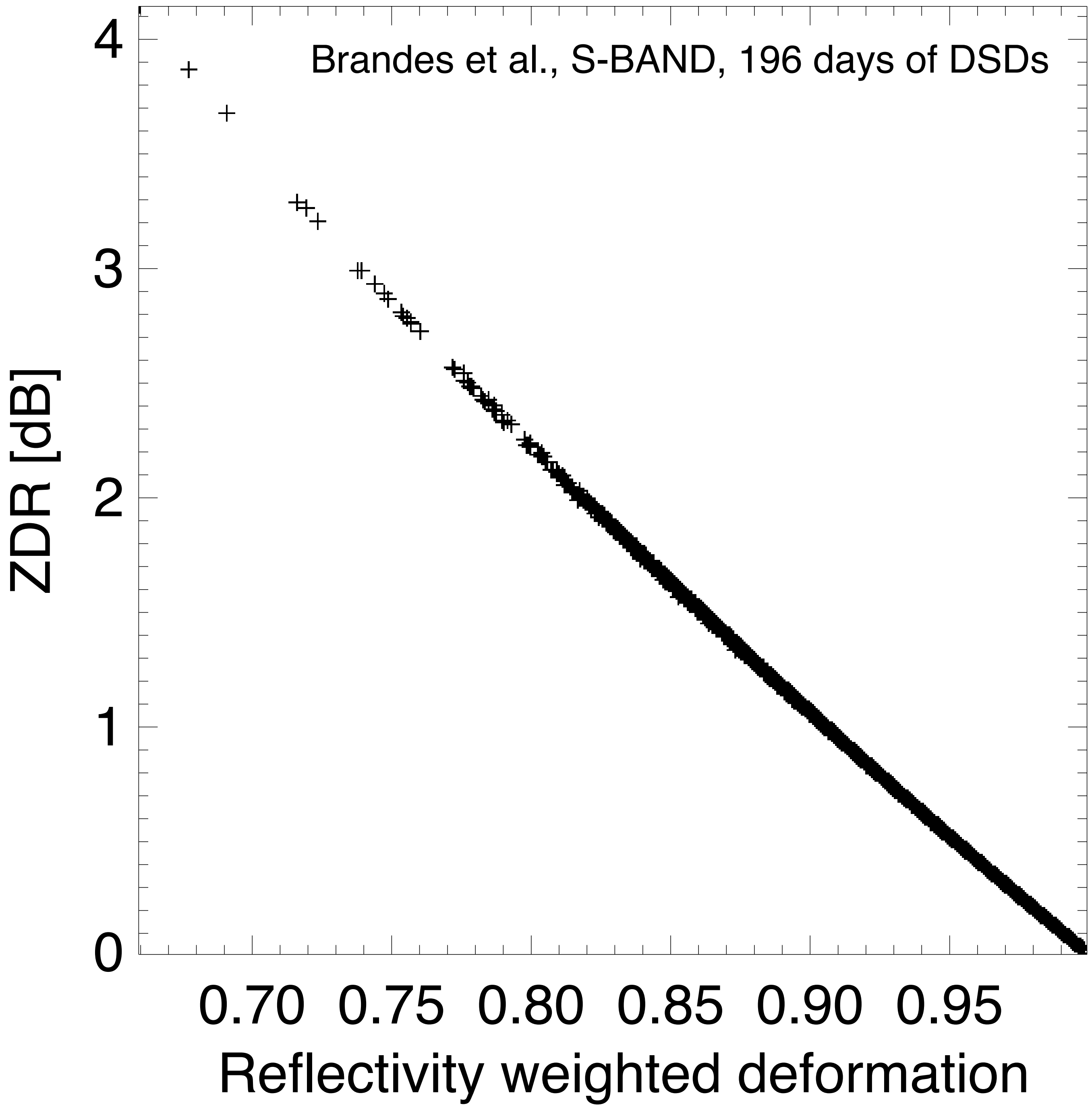
• The overbar indicates the average over several consecutive pulses.

If the shapes, orientations and distributions of targets do not change in time ρ_{HV}=1; if there is a complete reshufflings at every pulse ρ_{HV}=0. Measures the time change in the variety of particles, their shapes and their orientations

Polarimetric Measurements in Rain



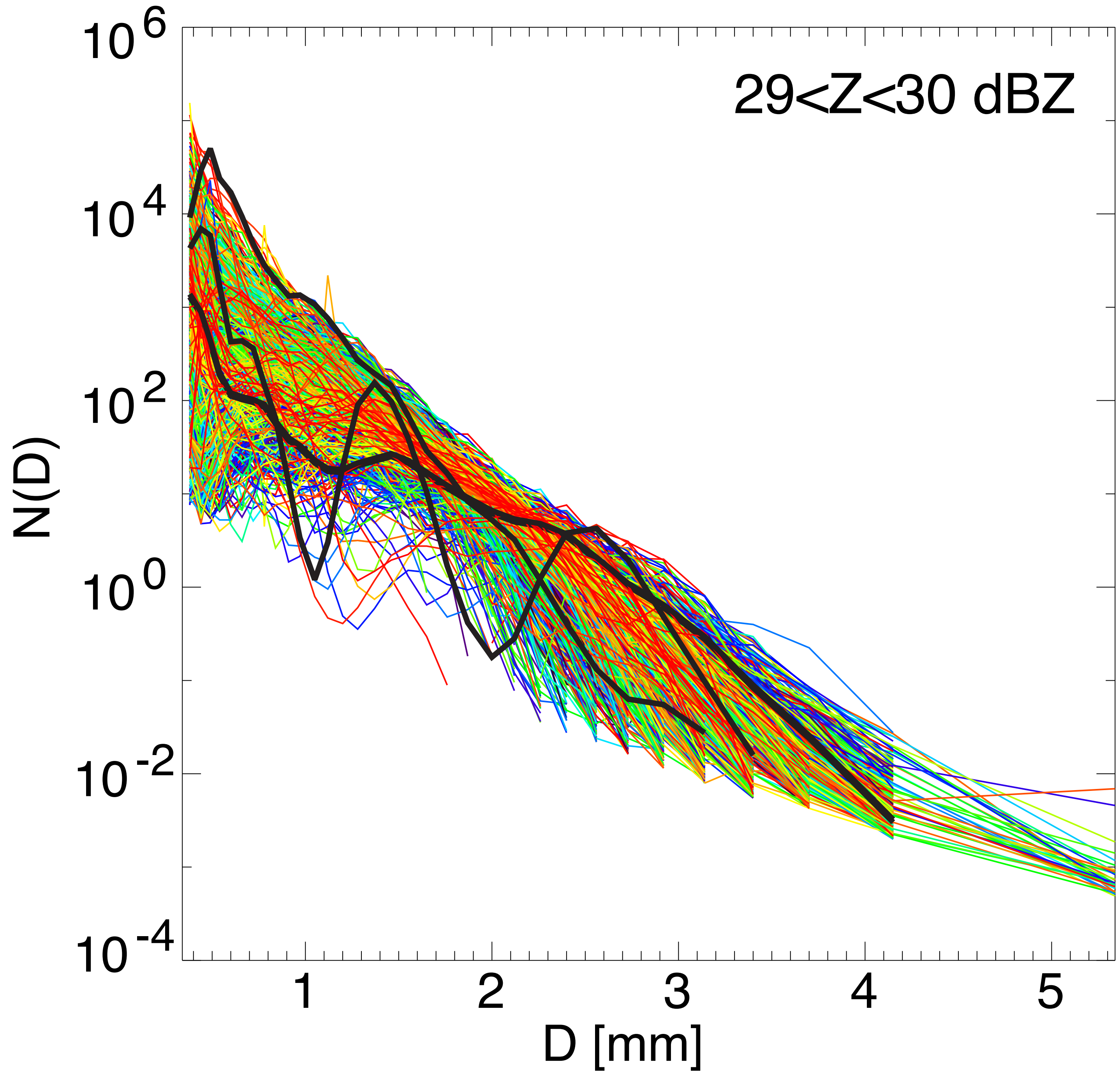
Polarimetric Measurements in Rain



Z_{DR} has a simple interpretation. All others polarimetric measured quantities have a more complex mathematical expressions and must be “tamed”.

Drop Size Distributions (DSDs) provide a guidance to understanding

For a given reflectivity there is a large variety of DSDs:



Moments of the distributions:

$$M_6 = Z = \int D^6 N(D)\, dD$$

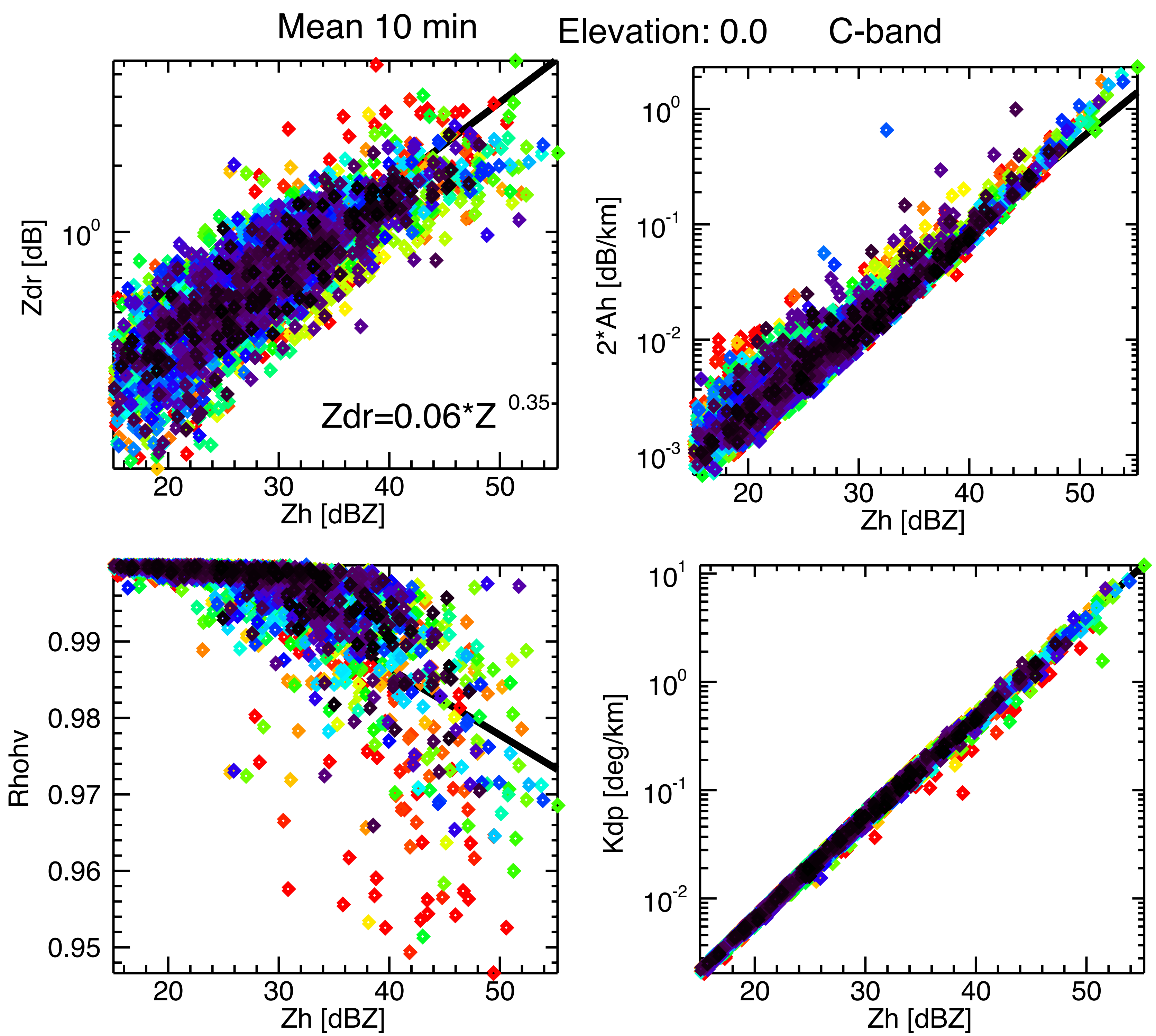
$$M \propto M_3 = \int D^3 N(D)\, dD$$

$$R \propto M_{3.67} = \int D^3 V(D) N(D)\, dD =$$

$$\int D^3 D^{0.67} N(D)\, dD$$

Some polarimetric relationships for rain

(climatology of over 34,000 DSDs, from 196 days with convection)



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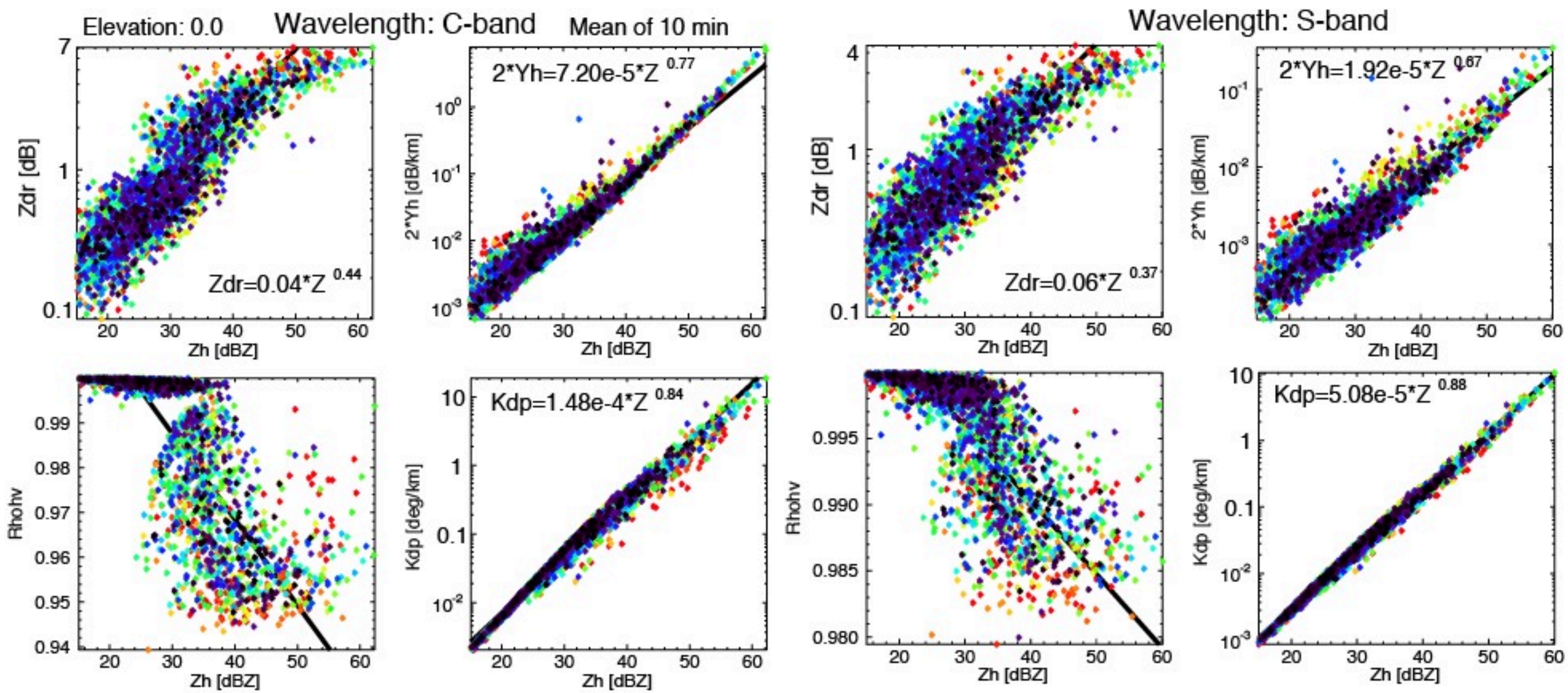
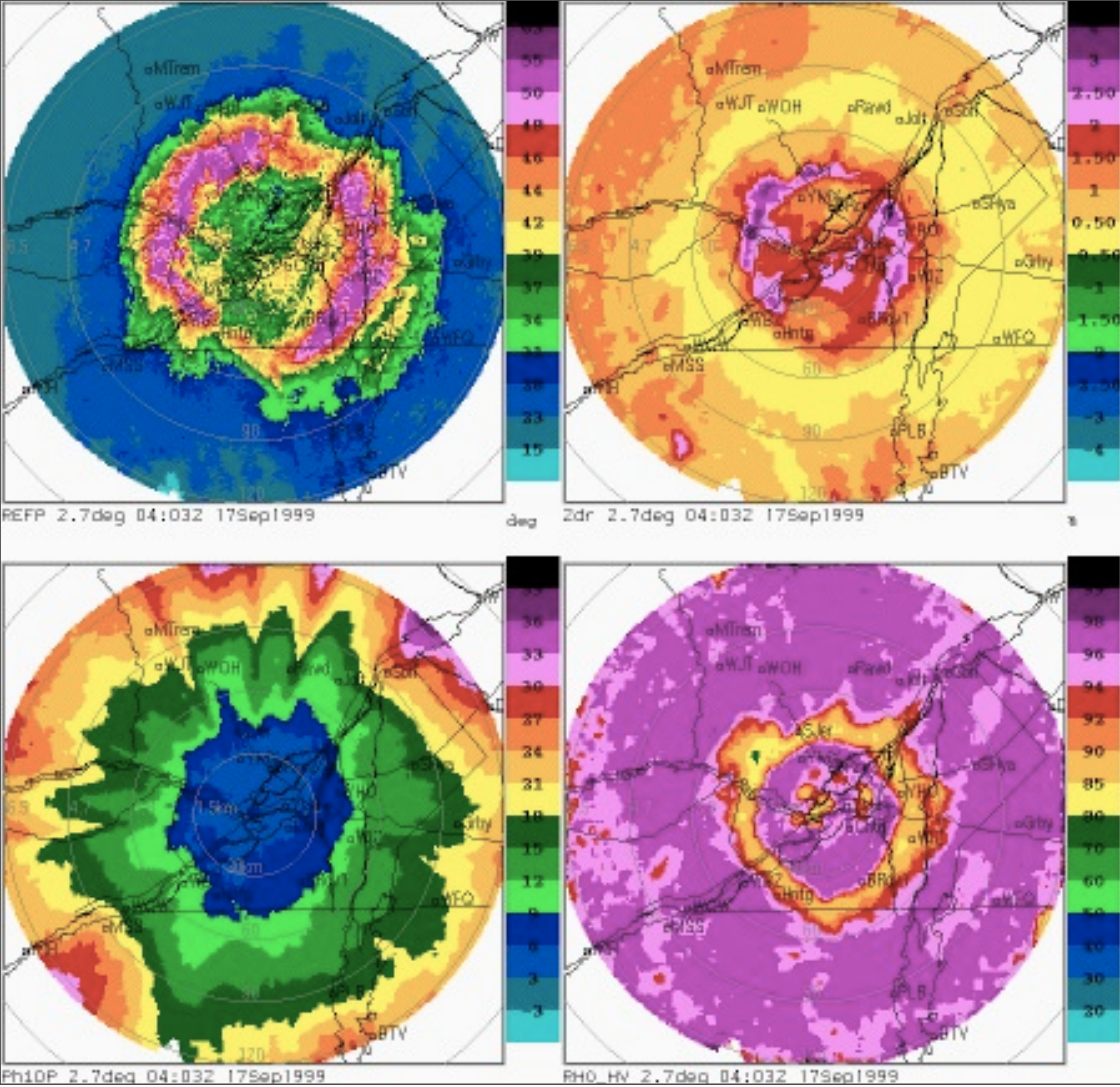


Polarimetric data at 6 rpm



The most important use of polarization diversity is target identification.

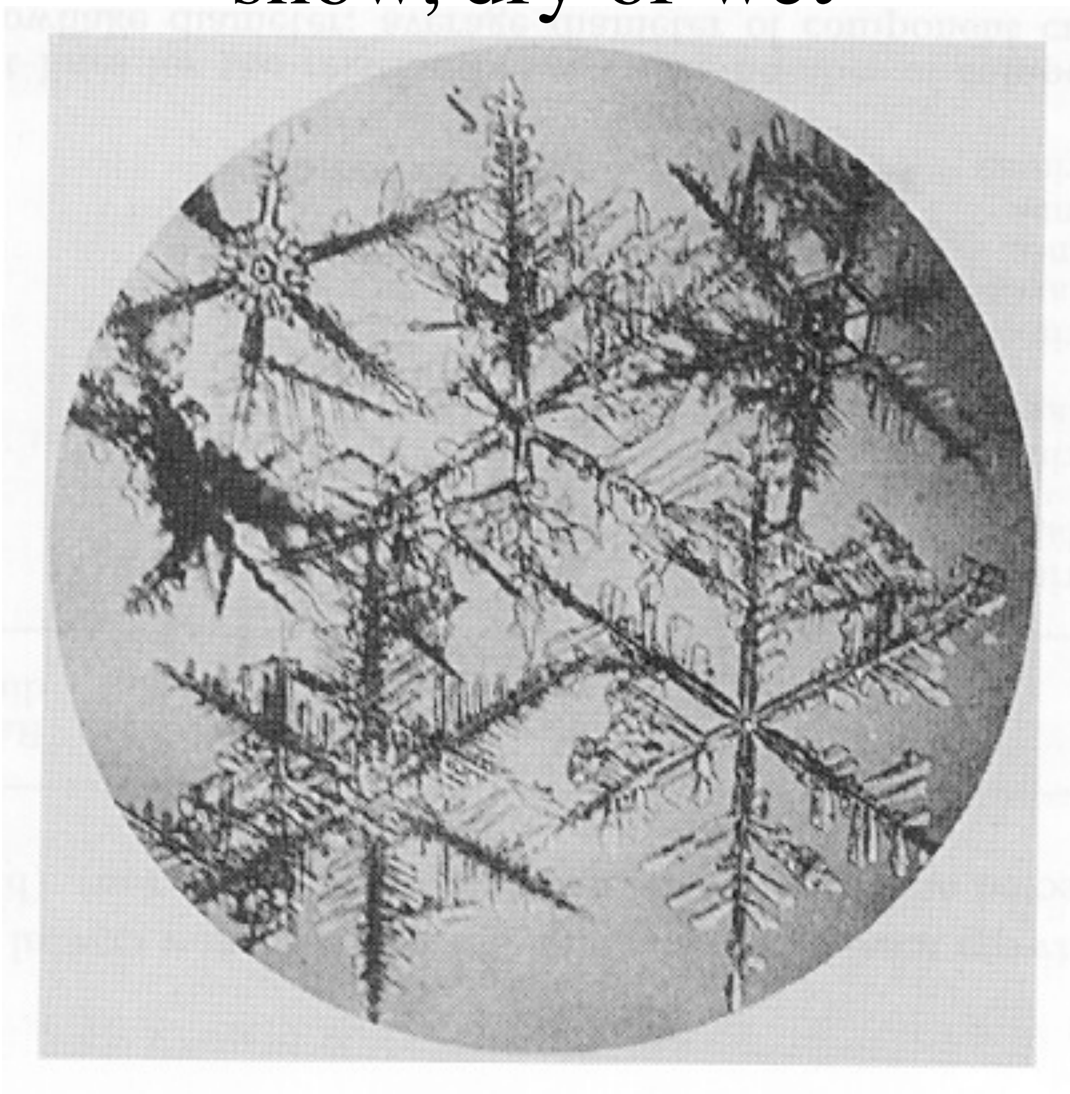
For C-band radars it is attenuation correction.

