



NCAR

# Antenna Polarization Errors and Biases in Polarimetric Variables for Simultaneous Horizontal and Vertical Transmit Radars

Third SoWMEX/TiMREX Science Workshop  
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310 Meeting Room, Central Weather Bureau,  
Taipei, Taiwan

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# Cross-Coupling of the H and V Polarized Waves

- SHV operation is based on two assumptions:
  1. The mean canting angle of precipitation in the propagation medium is zero
    - For rain this is a good assumption, but not for ice
  2. *Negligible antenna polarization errors*
    - *Is not well understood*



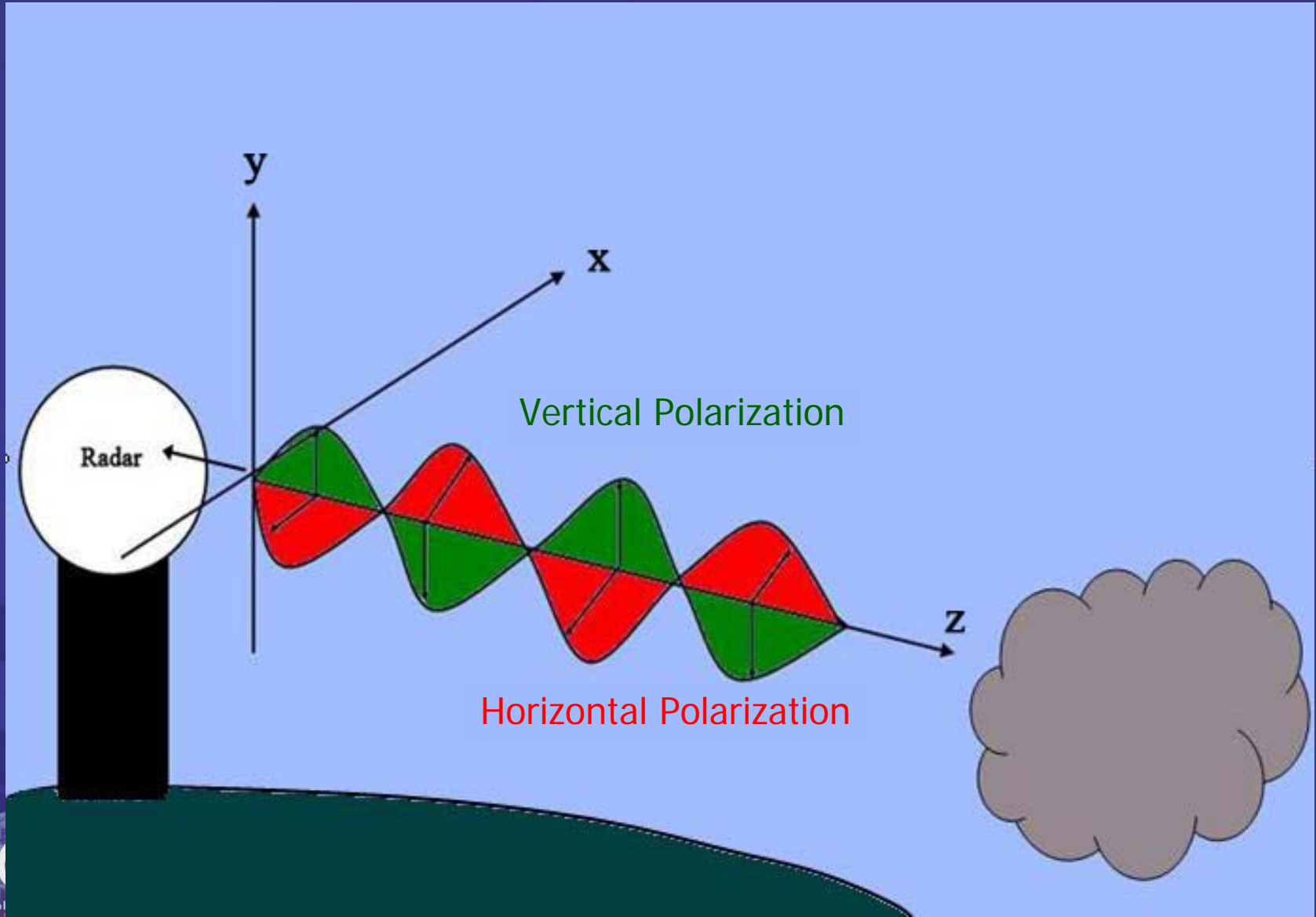
# Transmit H and V Waves SIMULTANEOUSLY!

Just use a power splitter

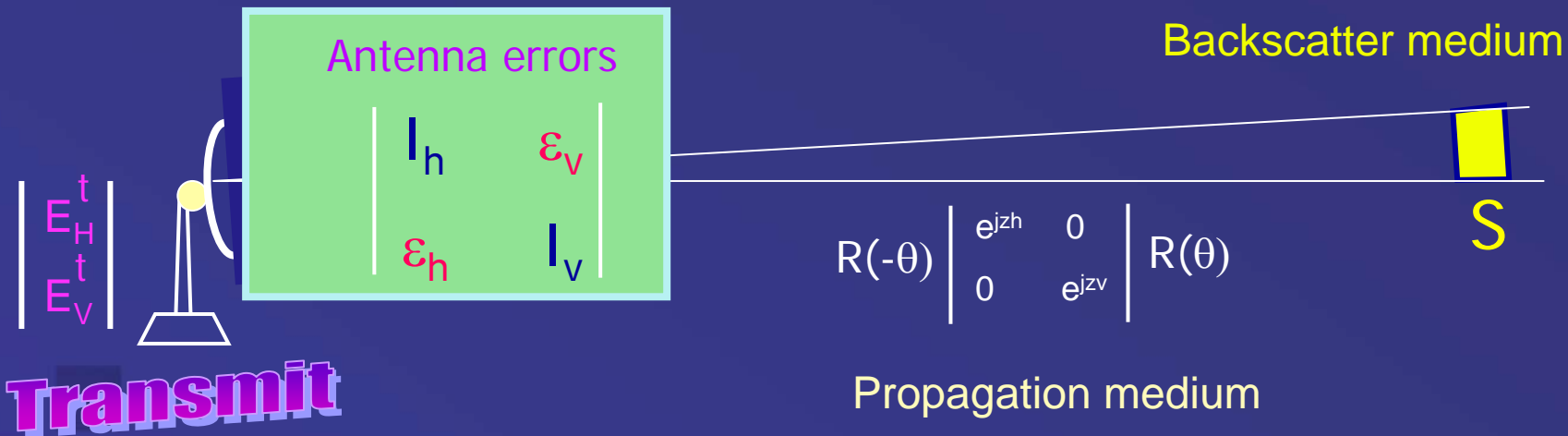
- Avoid pesky ferrite switches, dual transmitters or a fast mechanical switch that are needed for fast alternating H and V transmission!
- Less expensive, less maintenance
- NEXRADs will adopt this dual polarization technique



# Simultaneous H & V Transmission



# Modeling Radar Scatter