Detectable hydrometeores other than rain

snow, dry or wet

Detectable hydrometeores other than rain

snow, dry or wet



Detectable hydrometeores other than rain

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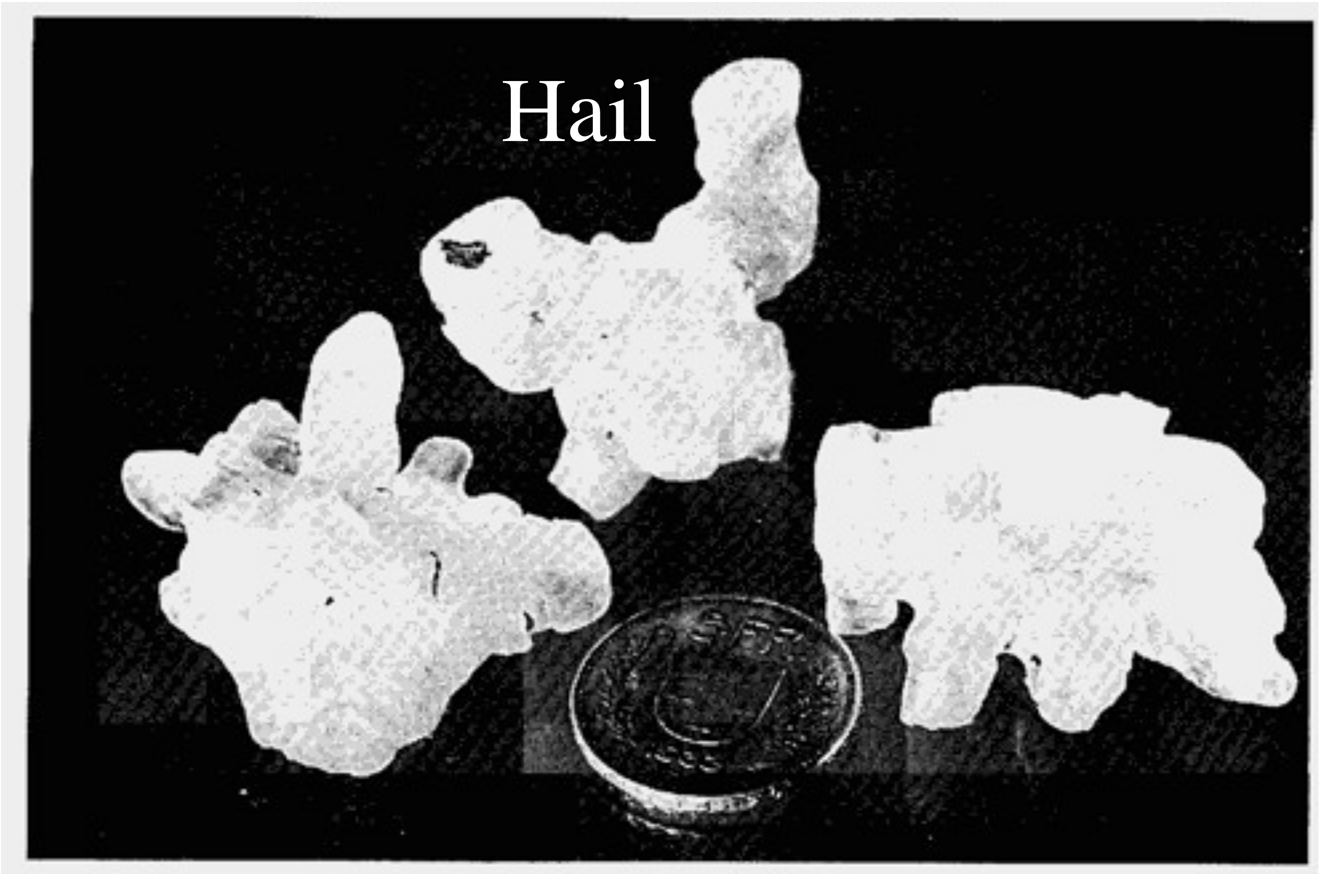
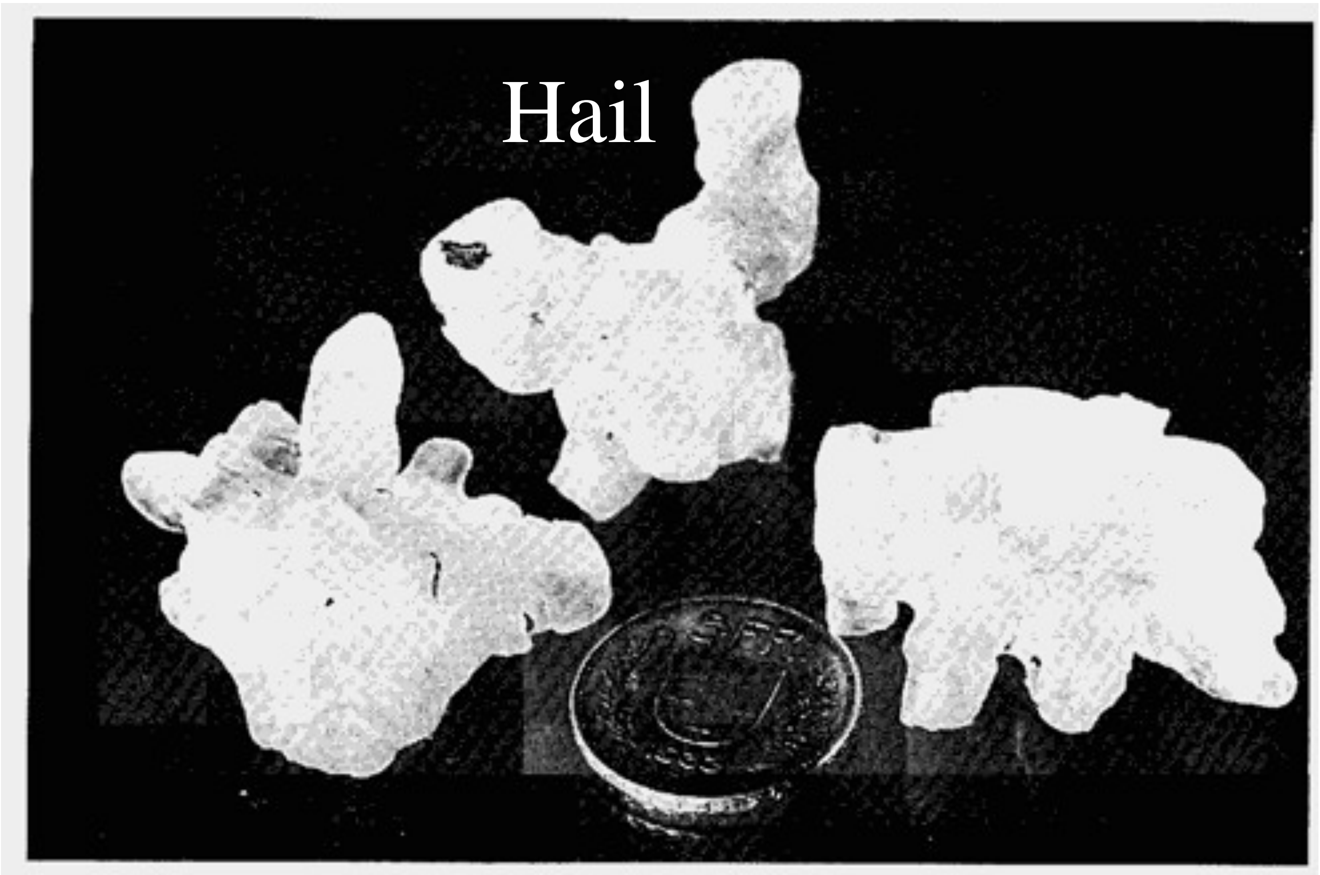
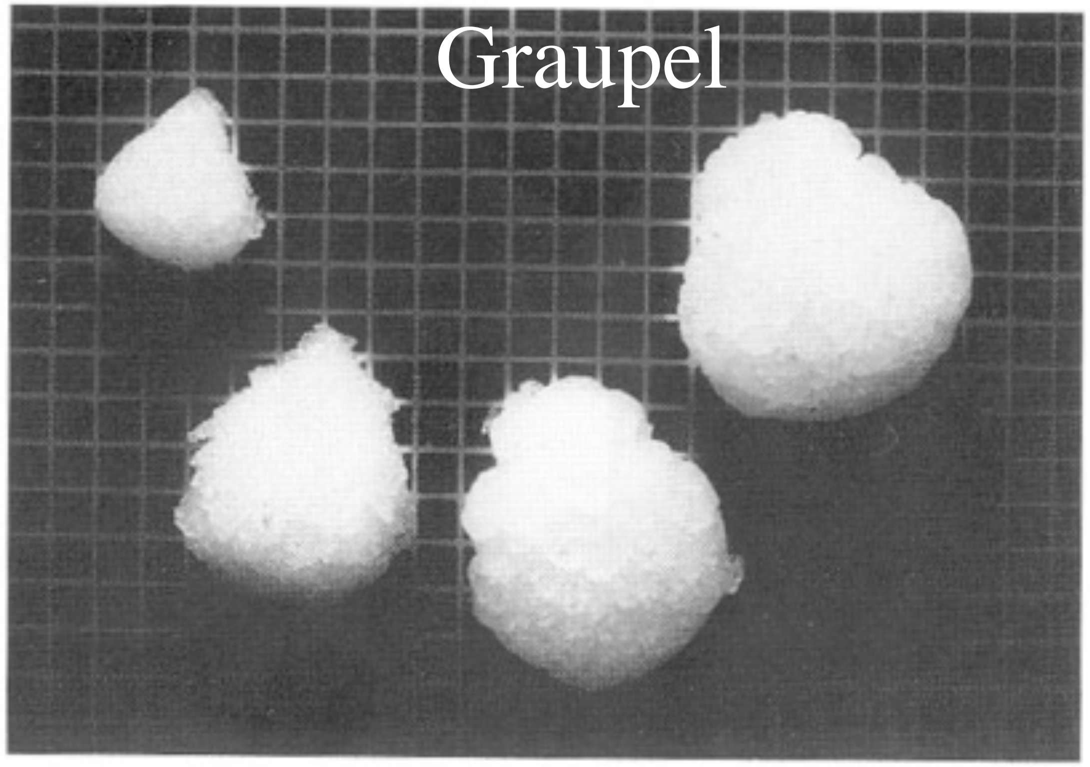


snow, dry or wet

From Pruppacher and Klett 1997

Detectable hydrometeores other than rain





snow, dry or wet

From Pruppacher and Klett 1997

Target ID - Particle Classification

Radar measurements used in algorithms

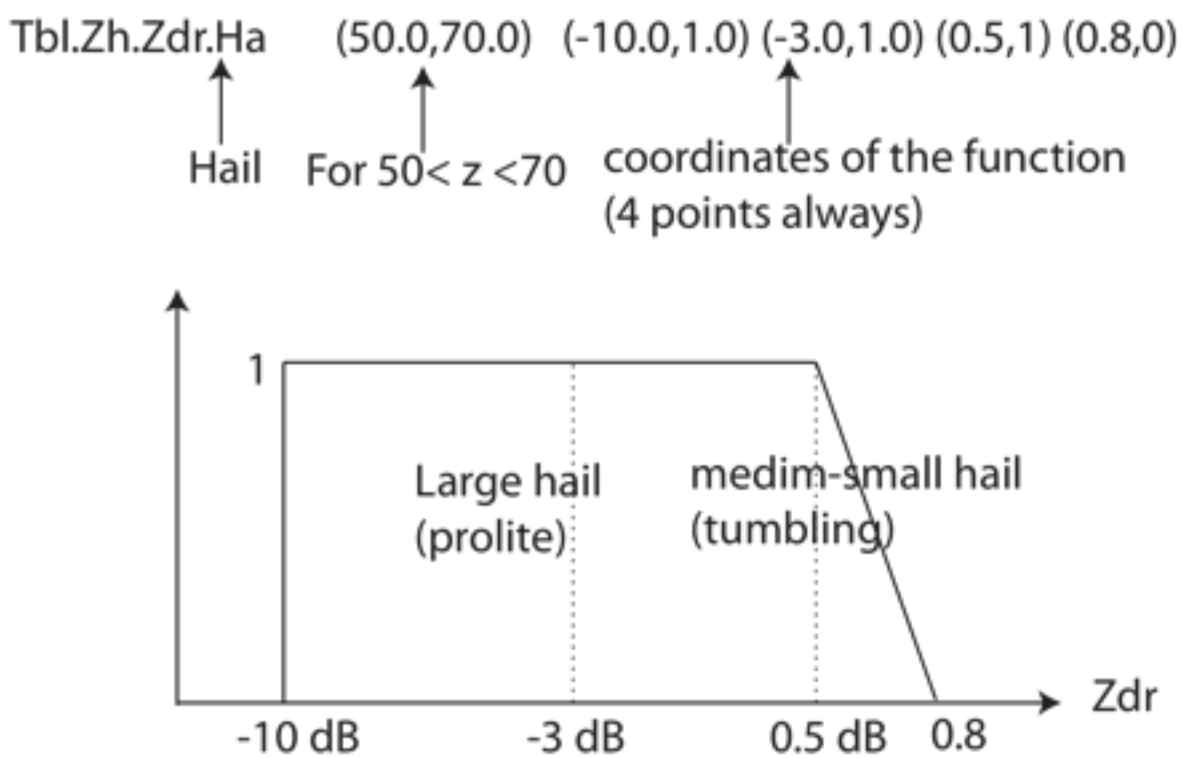
- Z
- Z_{DR}
- K_{DP}
- ρ_{HV}

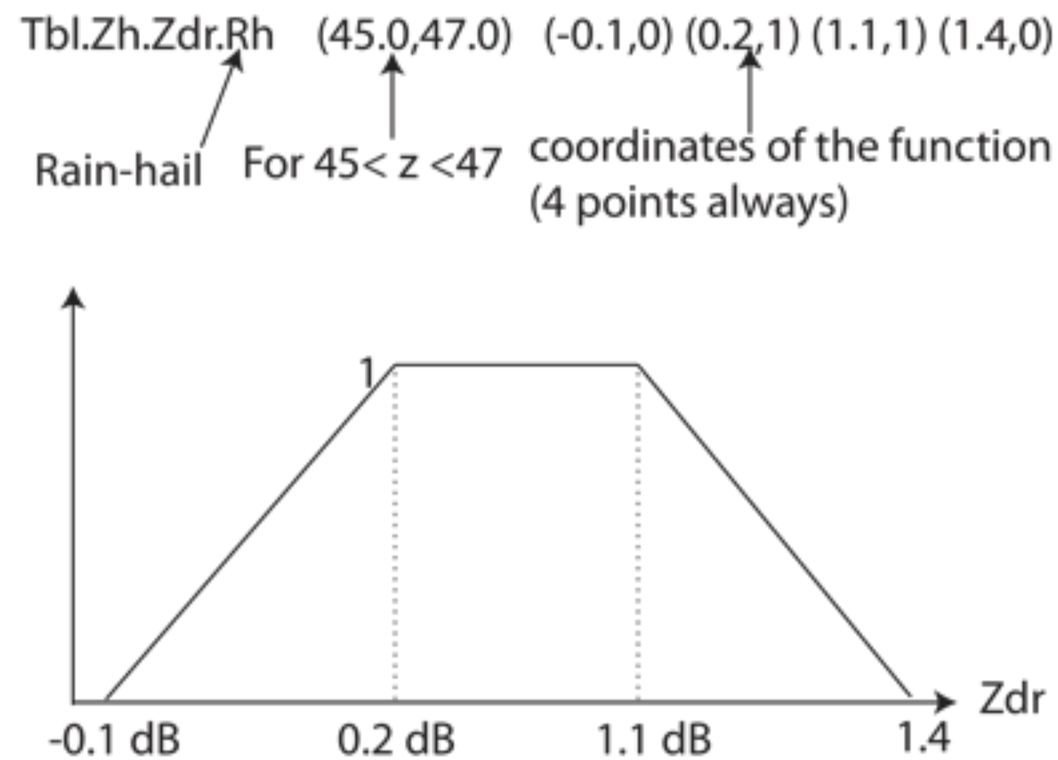
- Temperature – from soundings (Maniwaki (WMW) and Albany (ALB)Aircraft soundigns, model outputs
- Derived quantities (for ground clutter identification)
  - $\sigma(\Phi_{DP})$
  - $\sigma(V)$
  - $\sigma(Z_{DR})$

Automatic detection of hydrometeor type from polarimetry using fuzzy logic

Membership functions

Example Z_{DR} membership for hail and rain-hail:





For each parameter these functions give a membership value: $0 < P_H^{ZDR} < 1$, in the example of Z_{DR} membership for hail, and $0 < P_{RH}^{ZDR} < 1$ for rain-hail

Particle Classification

Take a weighted average of these values for each particle type i:

P_H^{Zdr}

P_H^{Z}

$P_H^{\rho hv}$

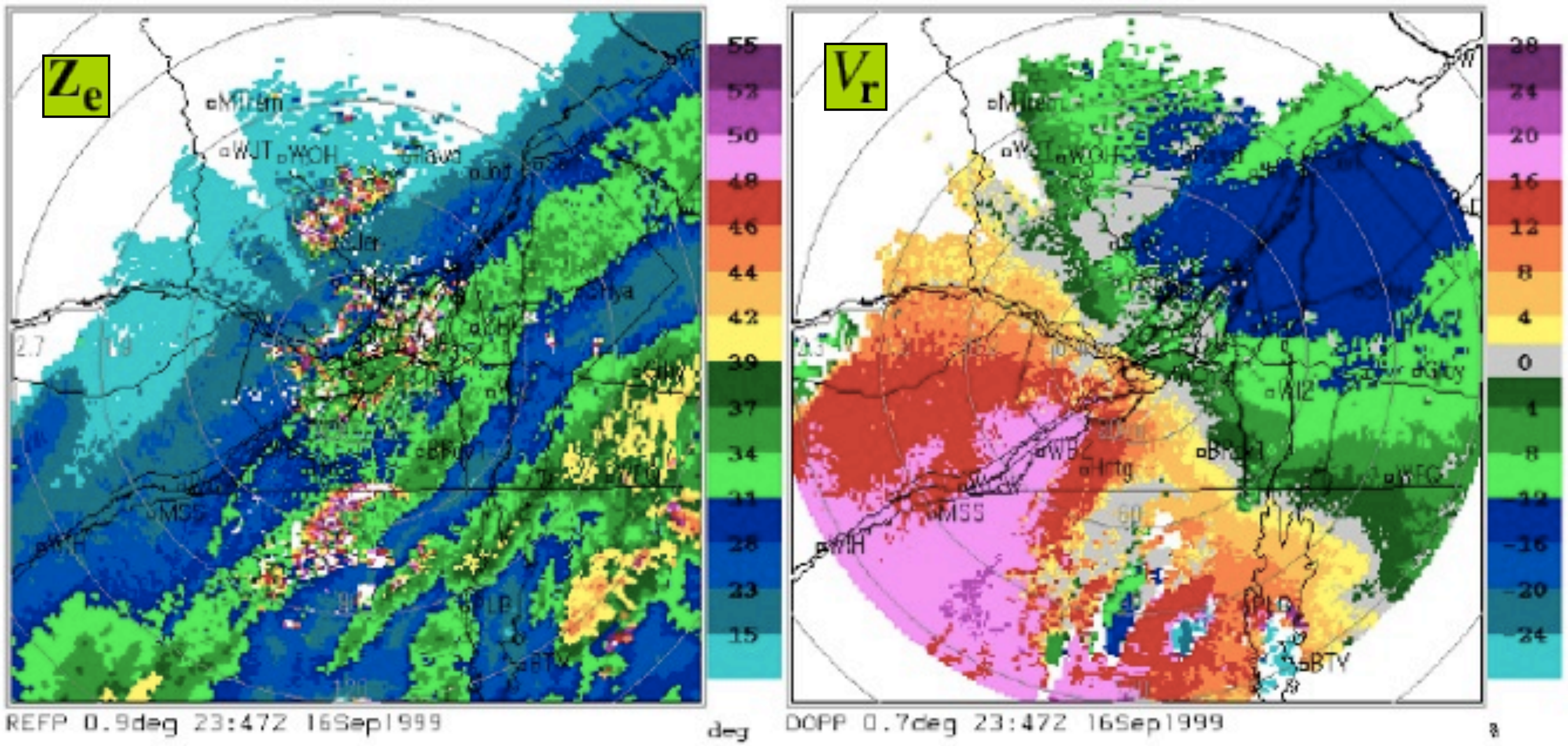
P_H^{Kdp}

$$Q_H = \sum_{j=1}^{4} P_H W_j \Rightarrow \mathfrak{M}ax\, Q_i \rightarrow particle\ type$$

IDENTIFICATION OF ARTIFACTS, etc. (on a 0.9º PPI)

Is it all rain?

BEFORE DUAL POLARIZATION



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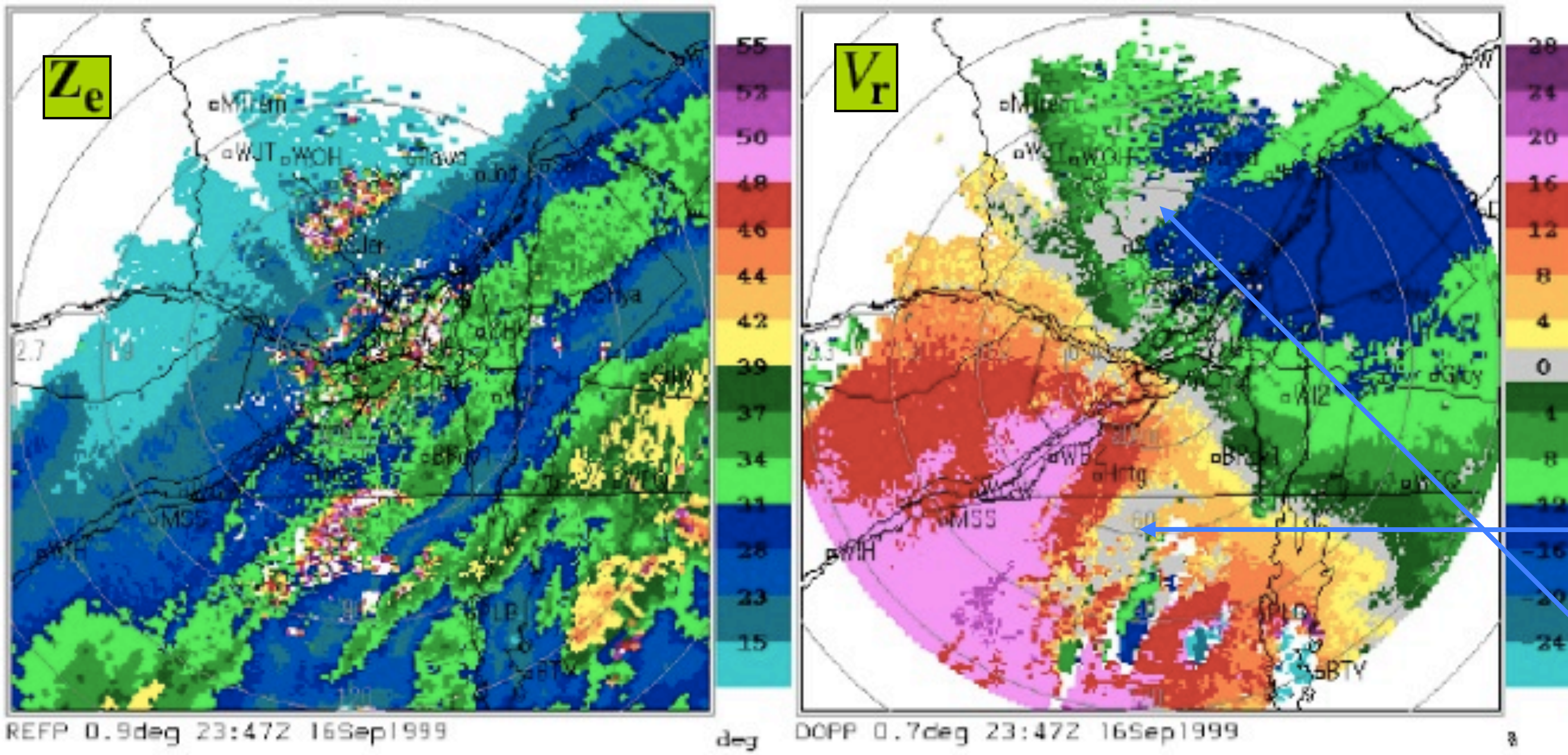

GROUND CLUTTER (identified By zero Doppler velocity)

IDENTIFICATION OF ARTIFACTS, etc. (on a 0.9º PPI)

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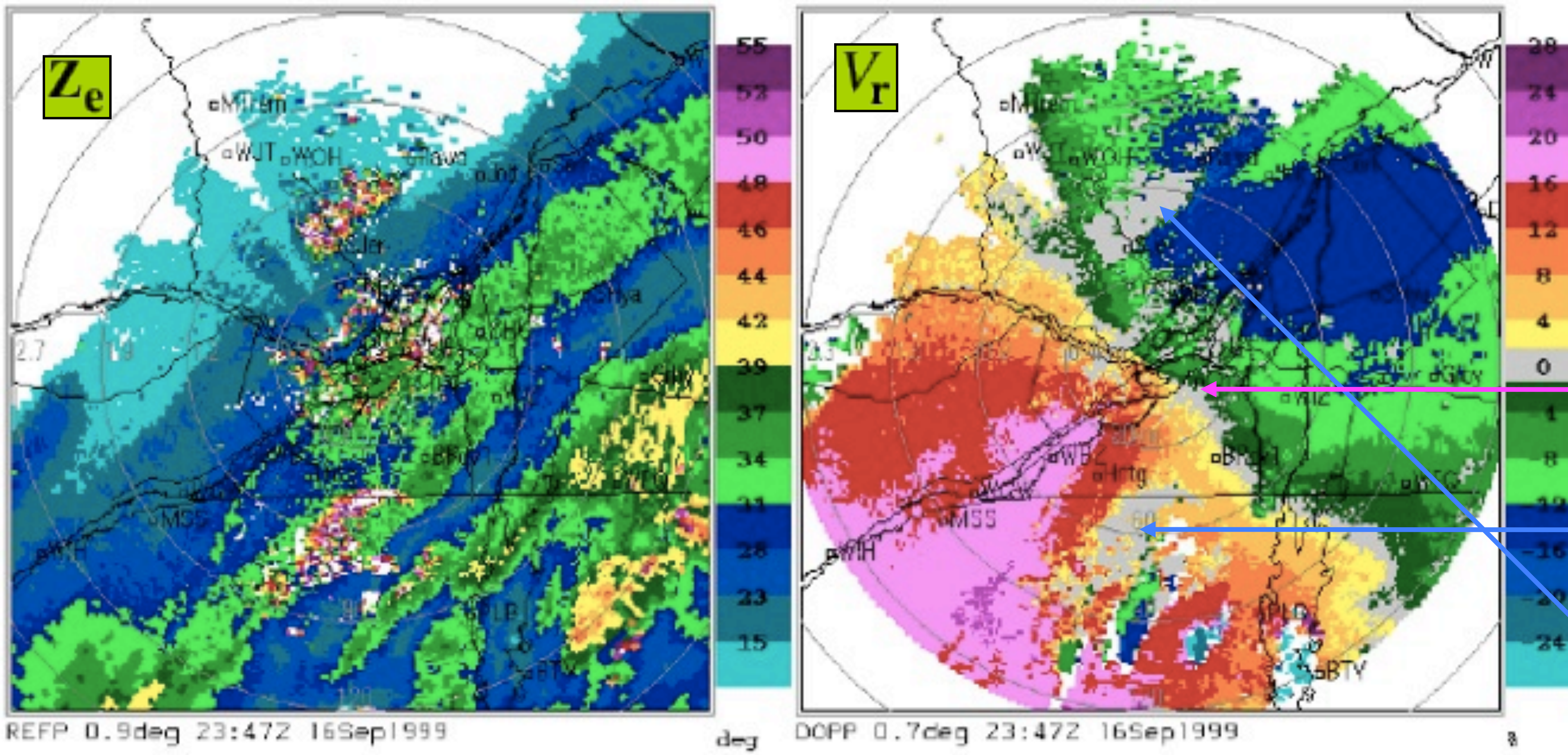
BEFORE DUAL POLARIZATION



But zero Doppler velocity is also found in precipitation.

GROUND CLUTTER (identified By zero Doppler velocity)

IDENTIFICATION OF ARTIFACTS, etc. (on a 0.9º PPI)

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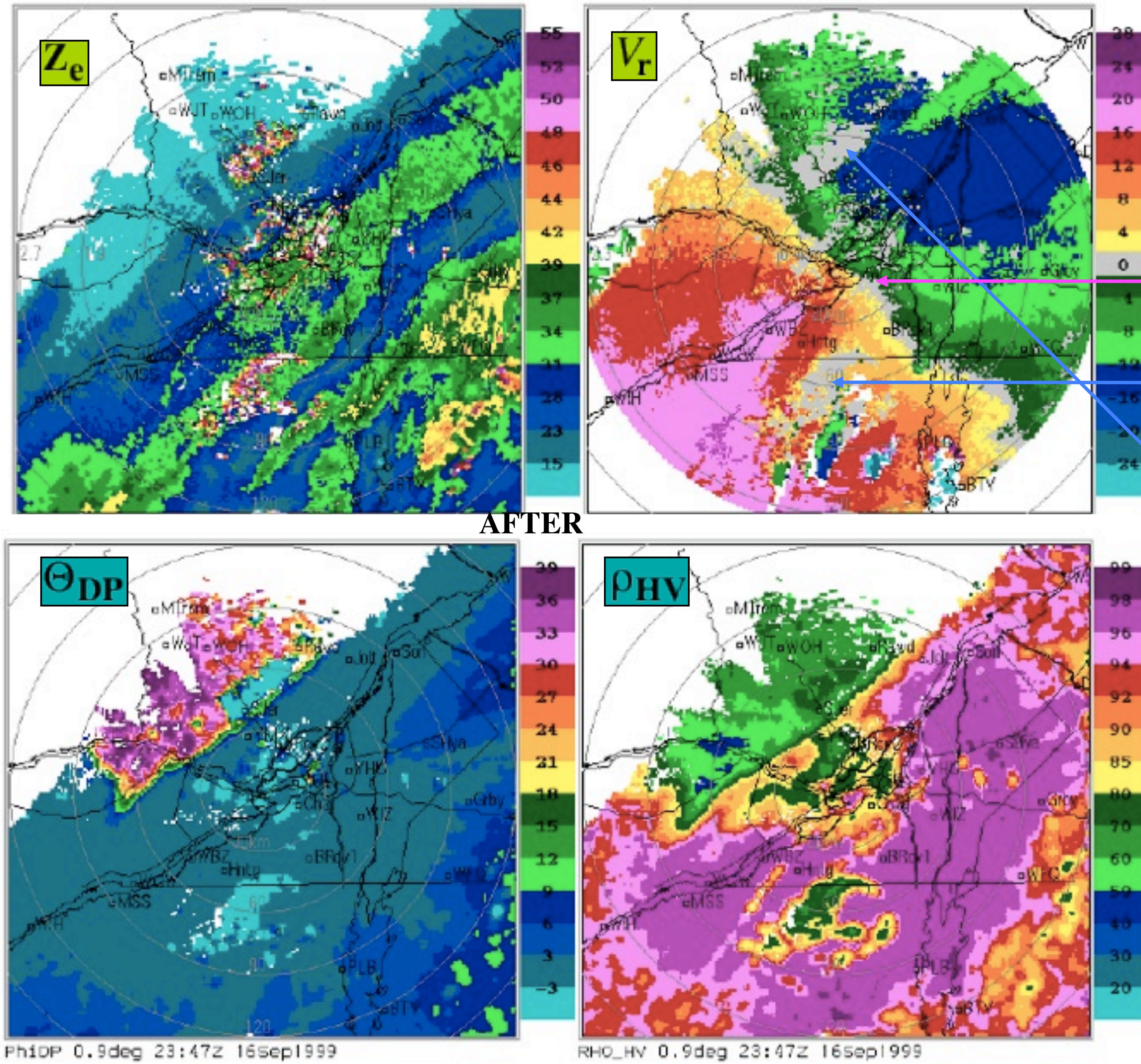
BEFORE DUAL POLARIZATION



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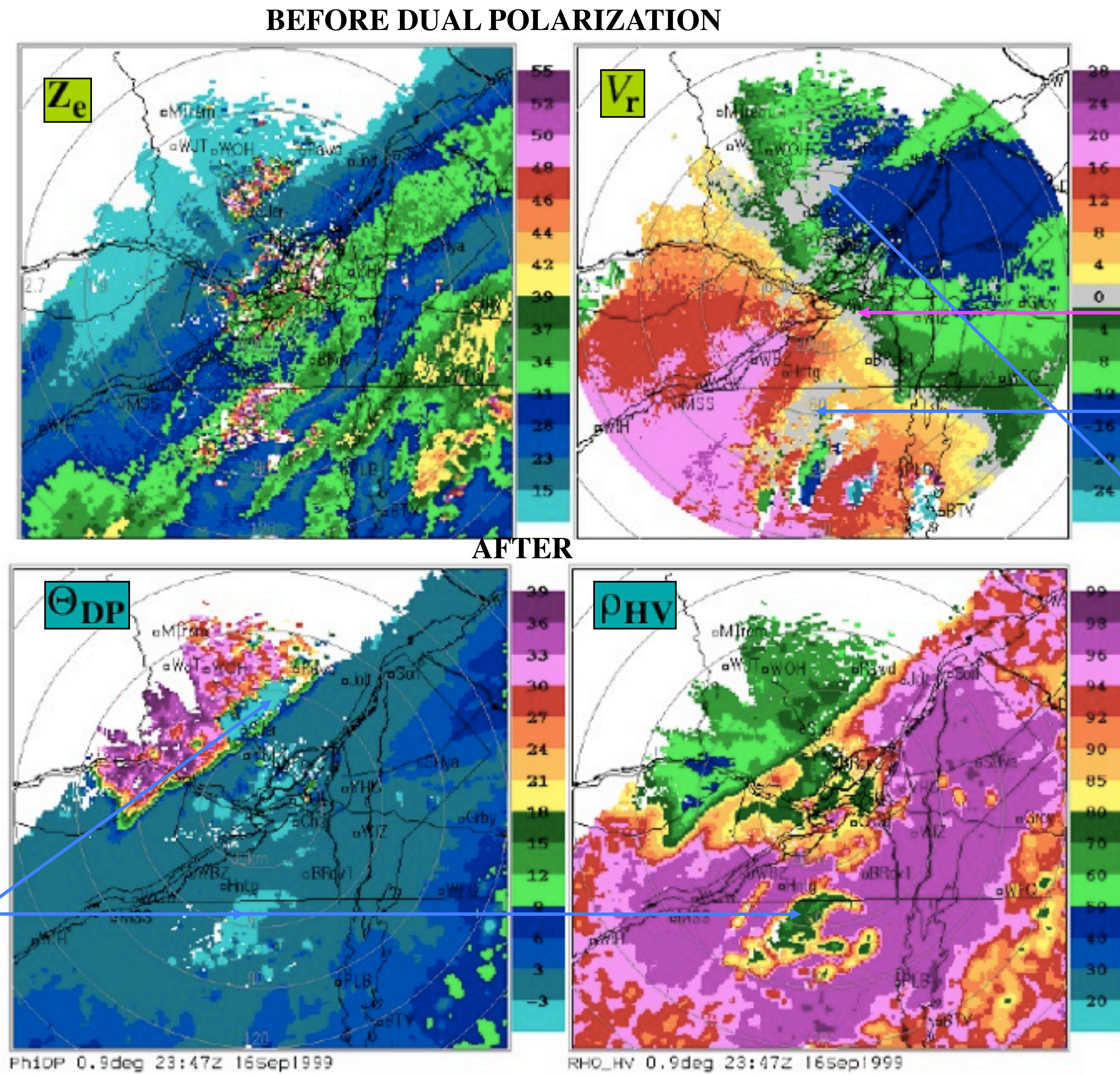

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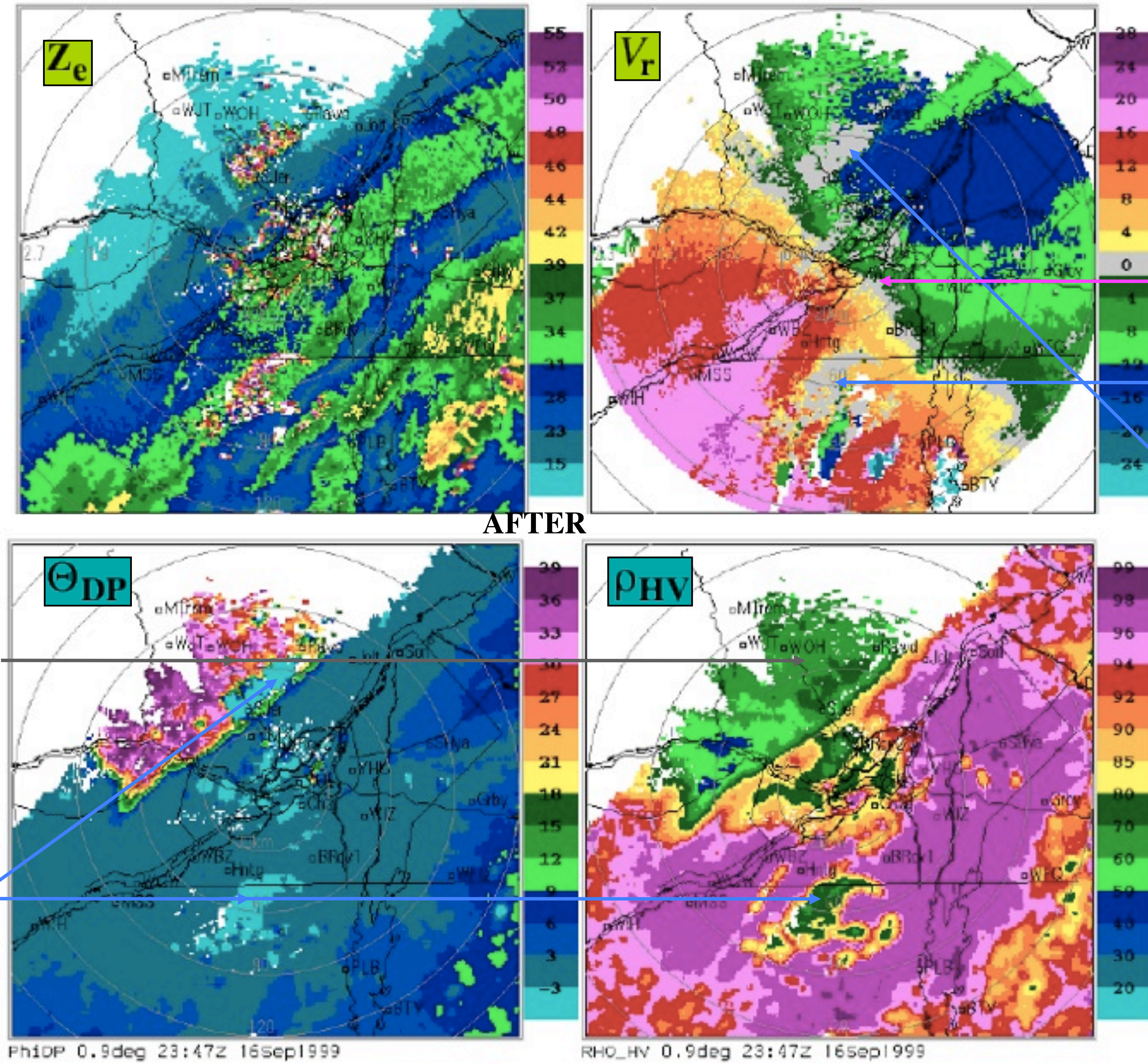

But zero Doppler velocity is also found in precipitation.

GROUND CLUTTER (identified By zero Doppler velocity)

More likely birds taking advantage of the good winds.

GROUND CLUTTER

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BEFORE DUAL POLARIZATION

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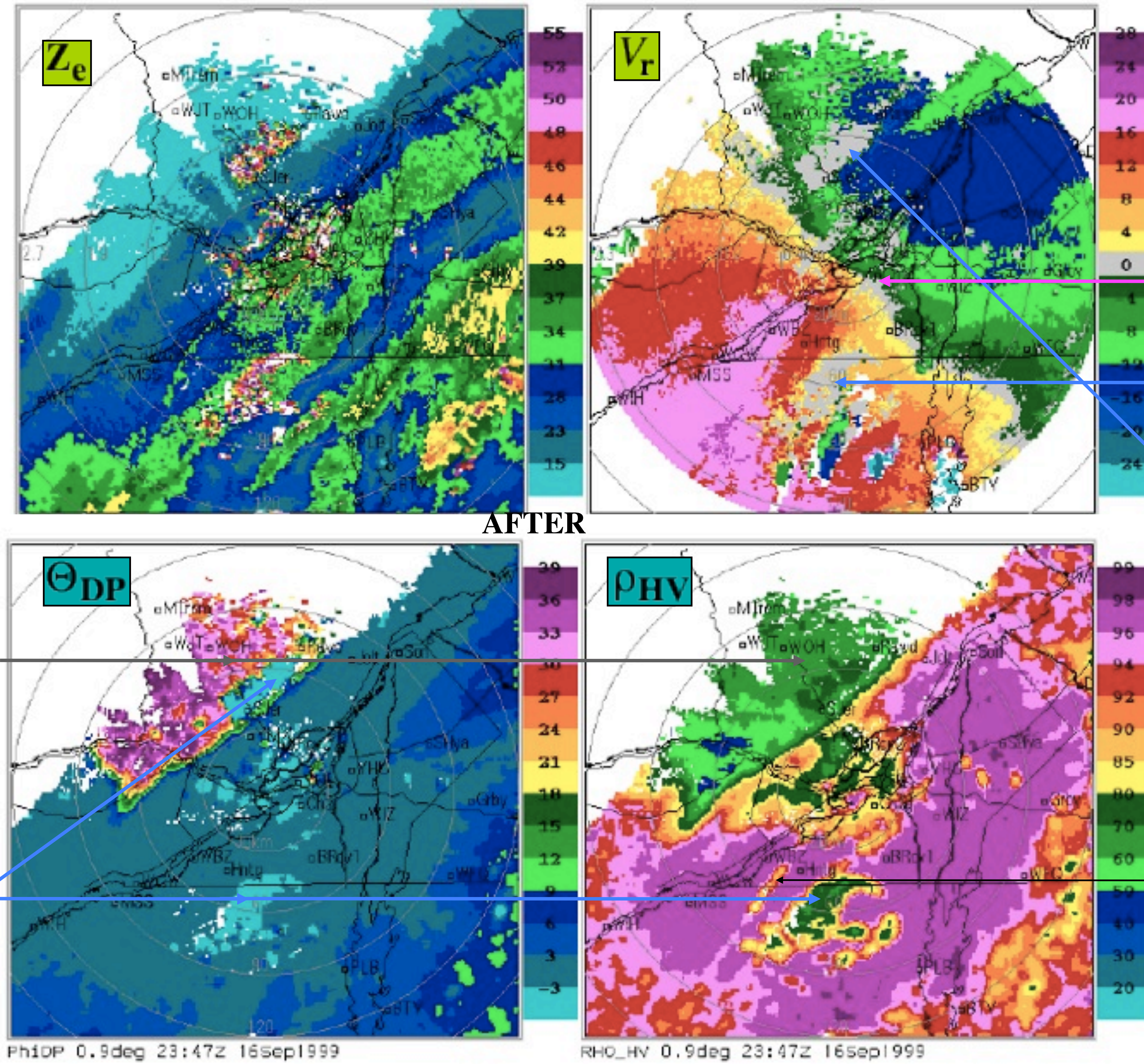

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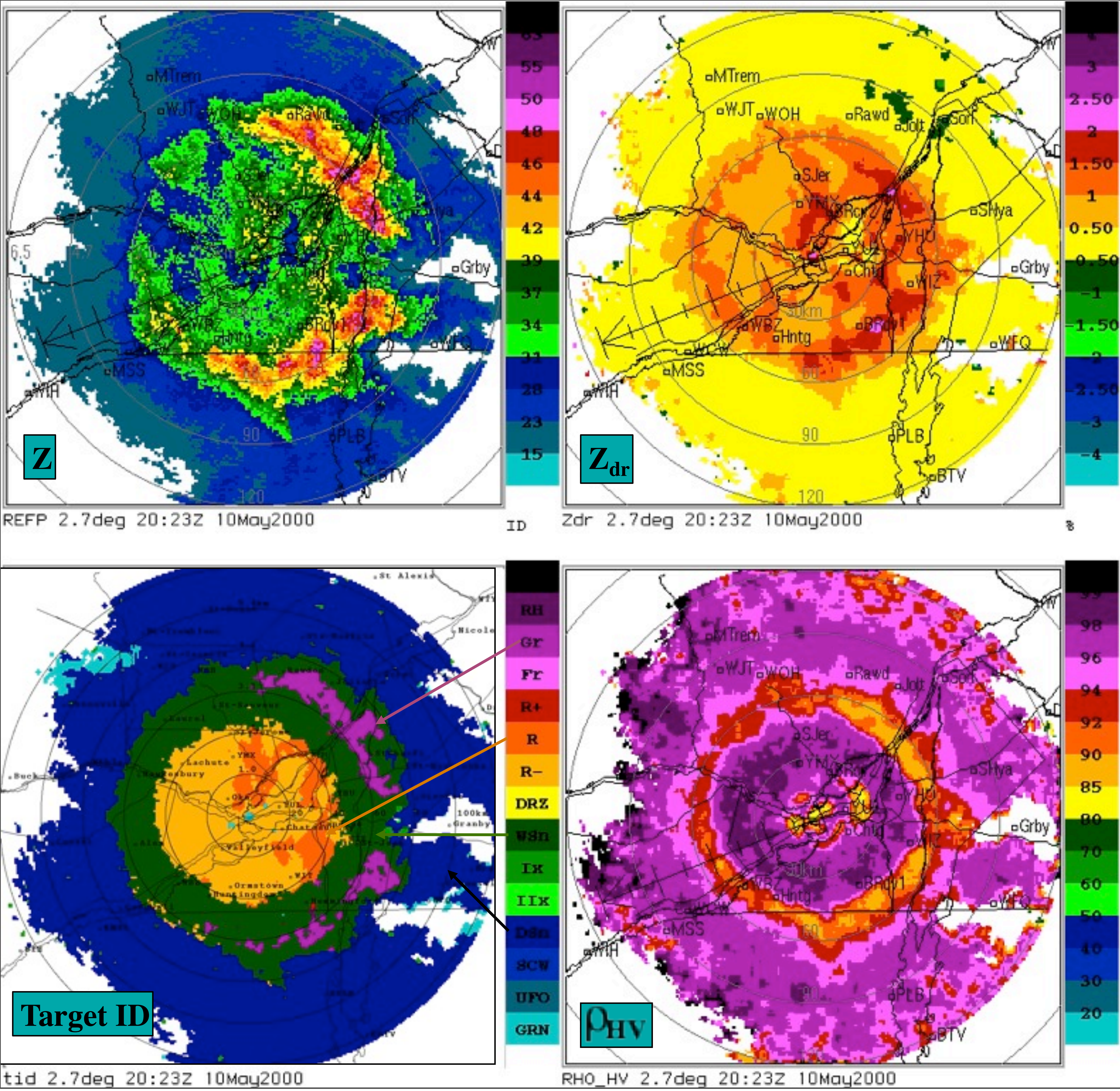
GROUND CLUTTER

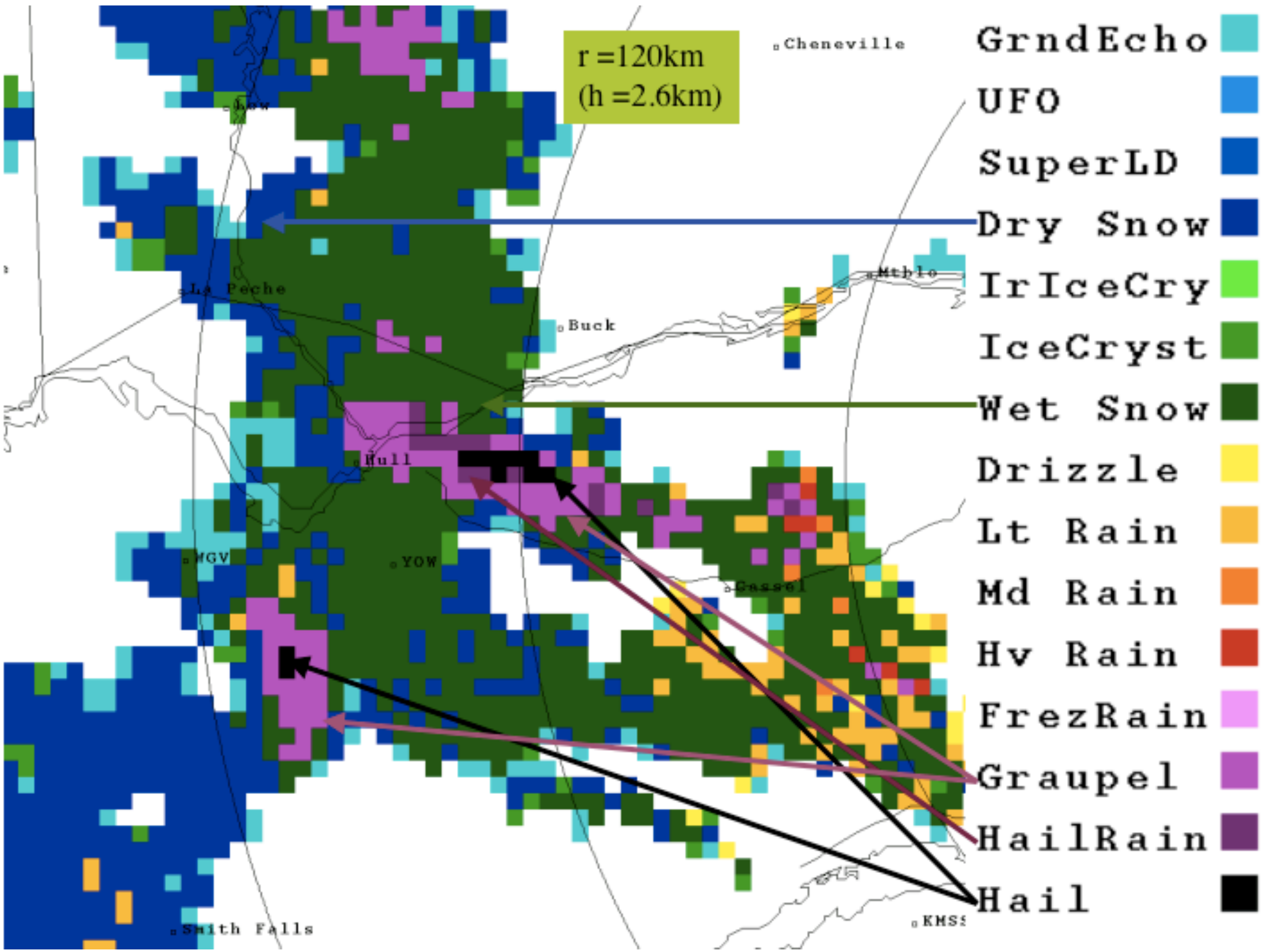
Partial beam blocking by a nearby building

2.7^0 PPI in stratiform precipitation

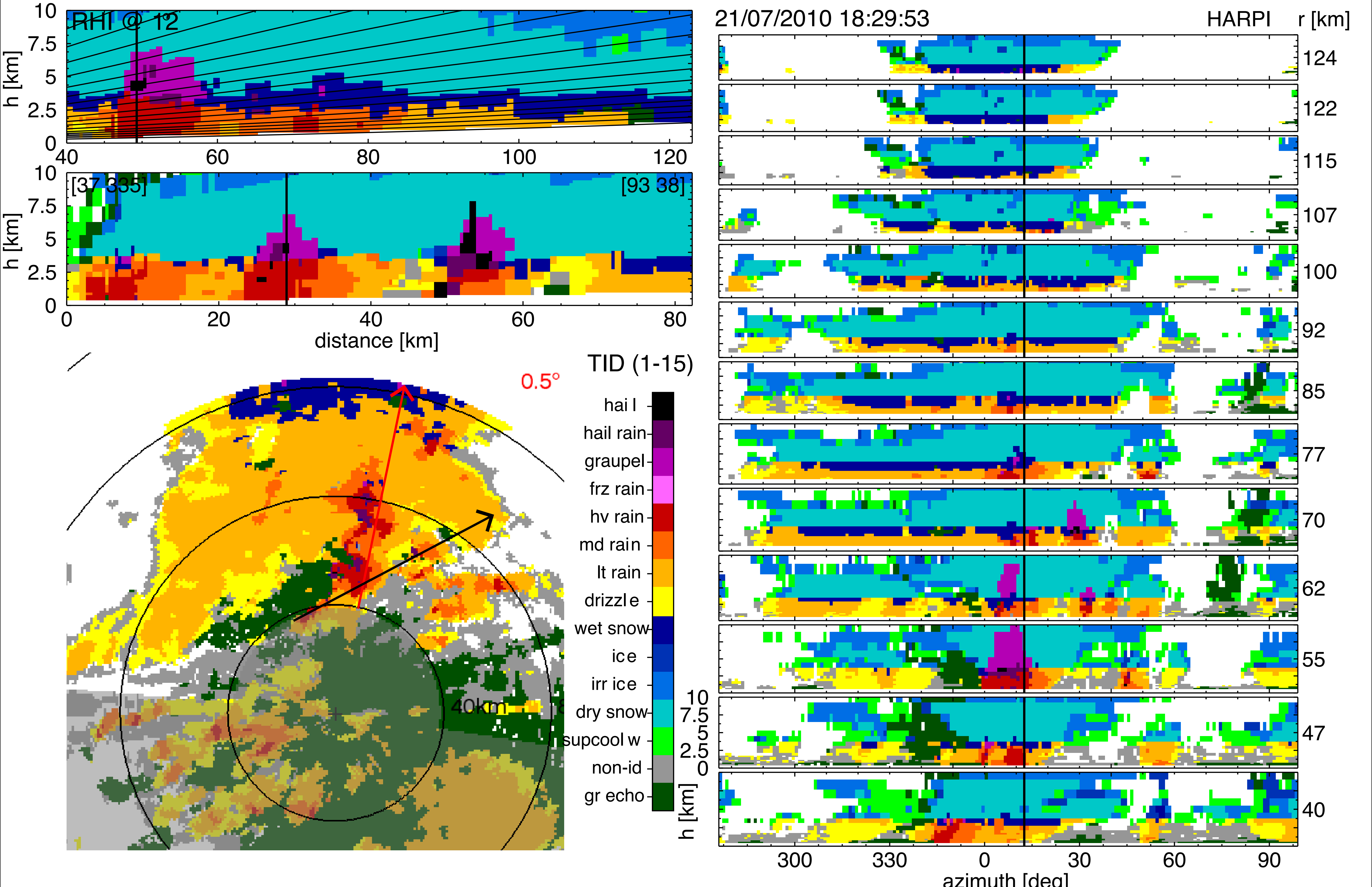


Friday, 9 August, 13

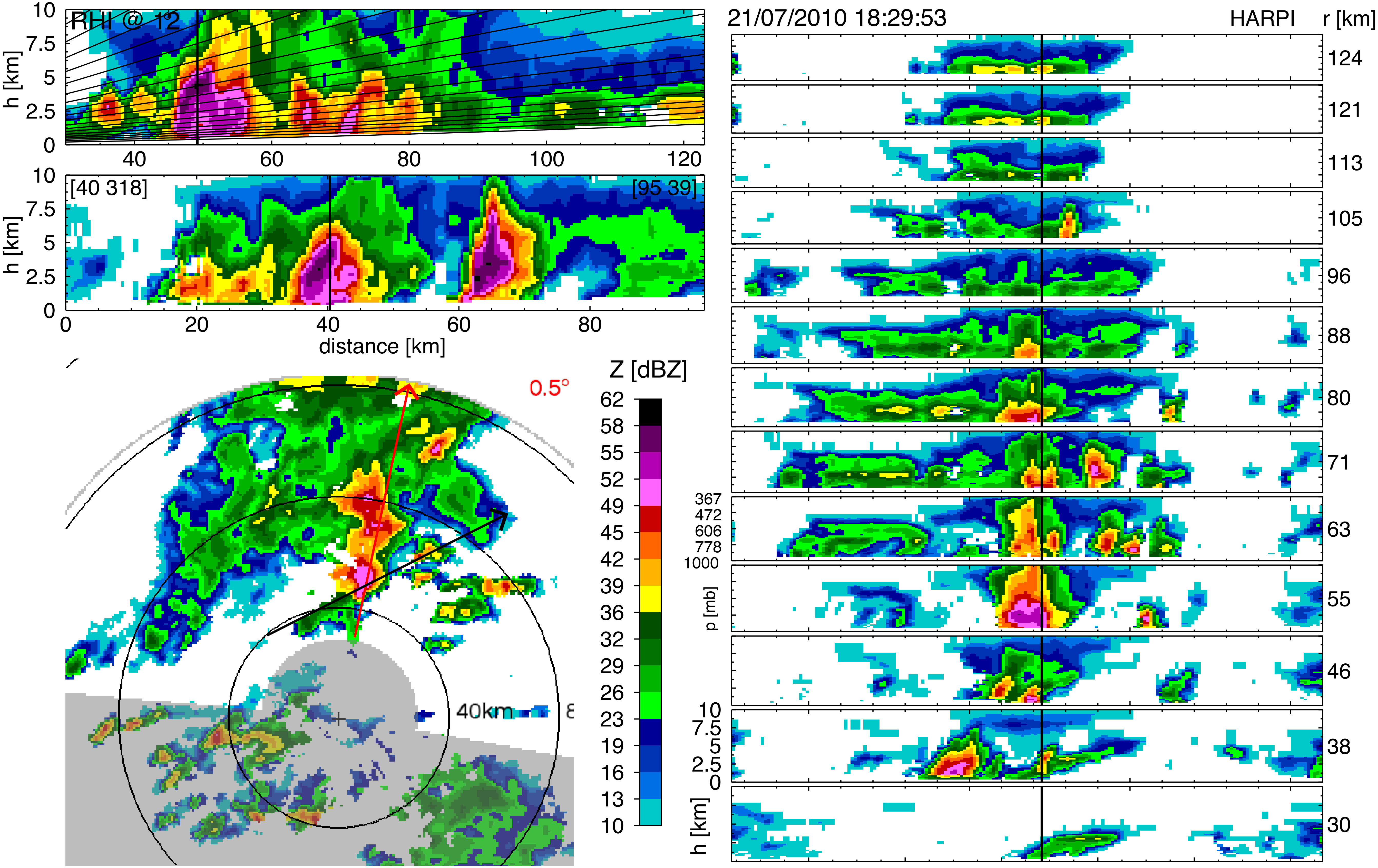
Target ID by polarimetry



Data cleaning

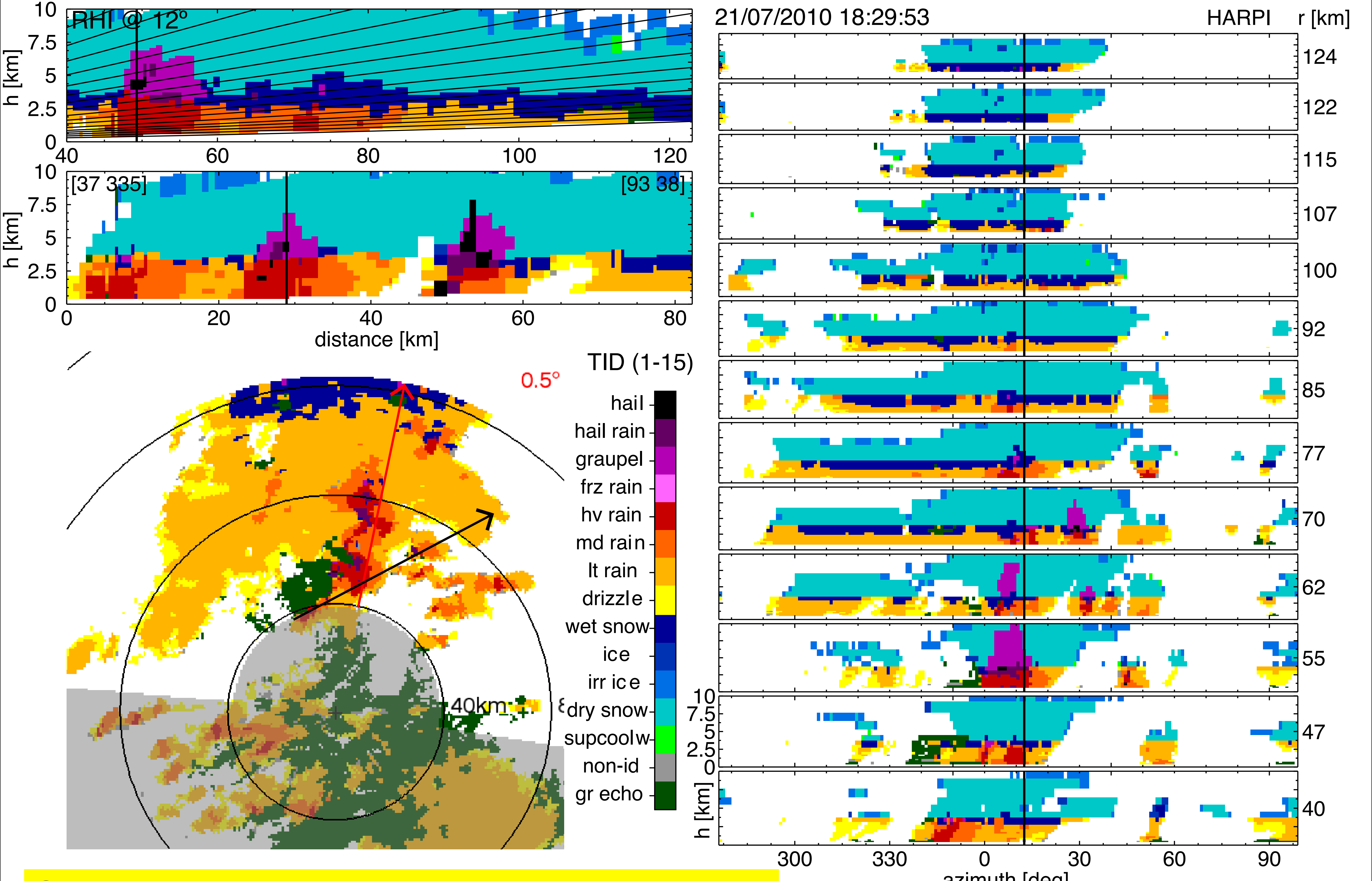


Data cleaning



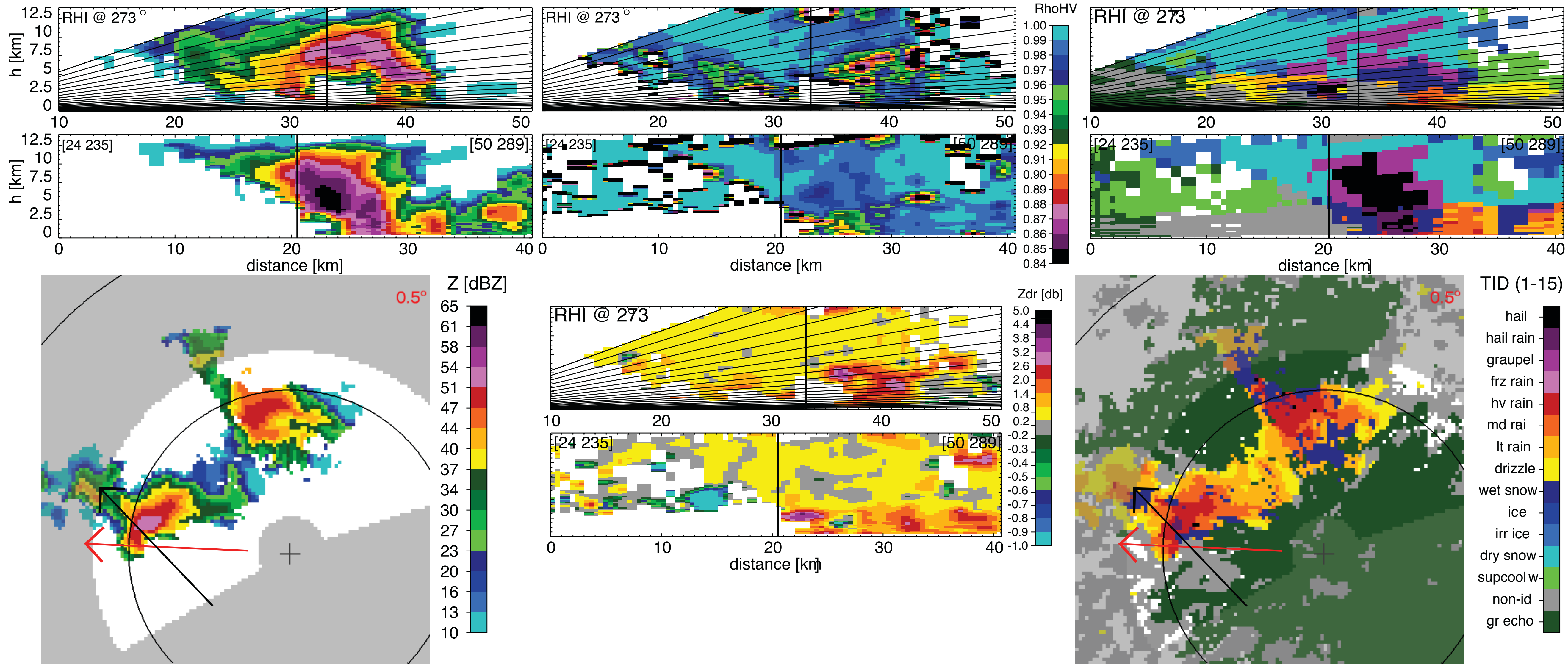
Sensitivity thresholds are added to select good data

Data cleaning

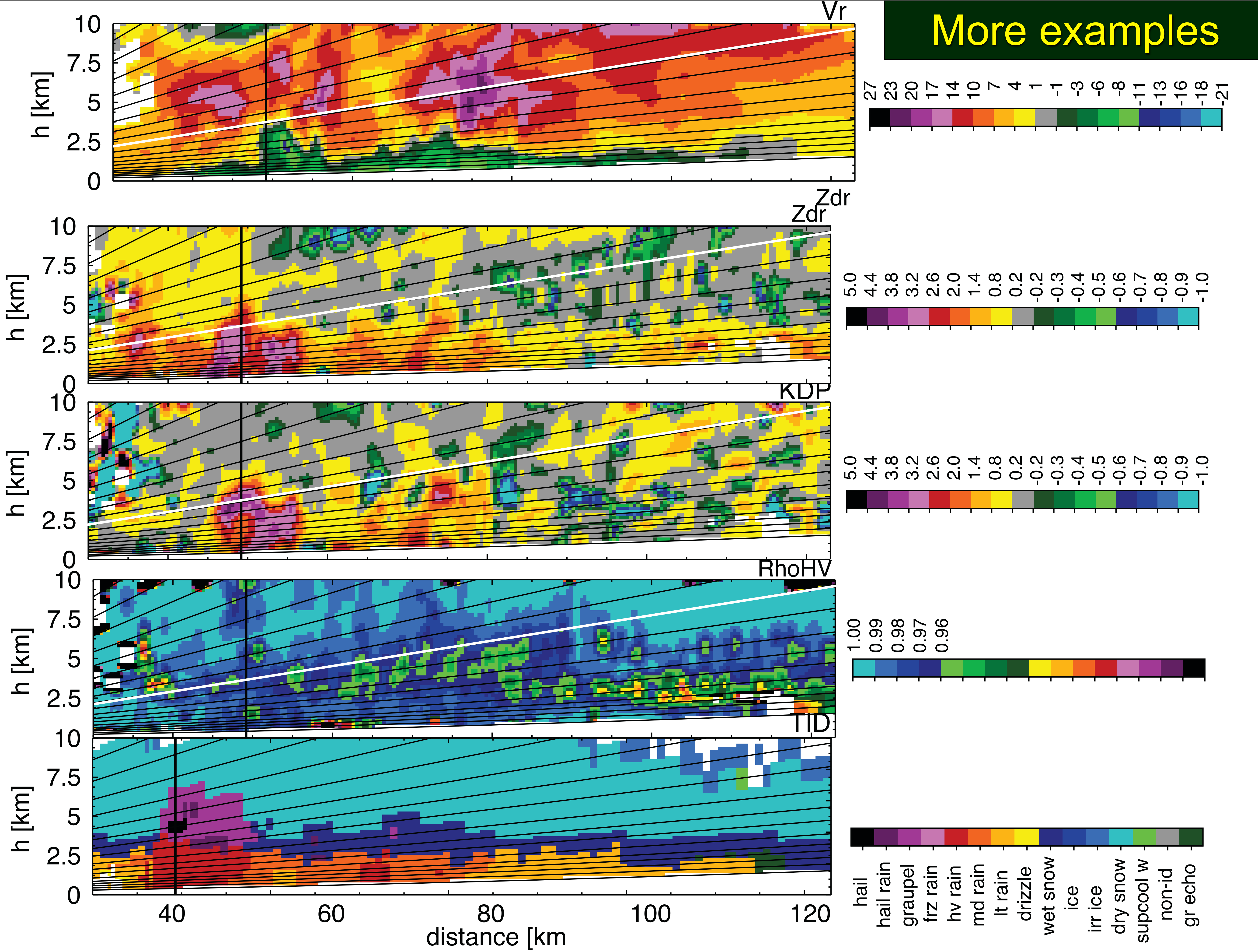


Sensitivity thresholds are added to select good data

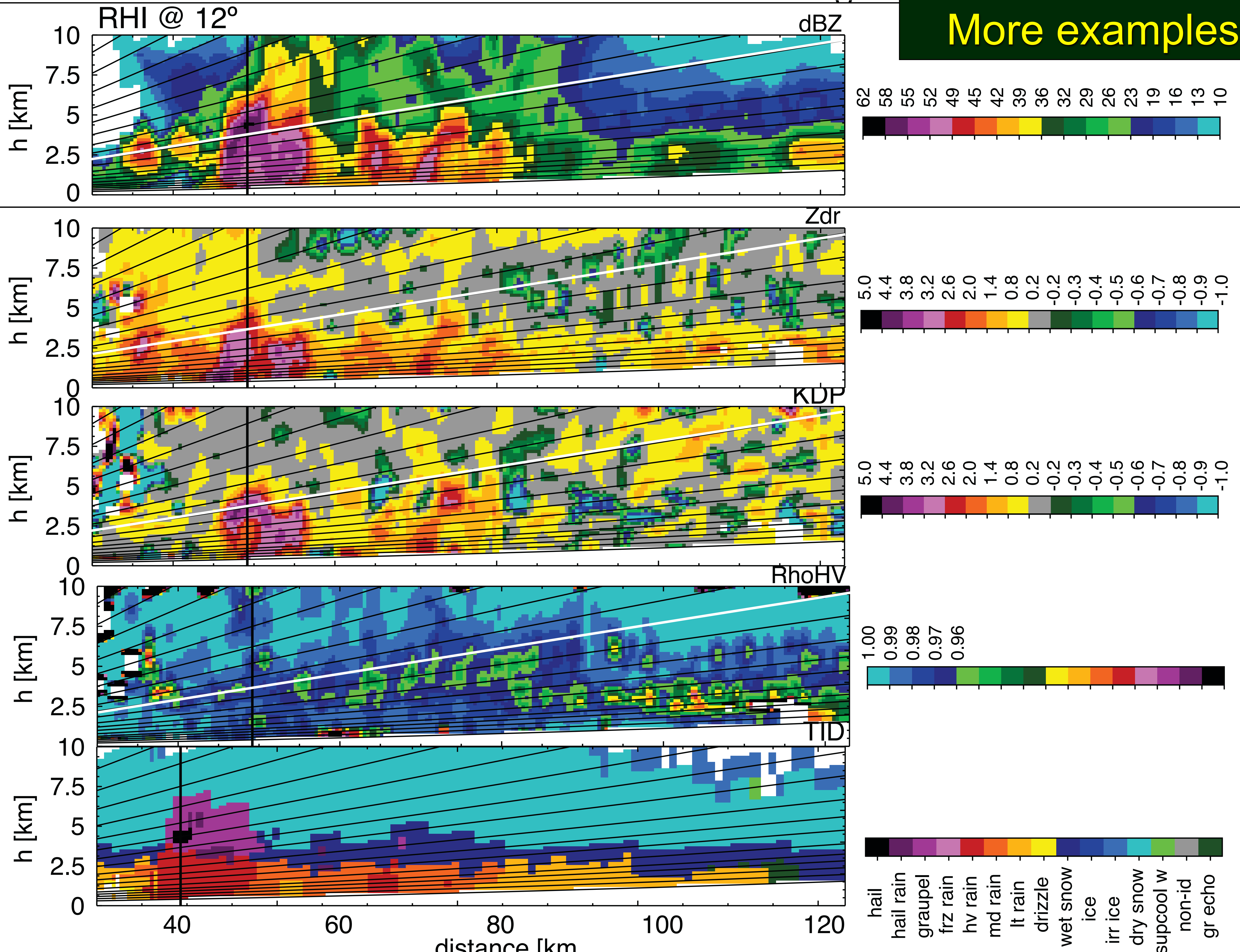
Automatic detection of hydrometeor type from polarimetry



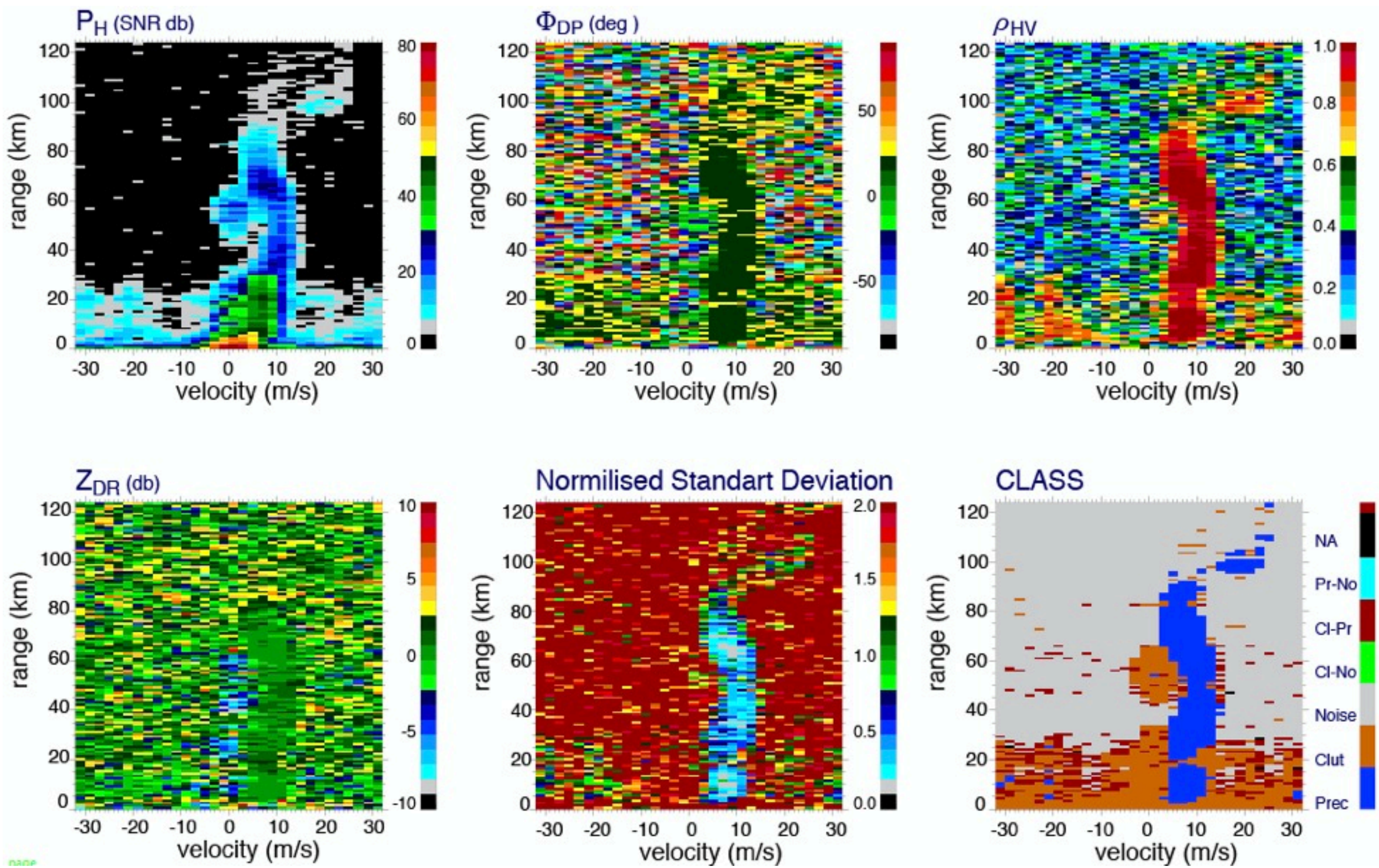
More examples



More examples



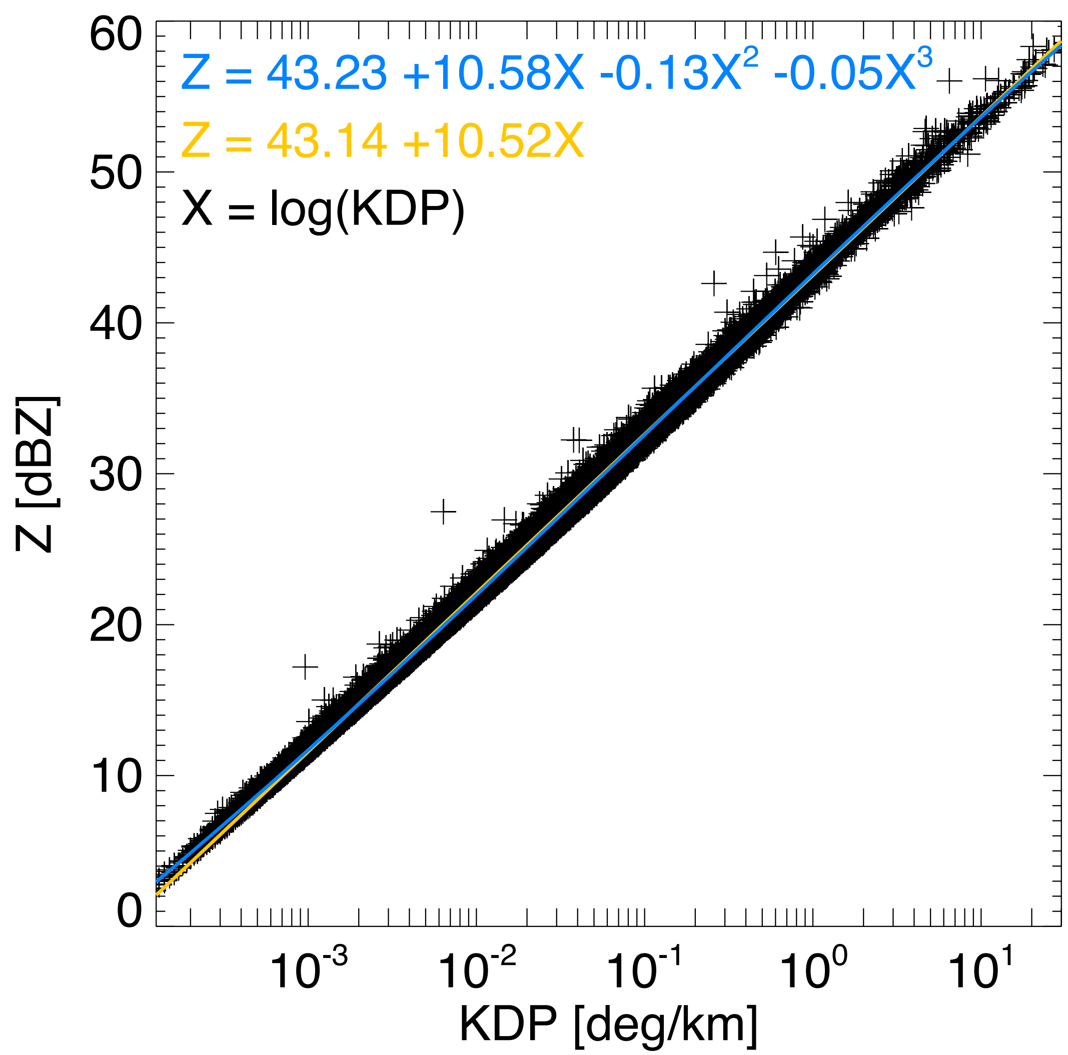
Still better signal processing



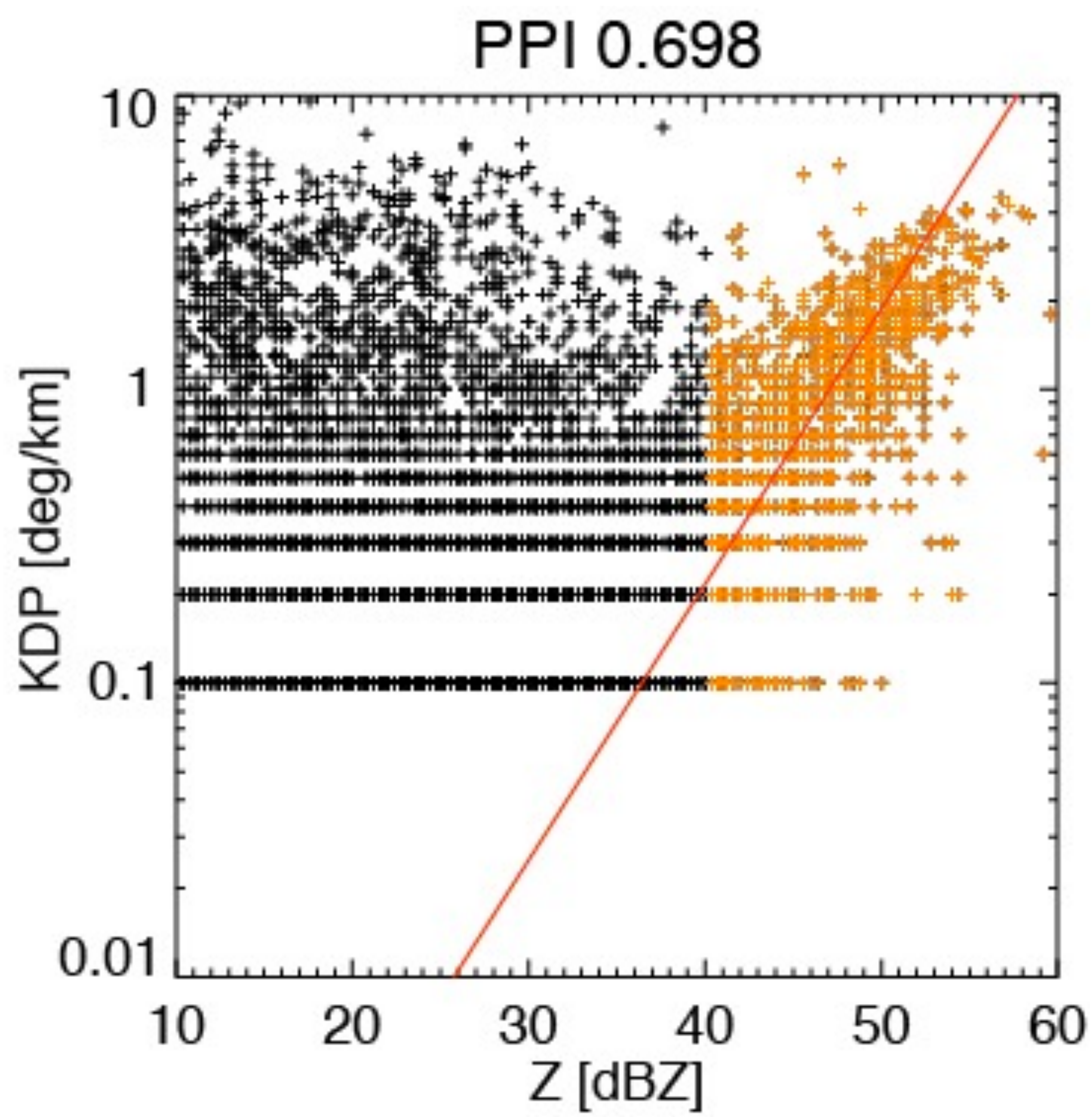
Polarimetry and precipitation measurements

KDP as alternative to Reflectivity

Computed from DSDs



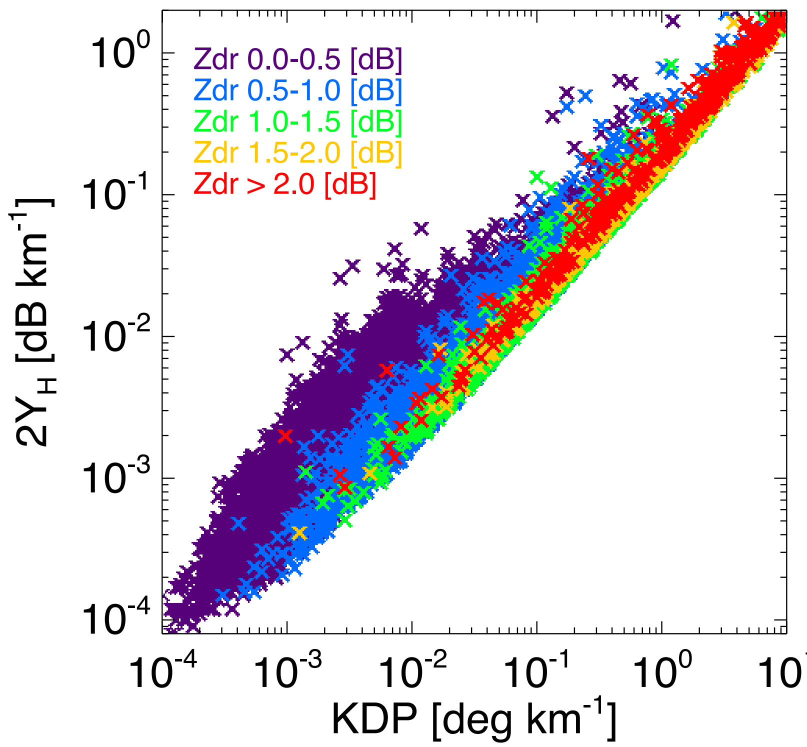
Measured by an S-Band radar

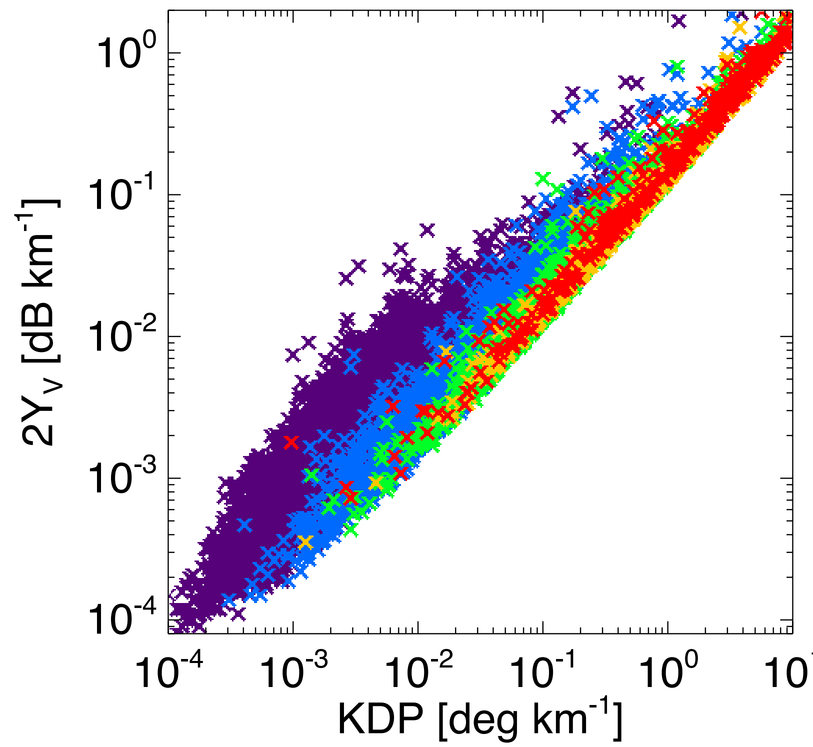


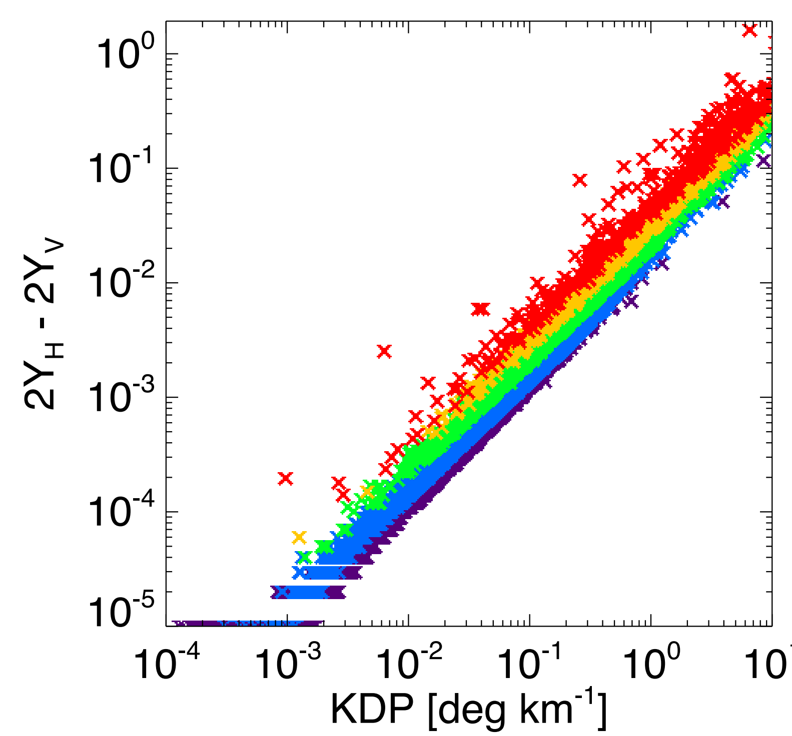
Specific attenuation computed from DSDs

Y_H [dB/km]: specific attenuation at horizontal polarization

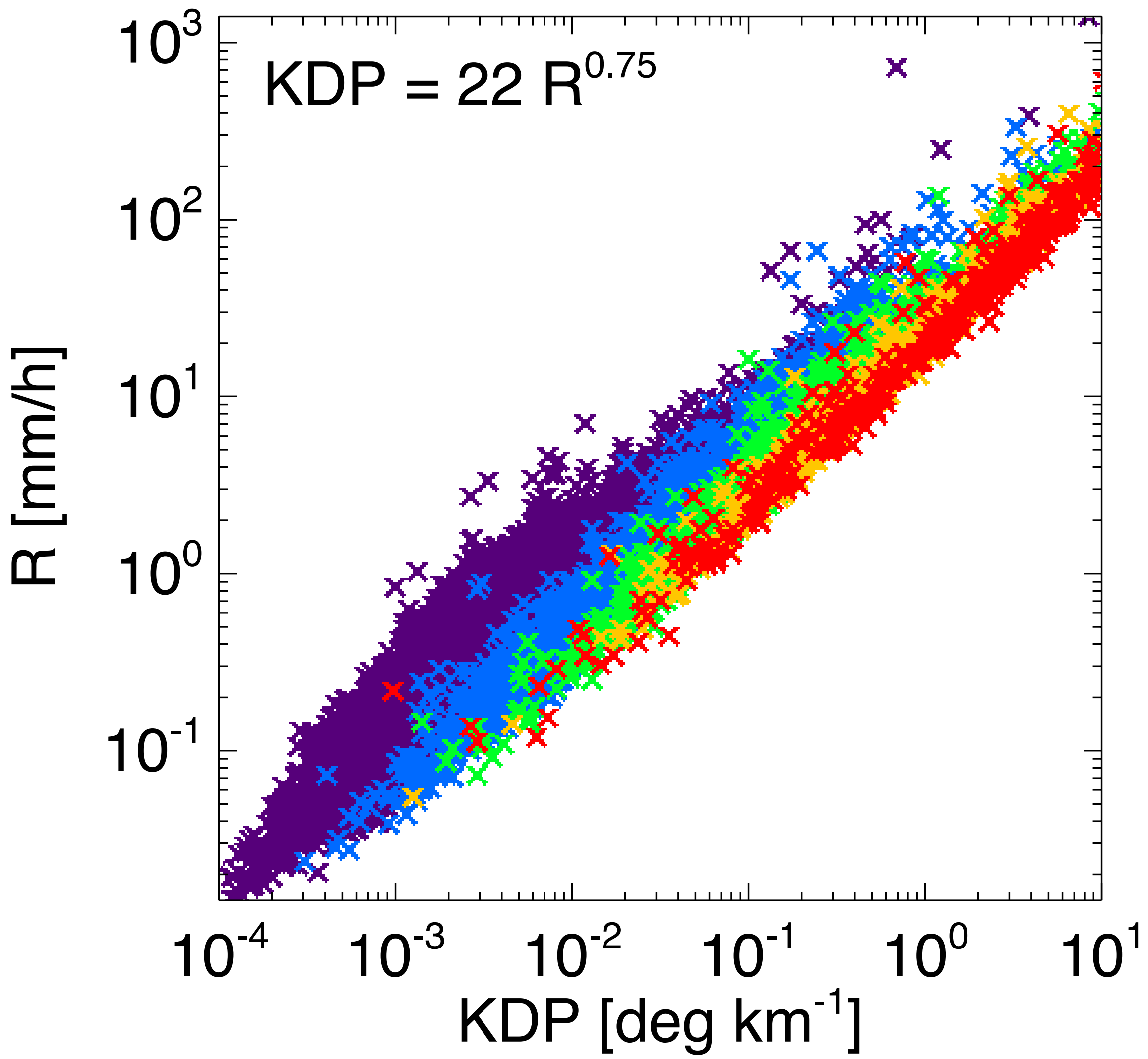
Y_{DP} [dB/km]: specific differential attenuation = Y_H-Y_V





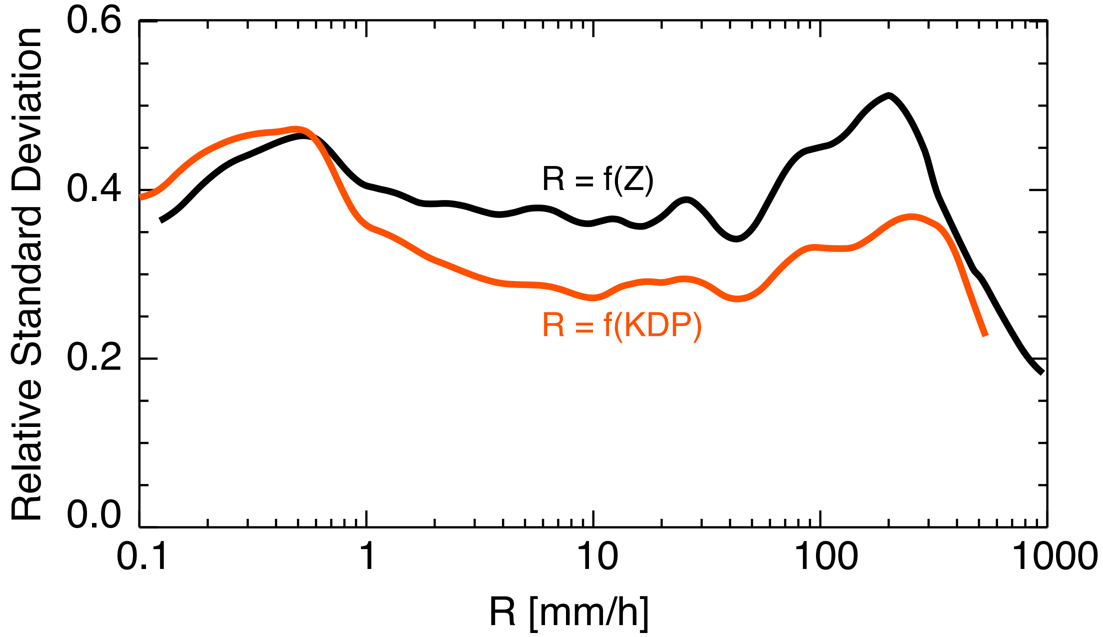


Advantages of K_{dp} over Z



Computed for C-band

Advantages of K_{dp} over Z



It has a better relationship with rain rate: the relative error of the conversion of K_{dp} into R is smaller than that of the Z-R relationship

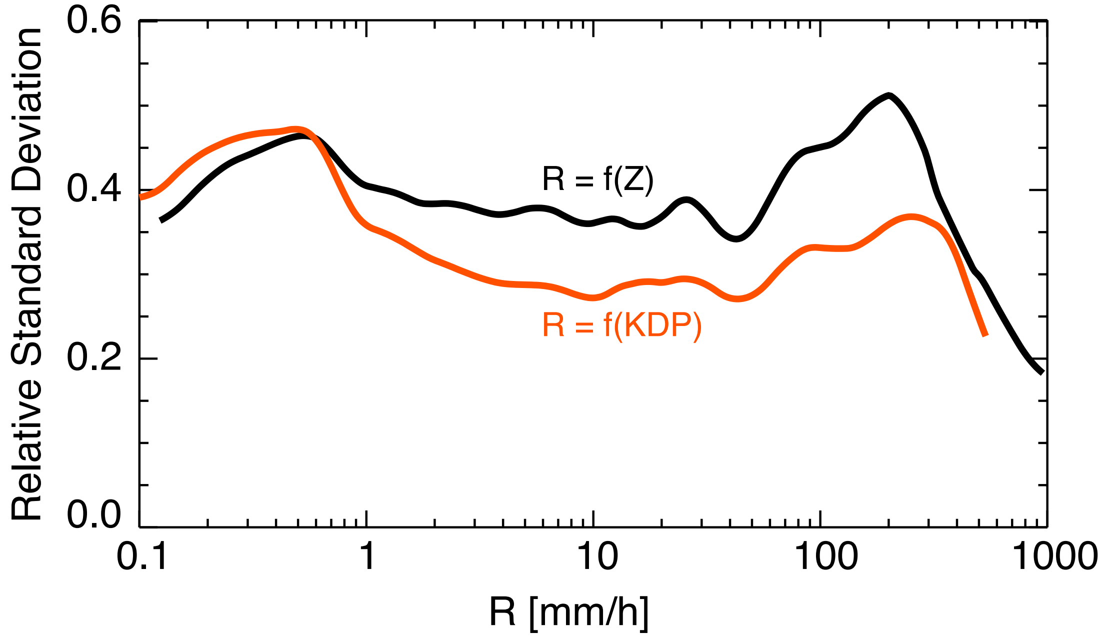
It is not affected by attenuation

It is not affected by partial beam blocking

The disadvantages is that it is difficult to measure values below 1°/km

And at C-band it is sensitive to resonances at the very large drops:

Advantages of K_{dp} over Z



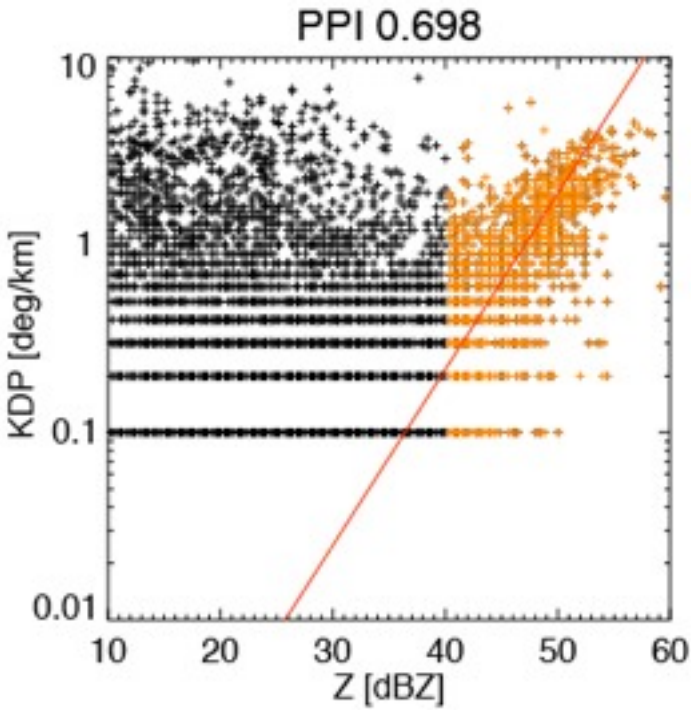
It has a better relationship with rain rate:
the relative error of the conversion of K_{dp} into R is smaller than that of the Z-R relationship

It is not affected by attenuation

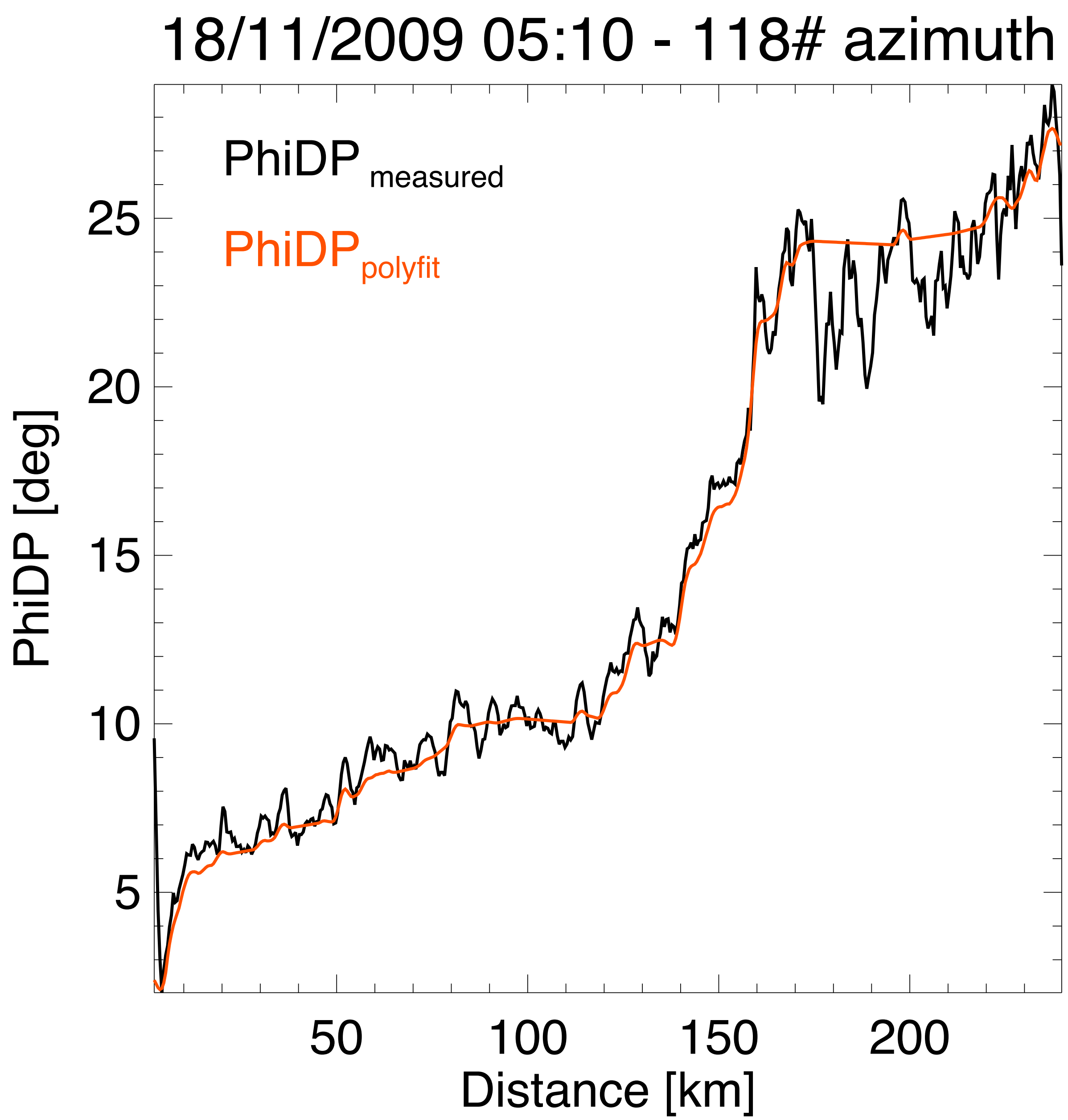
It is not affected by partial beam blocking

The disadvantages is that it is difficult to measure values below 1°/km

And at C-band it is sensitive to resonances at the very large drops:



Critical issue: computing KDP from ΦDP



Fit a quadratic to 9 points and take the derivative at the center point; go to next range

Eliminate outliers: if a value is greater that the 5 next reject. If a values is lower than the preceding 5 reject.

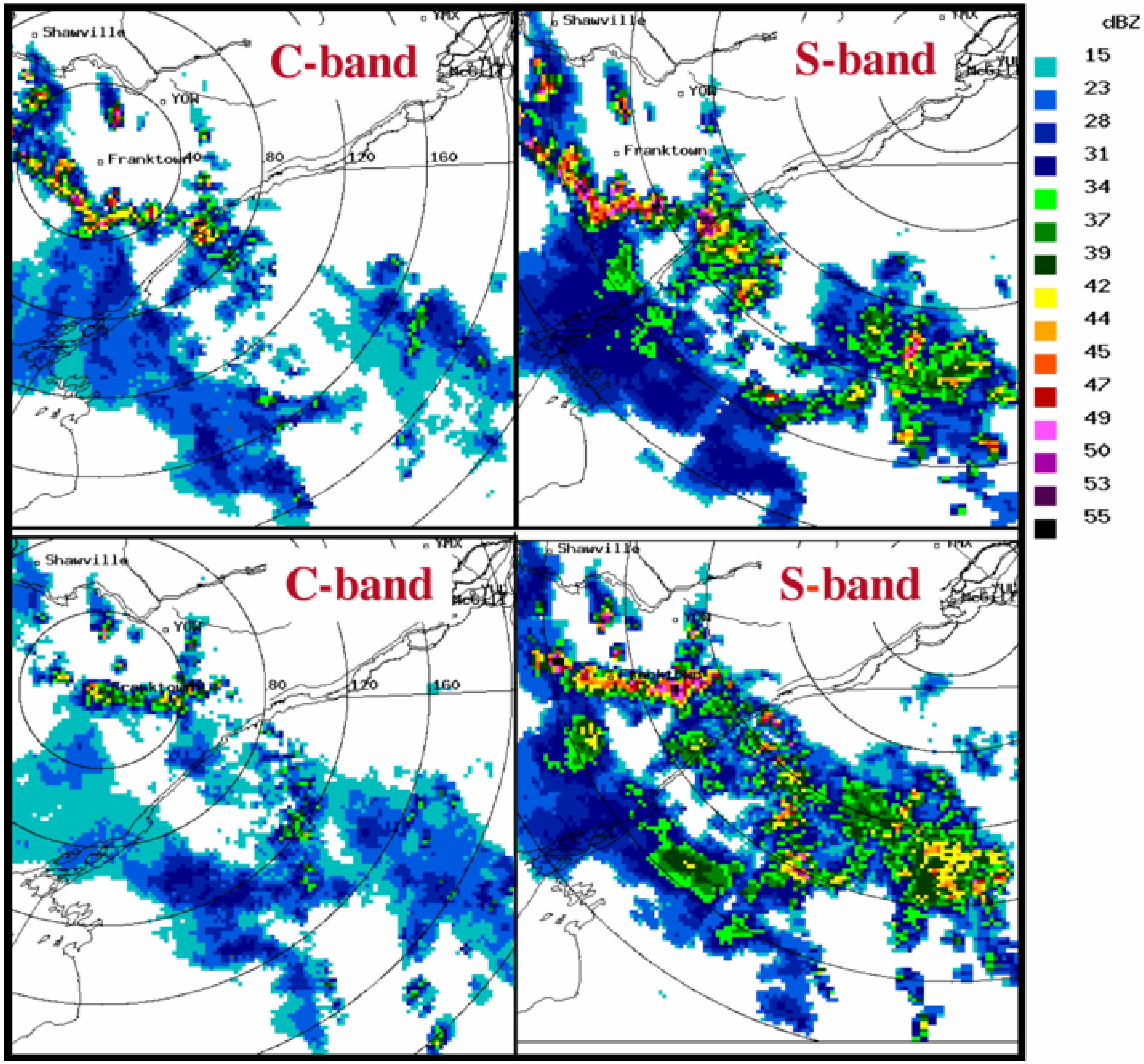
Works better that SIGMET

At C-band and X-band attenuation is a serious problem

Correction for attenuation is necessary for quantitative measurements

Observation of attenuation at C-band

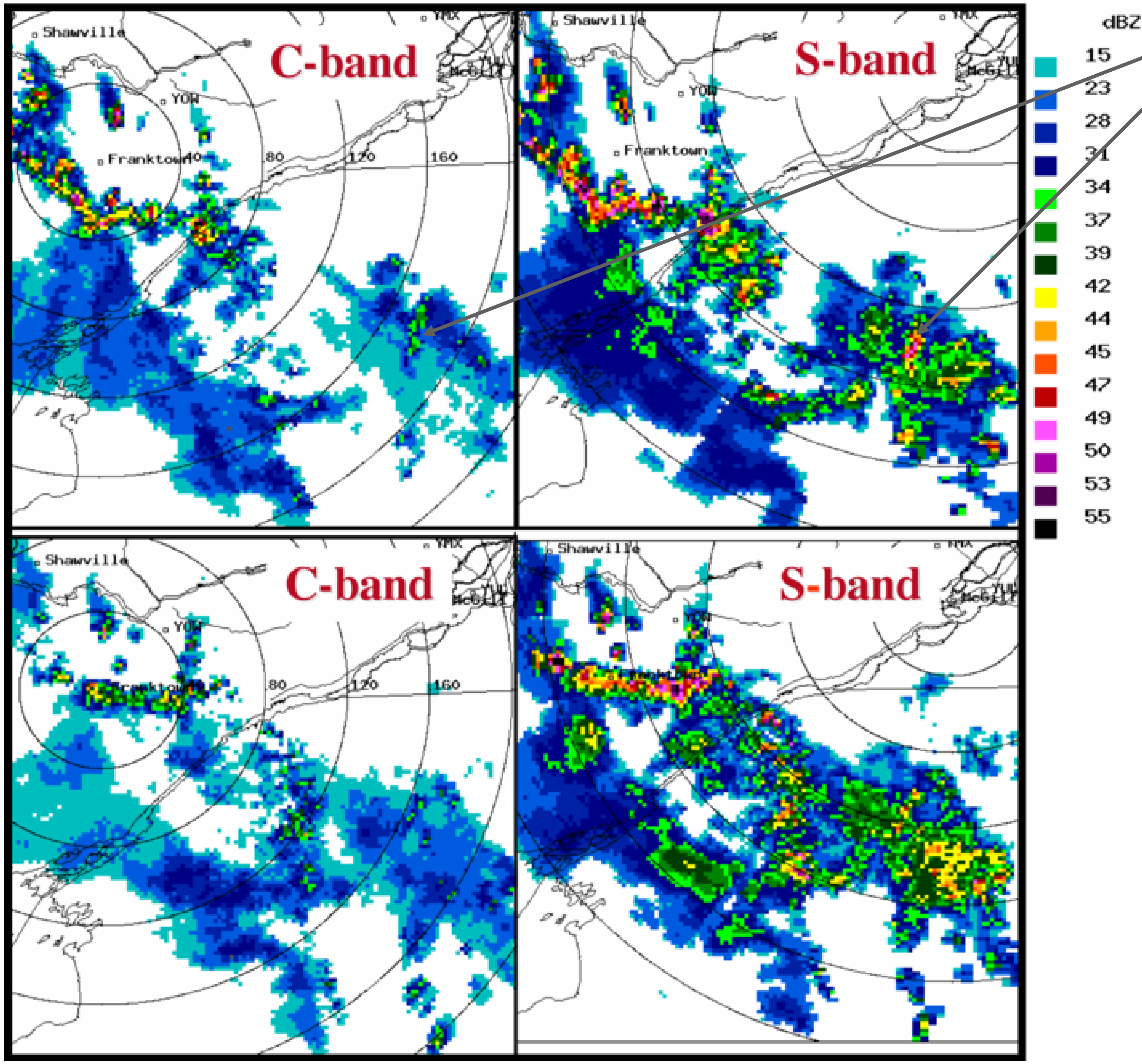
Comparison of S and C-band cross-calibrated radars



Observation of attenuation at C-band

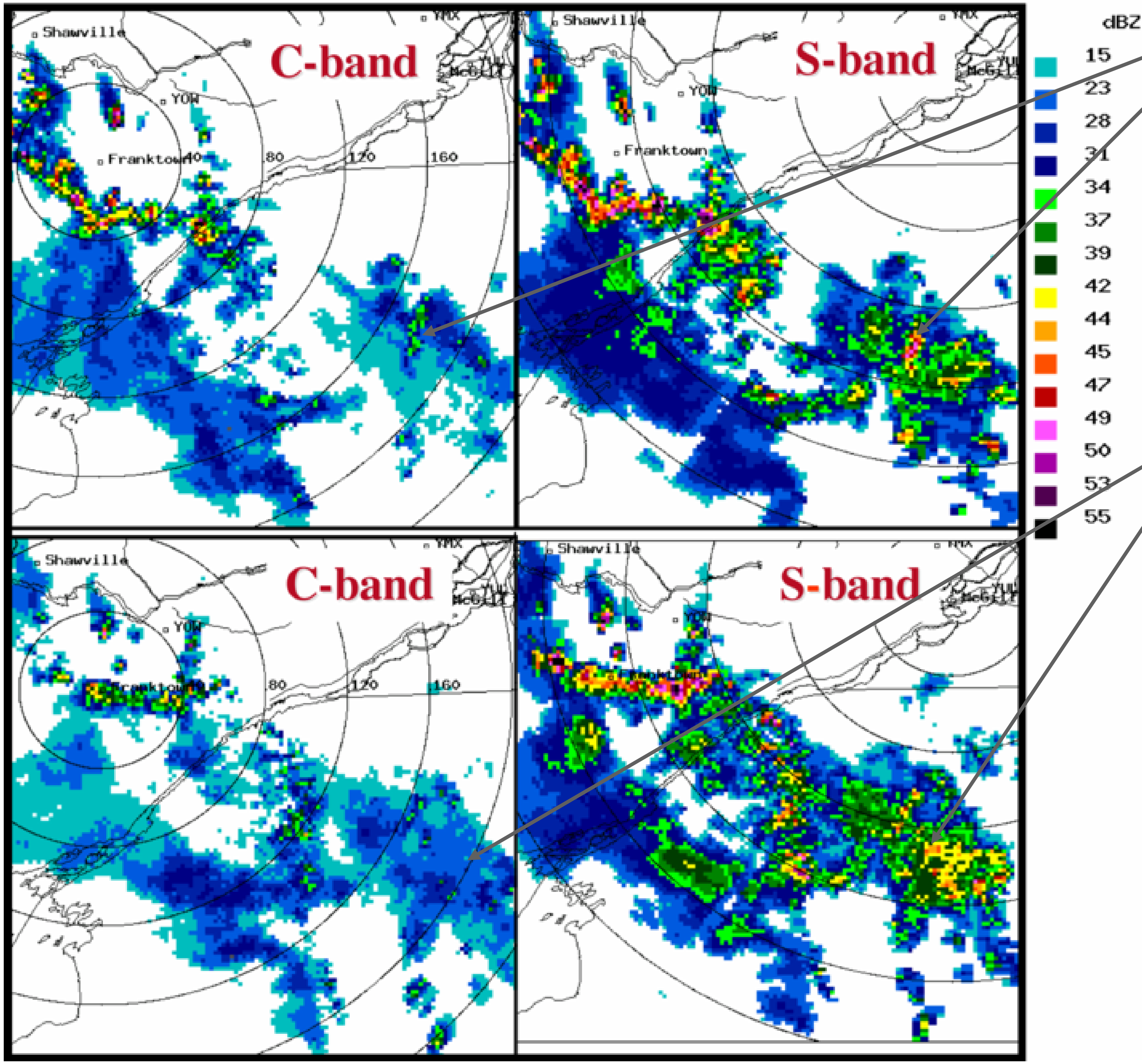
Comparison of S and C-band cross-calibrated radars

11 dBZ difference in equidistant weather due to in-rain attenuation



Observation of attenuation at C-band

Comparison of S and C-band cross-calibrated radars

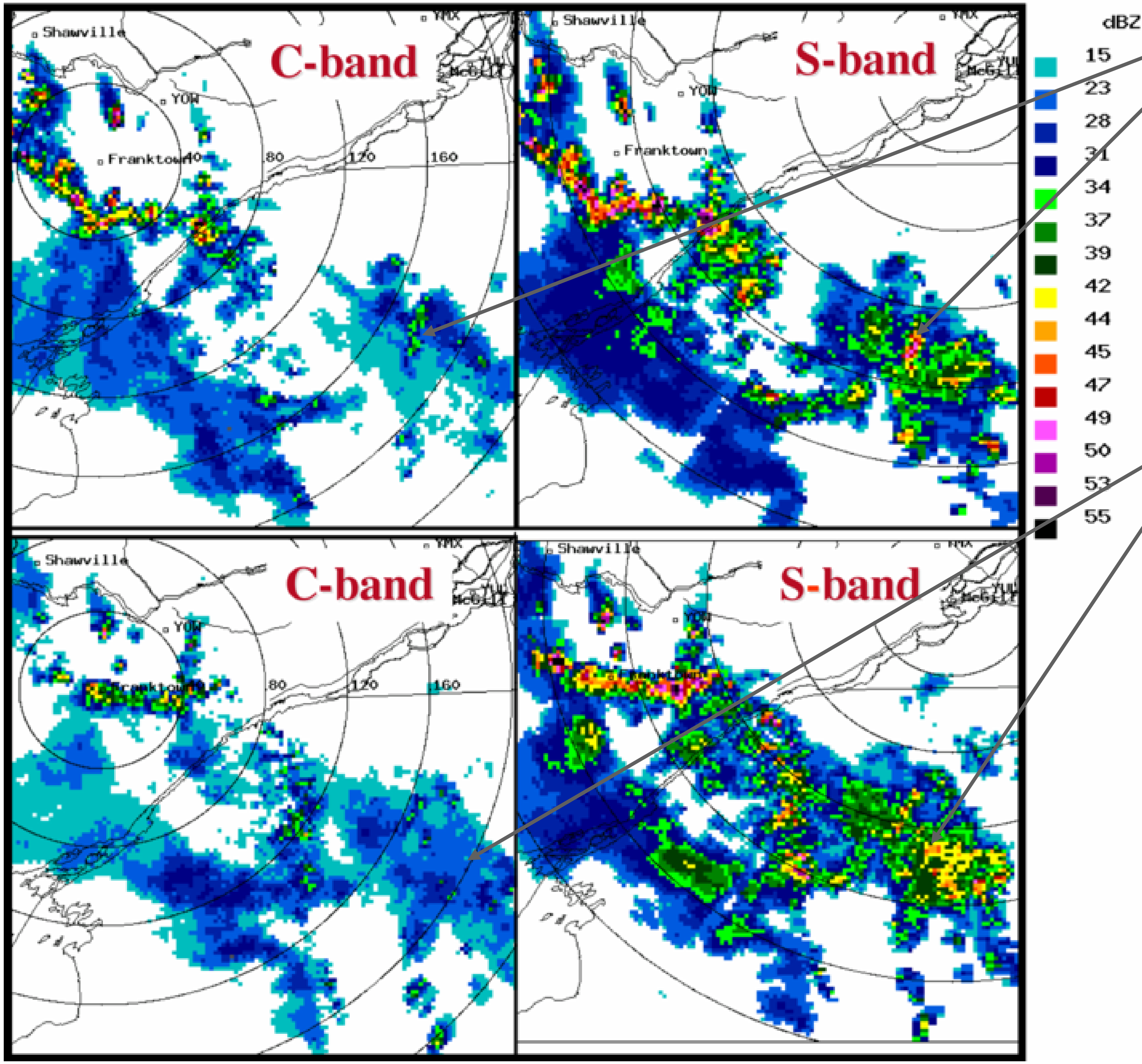


11 dBZ difference in equidistant weather due to in-rain attenuation

Additional 5dBZ due to radome attenuation

Observation of attenuation at C-band

Comparison of S and C-band cross-calibrated radars



11 dBZ difference in equidistant weather due to in-rain attenuation

Additional 5dBZ due to radome attenuation

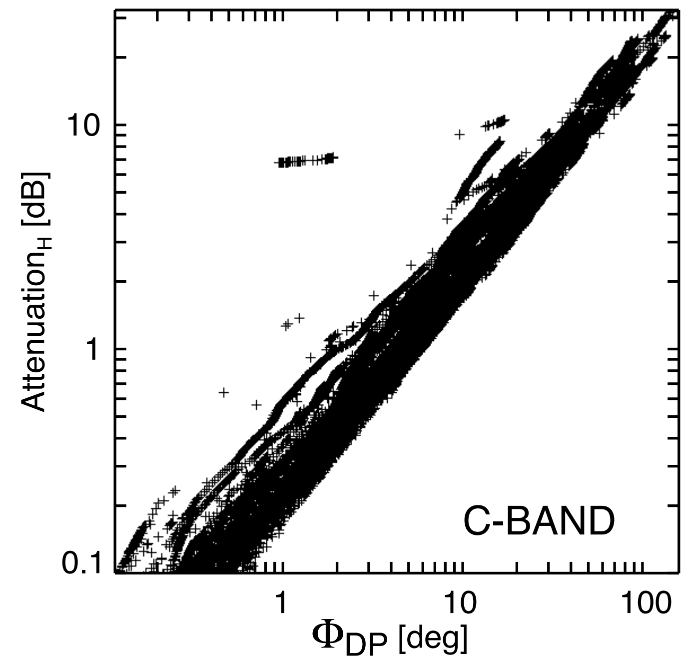
No QPE at C-band without attenuation correction!

Radome attenuation is a major problem.

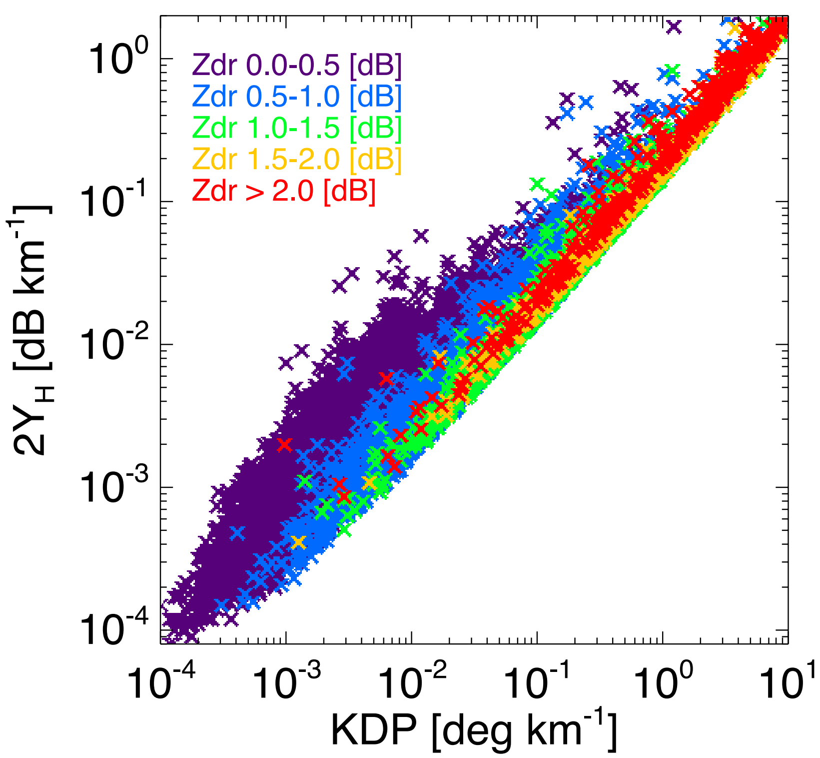
Attenuation correction

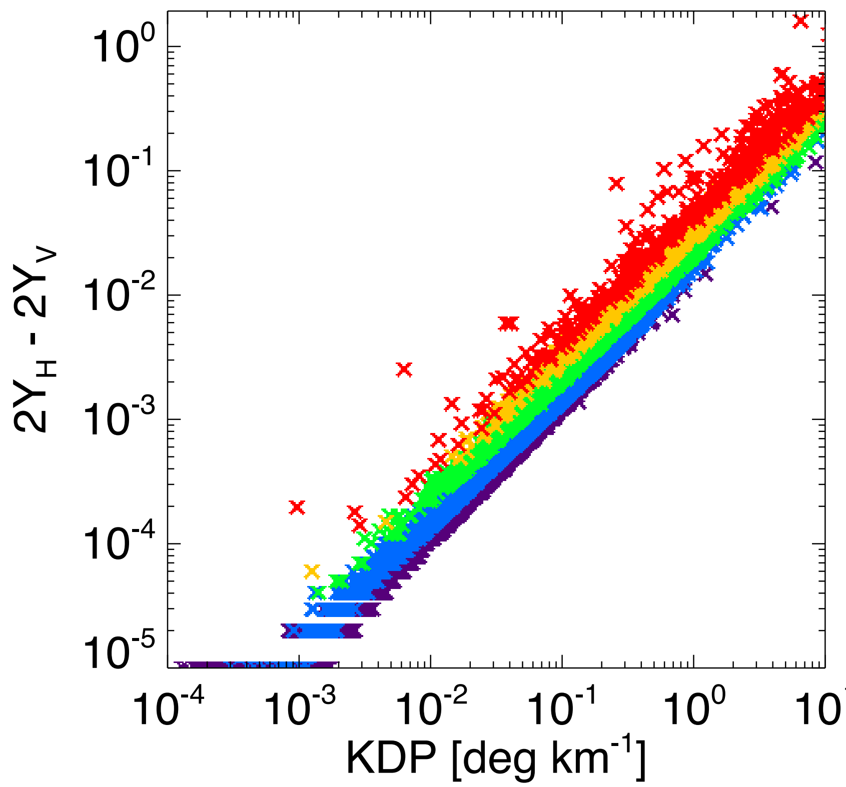
Y_H [dB/km]: specific attenuation at horizontal polarization
Y_{DP} [dB/km]: specific differential attenuation = Y_H-Y_V

$$\Delta Z=\alpha\ \Phi_{DP} \quad \text{and} \quad \Delta Z_{DR}=\beta\ \Phi_{DP}$$



where α and β are obtained from $Y_H=\alpha K_{DP}$ and $Y_{DP}=\beta K_{DP}$





Attenuation correction

Y_H [dB/km]: specific attenuation at horizontal polarization

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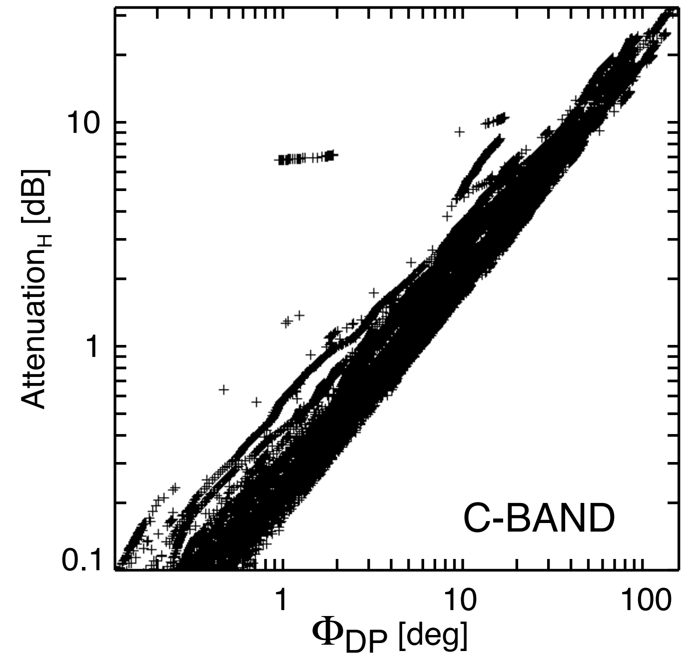
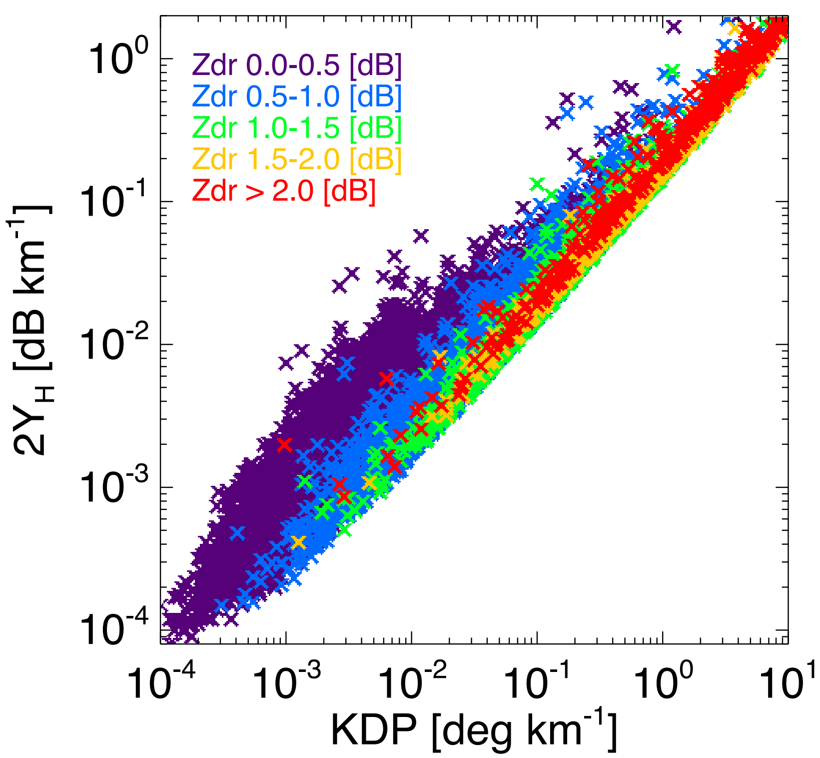
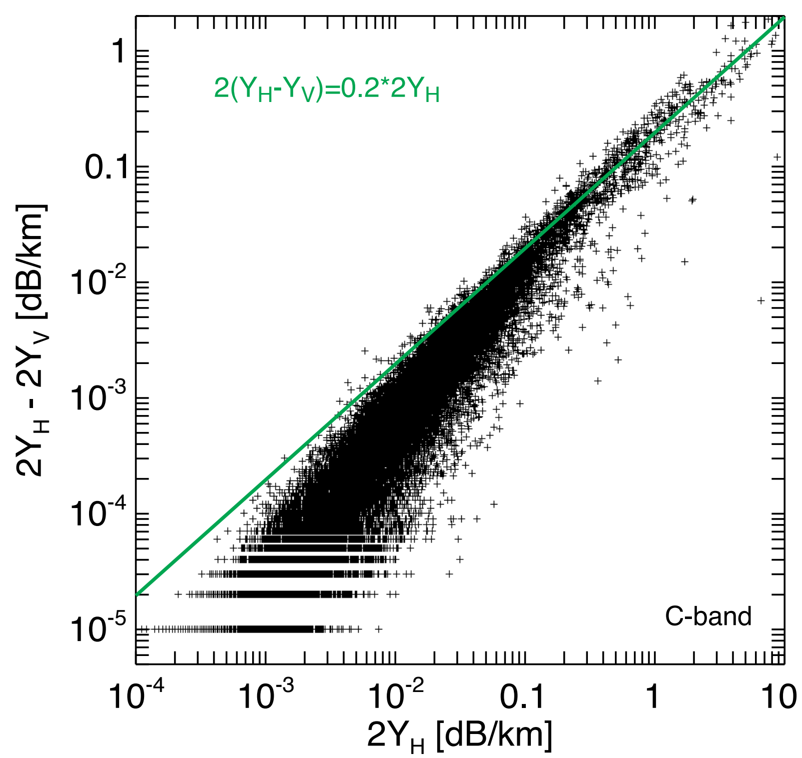
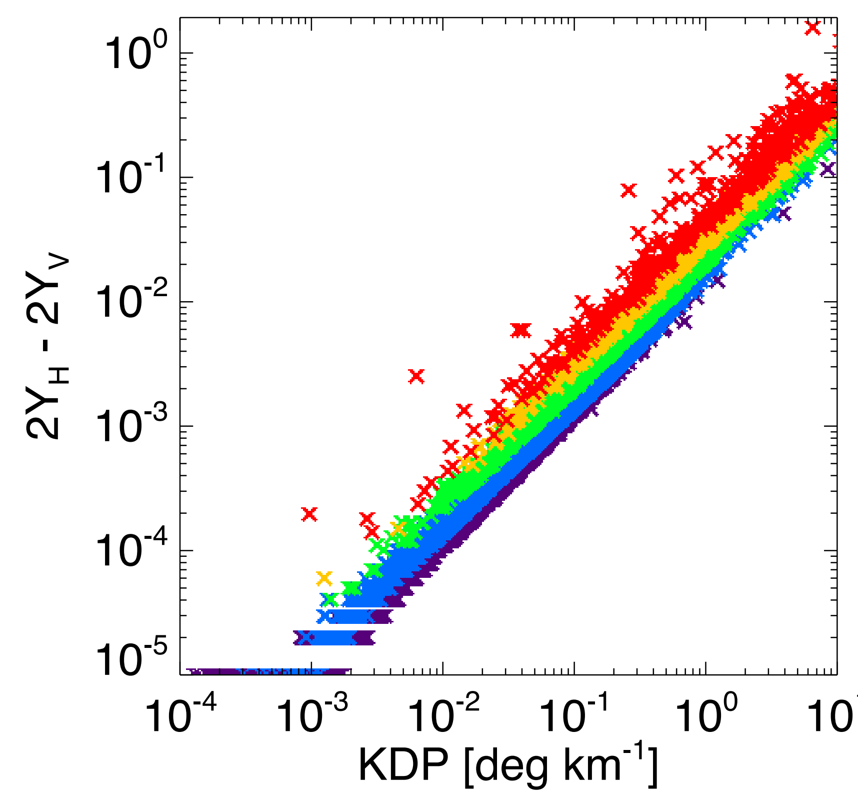
$$\Delta Z=\alpha\ \Phi_{DP} \quad \text{and} \quad \Delta Z_{DR}=\beta\ \Phi_{DP}$$



where α and β are obtained from $Y_H=\alpha K_{DP}$ and $Y_{DP}=\beta K_{DP}$





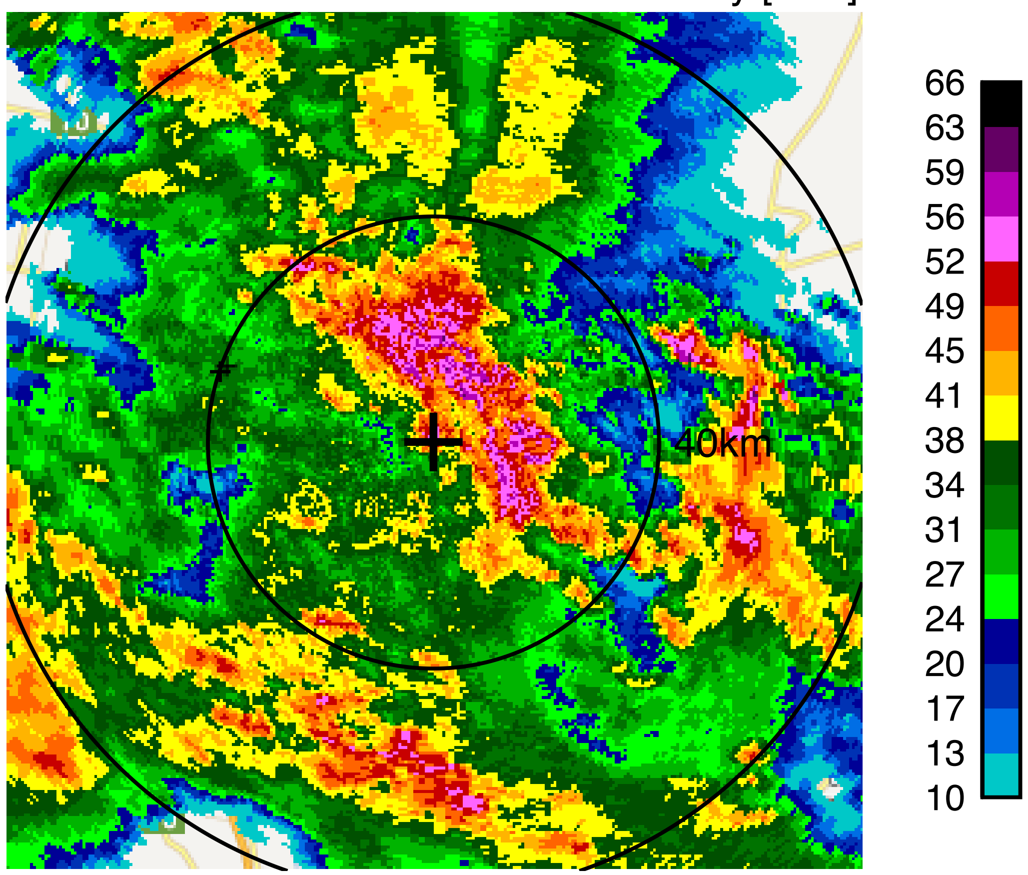


Attenuation correction; example

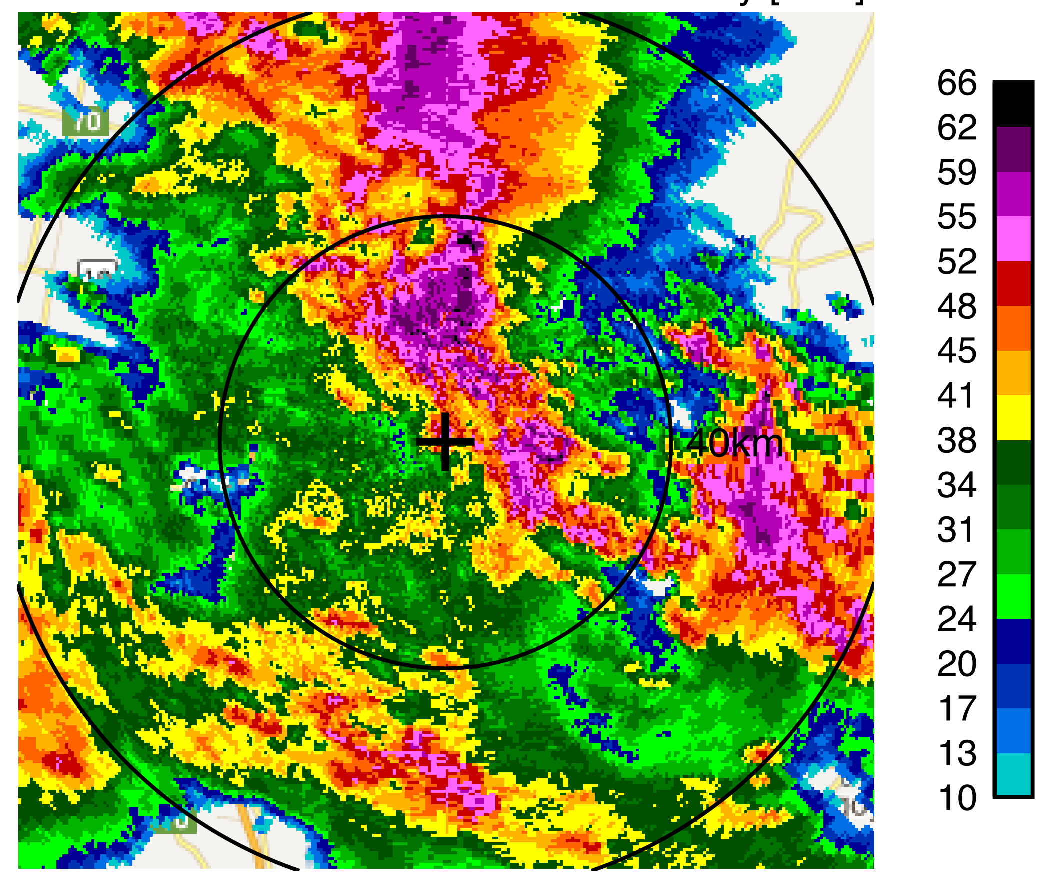
Y_H [dB/km]: specific attenuation at horizontal polarization
Y_{DP} [dB/km]: specific differential attenuation = Y_H-Y_V

where α and β are obtained from $Y_h=\alpha K_{dp}$ and $Y_{DP}=\beta K_{dp}$

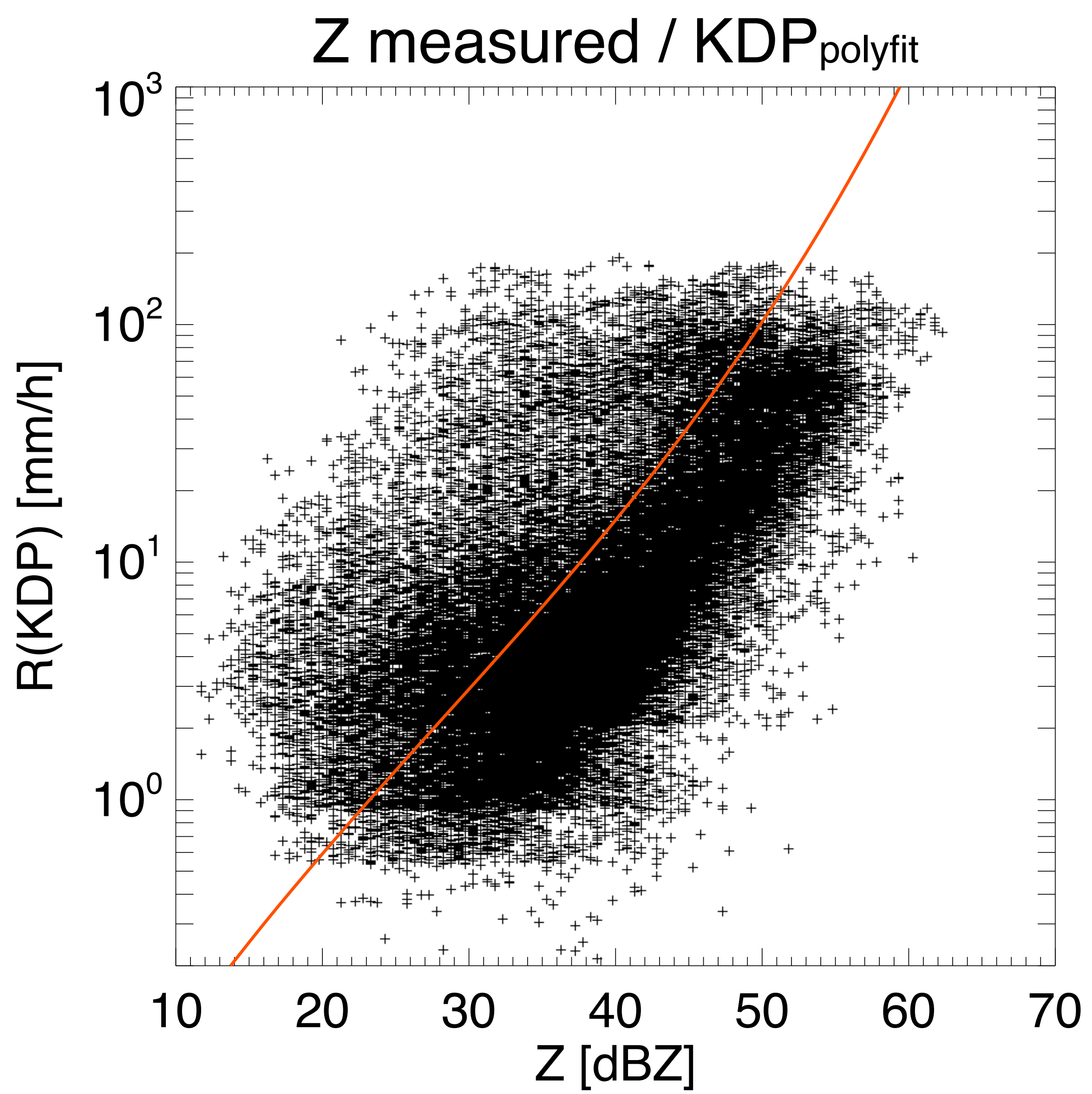
18/11/2009 04:30 Reflectivity [dBZ]

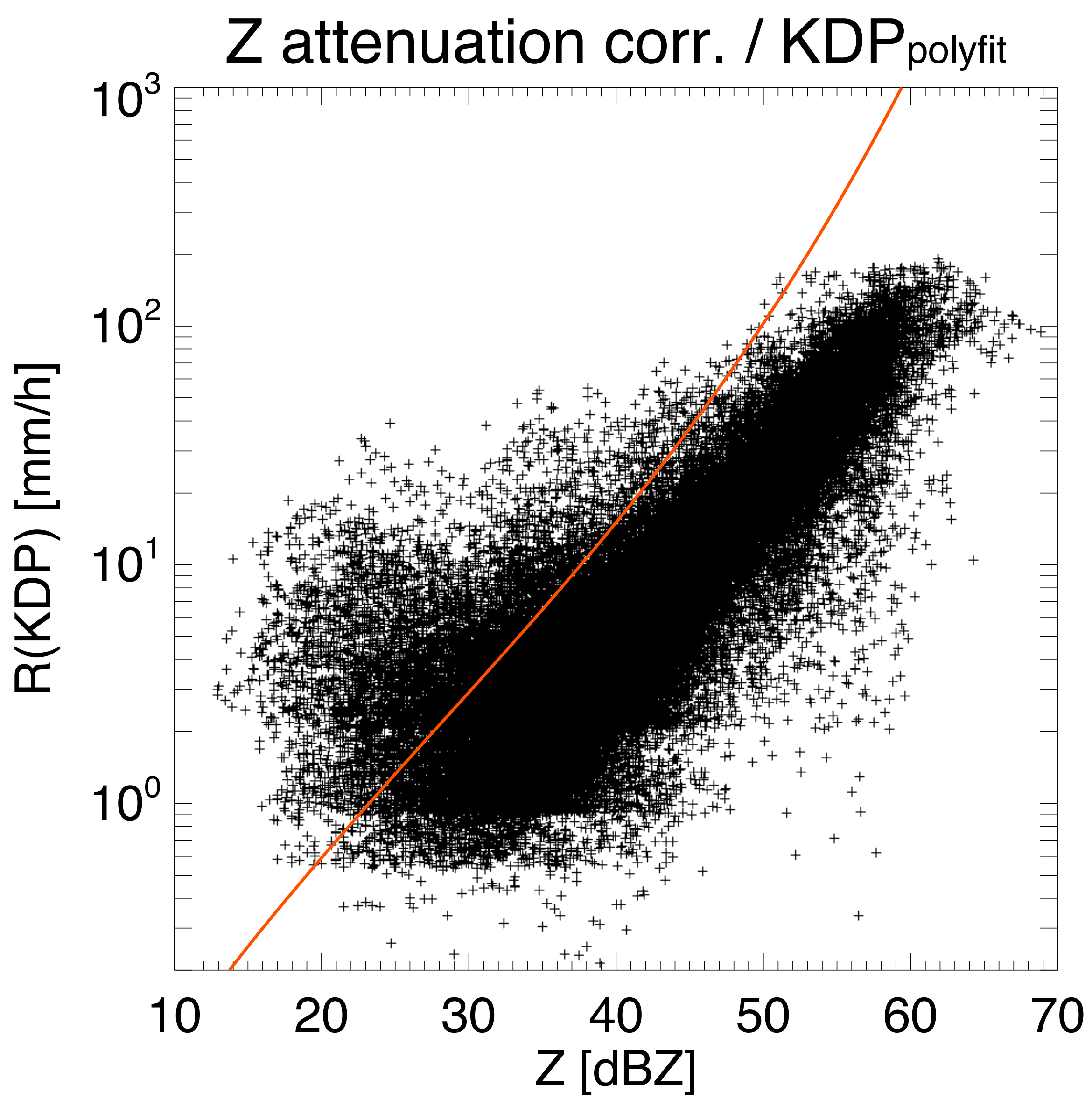


0.5° Corrected reflectivity [dBZ]



Correction for attenuation

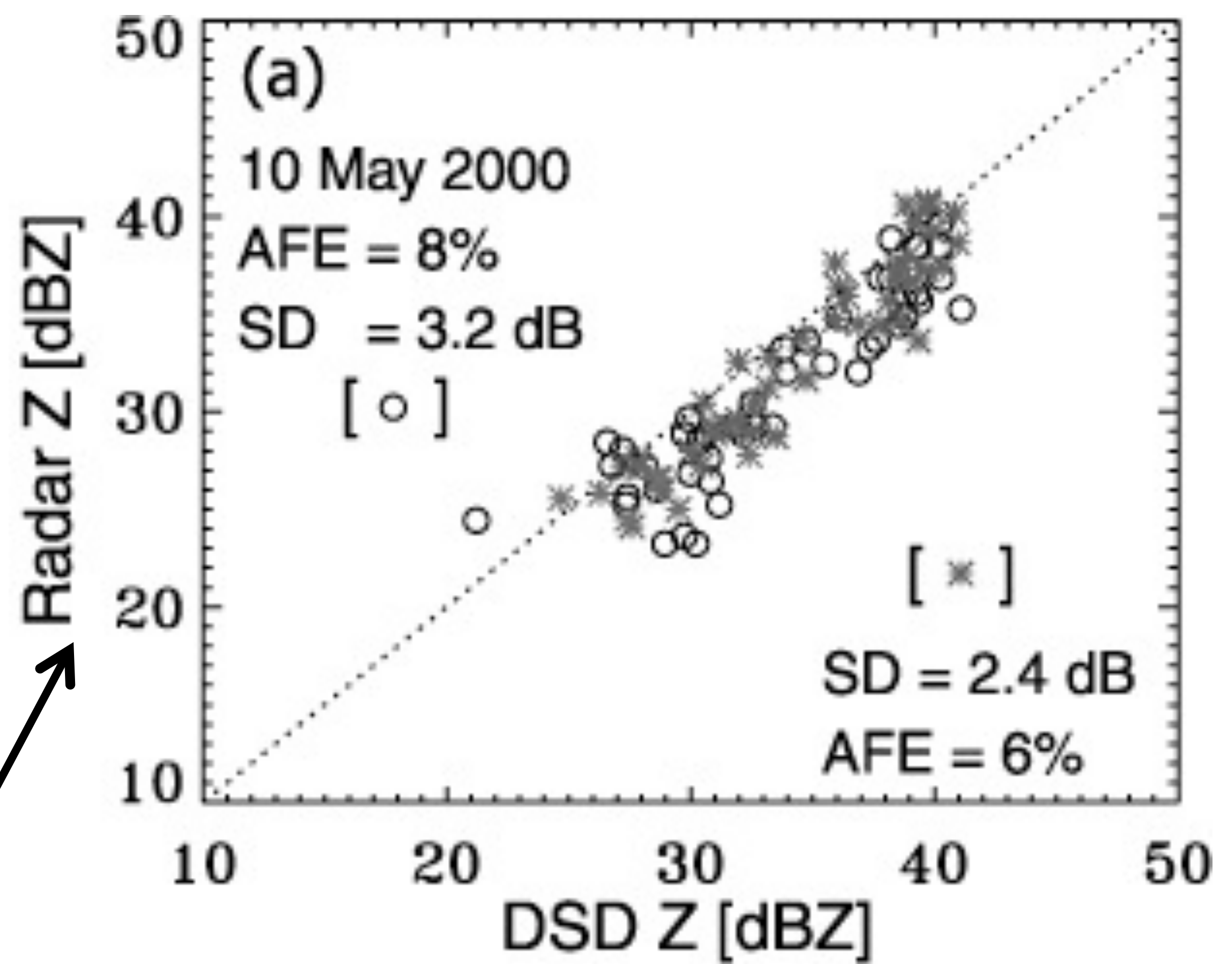




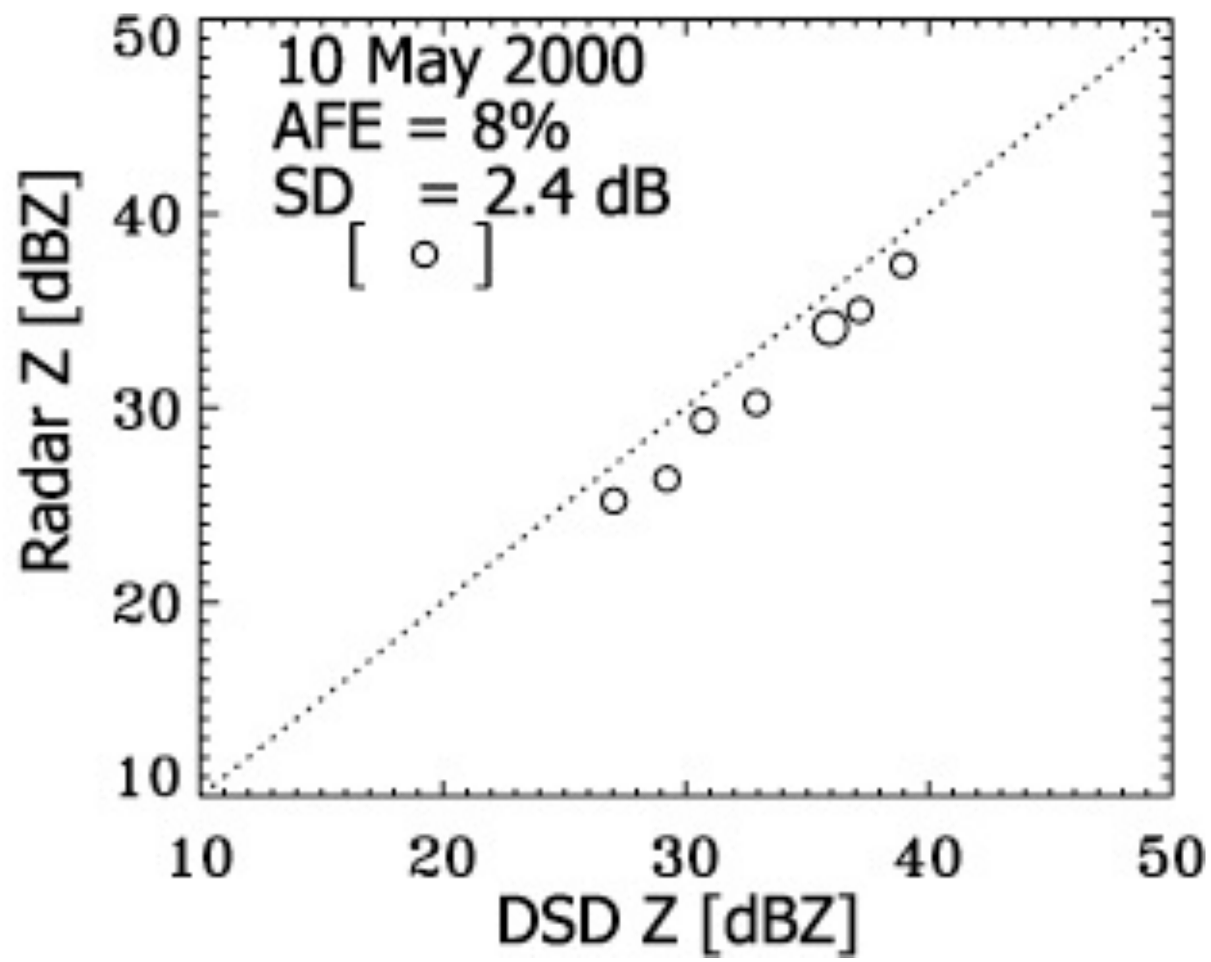
Calibration

Radar calibration with a disdrometer:
Observed radar and disdrometric data

Without filtering



With SIFT filtering



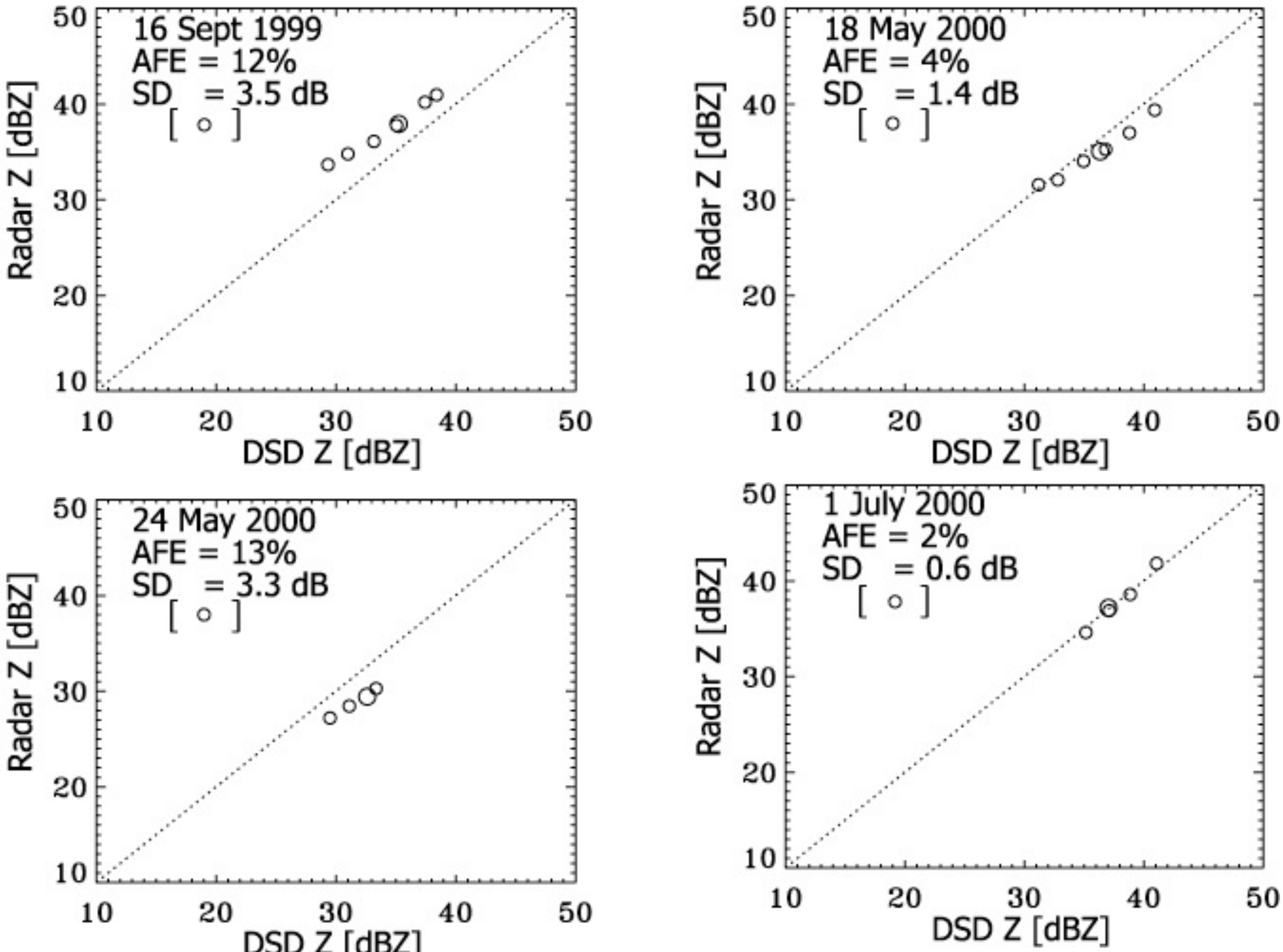
Radar measurements

(r=30 km, H=1.2 km)

Disdrometer measurements

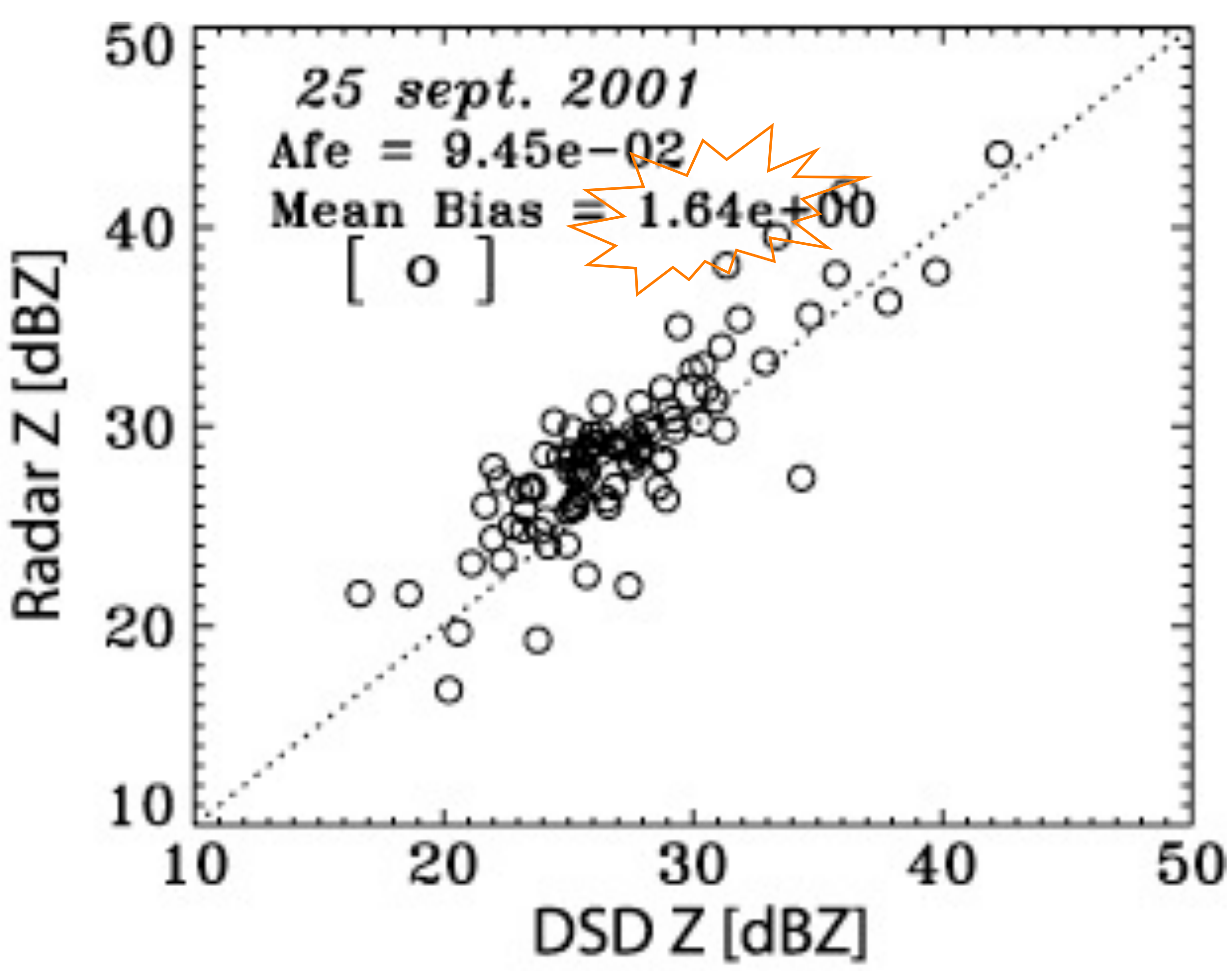
on the ground

Radar calibration with a disdrometer:
A few examples

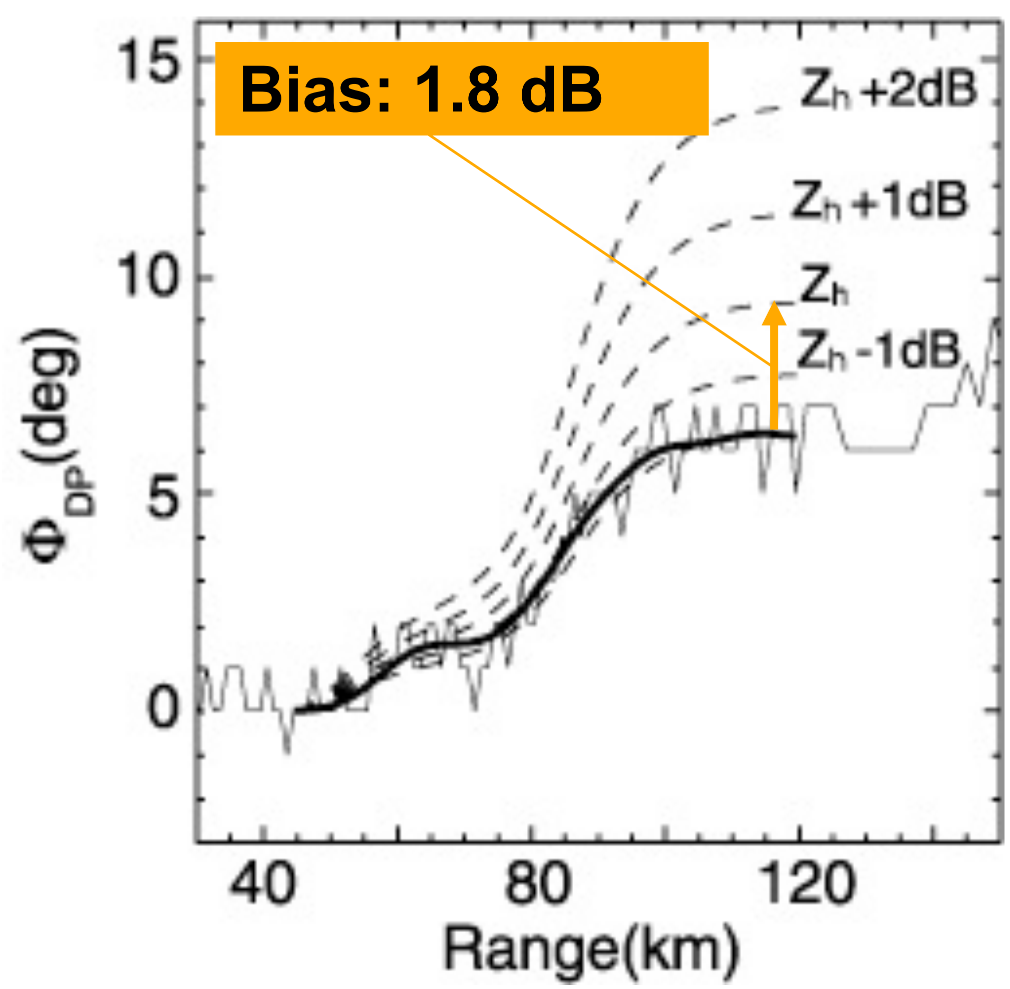


Consistency:
comparison with polarimetric radar calibration

by a disdrometer

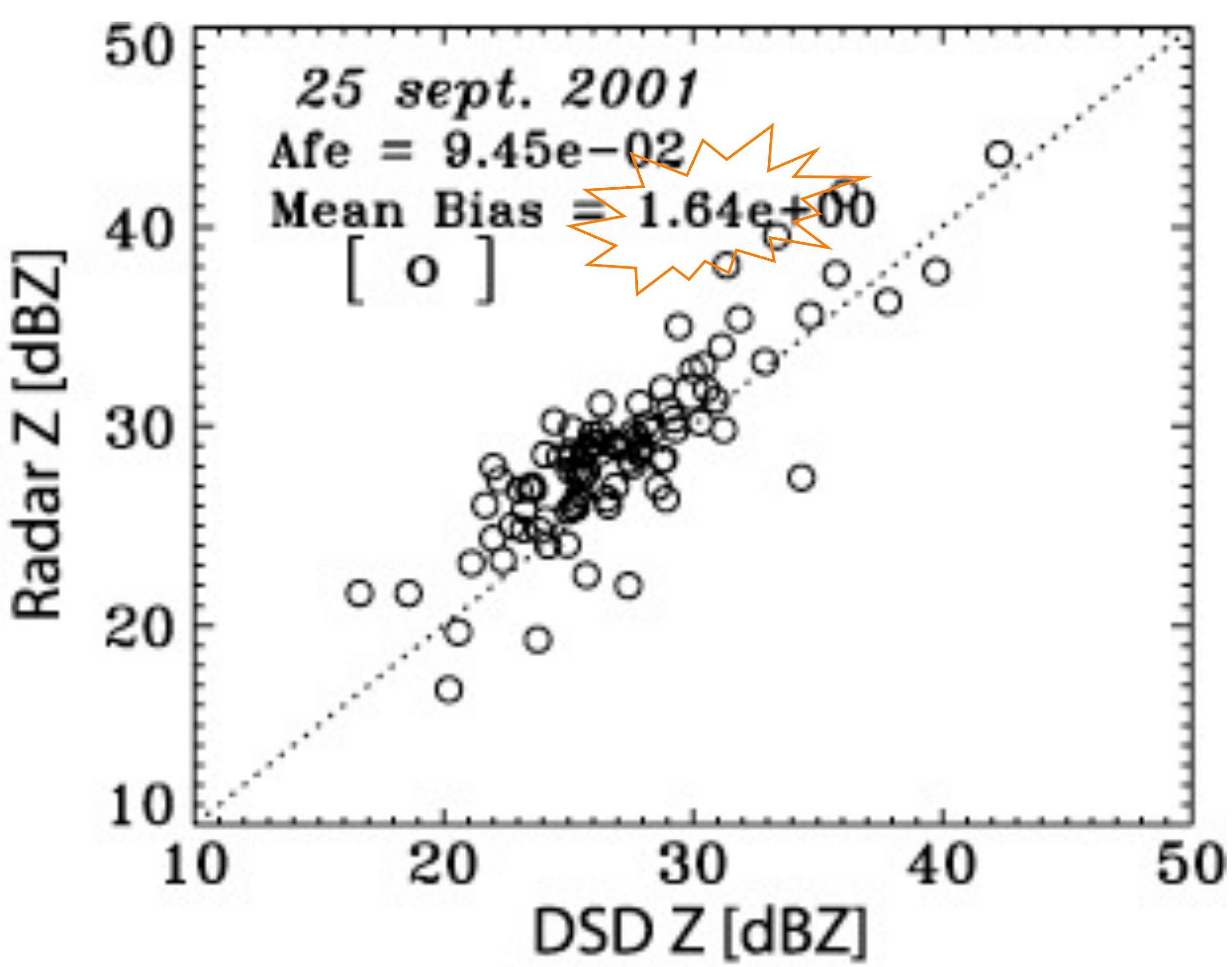


by polarimetry

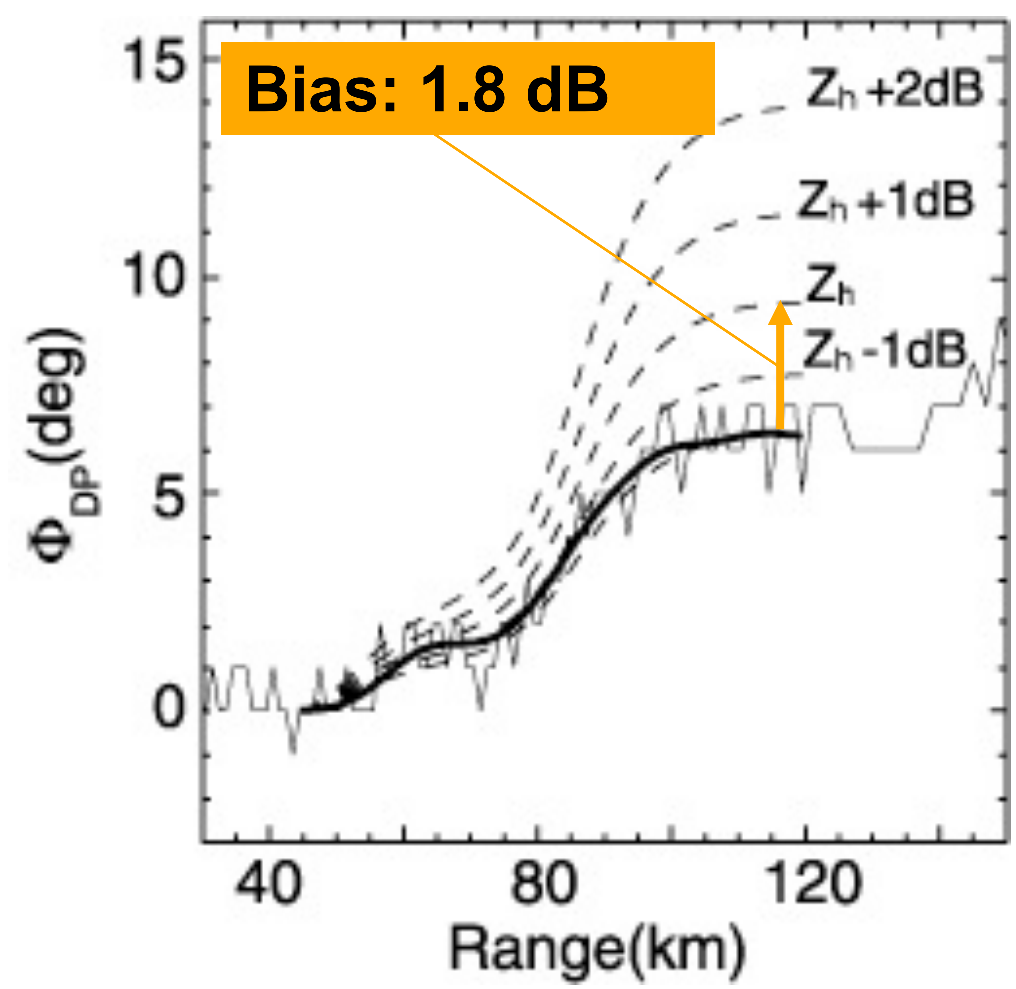


Consistency:
comparison with polarimetric radar calibration

by a disdrometer



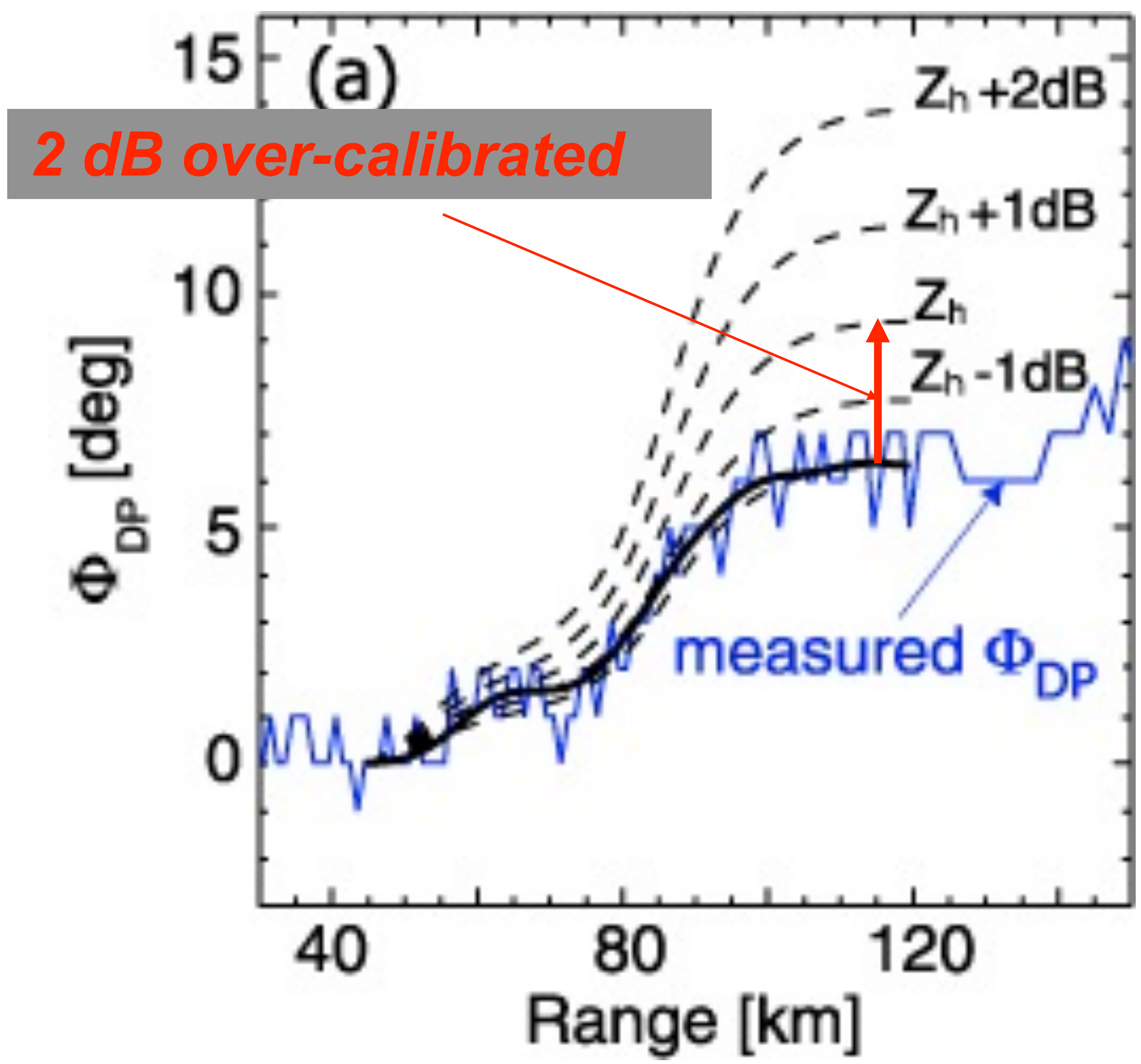
by polarimetry



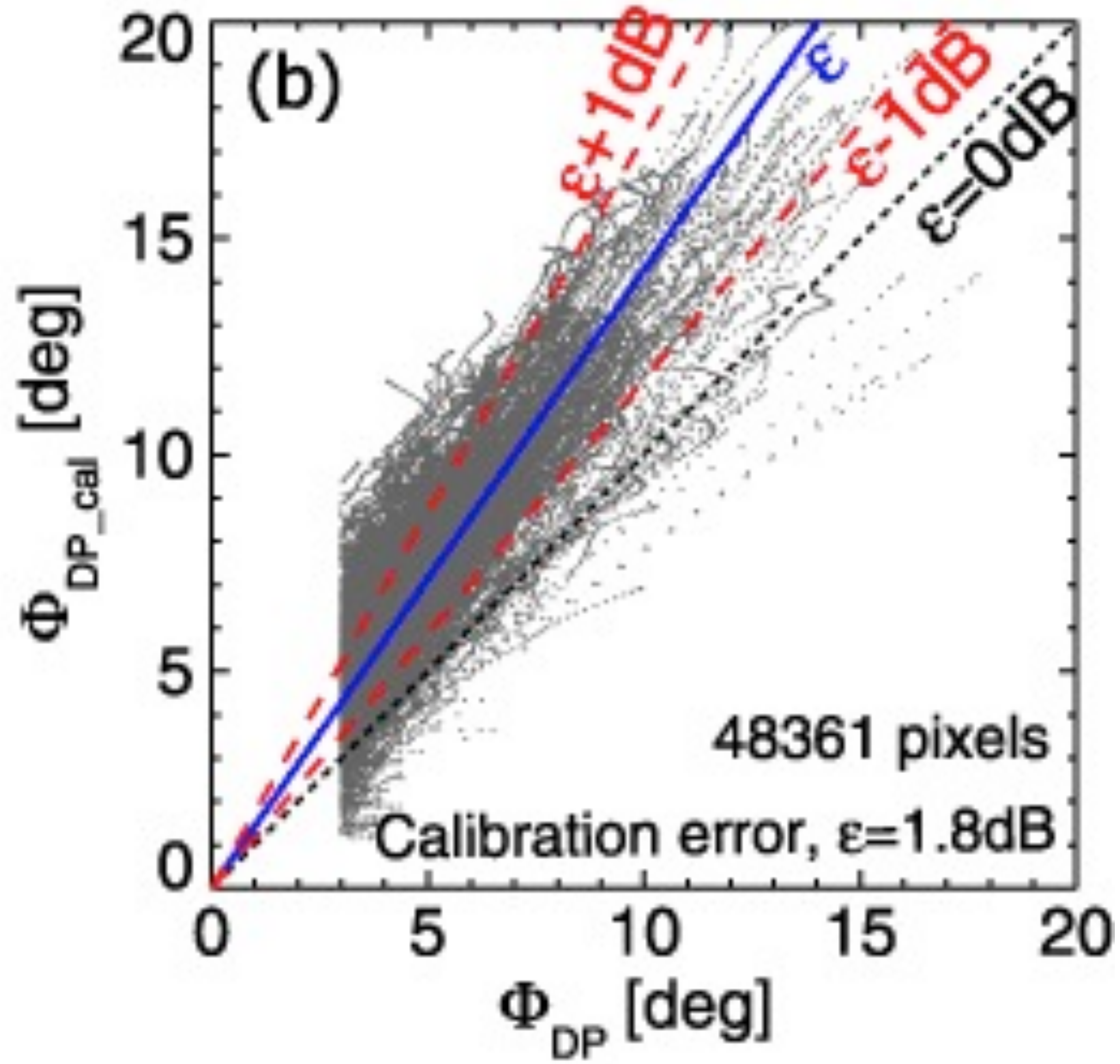
Consistency between disdrometric and polarimetric calibrations !!

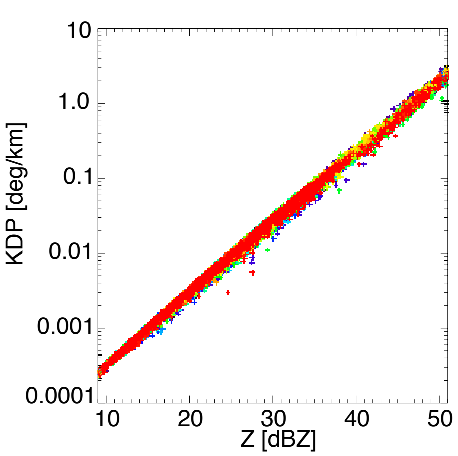
Radar calibration with polarimetry: With actual radar data

one radial at 0.9 deg elevation



All radials at 0.9 deg elevation

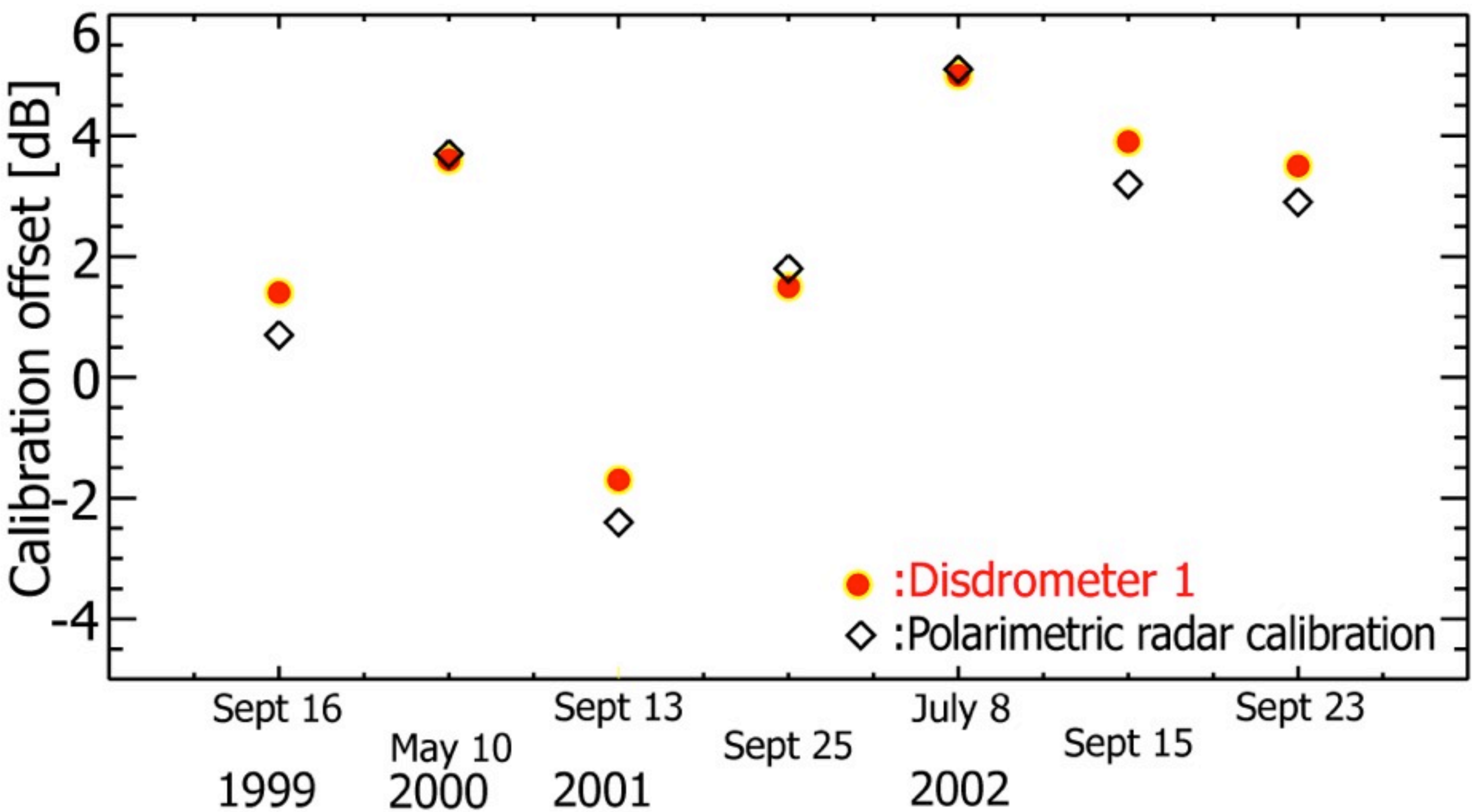




$$\varepsilon\,[dB] = 10b\log(\tan\theta)$$

$$Z_h = aK_{DP}^{b} \qquad \tan\theta = \frac{\sum \Phi_{DP\_cal}\Phi_{DP}}{\sum \Phi_{DP}^{2}}$$

Consistency:
comparison with polarimetric radar calibration



THE END ...

THE END …

not really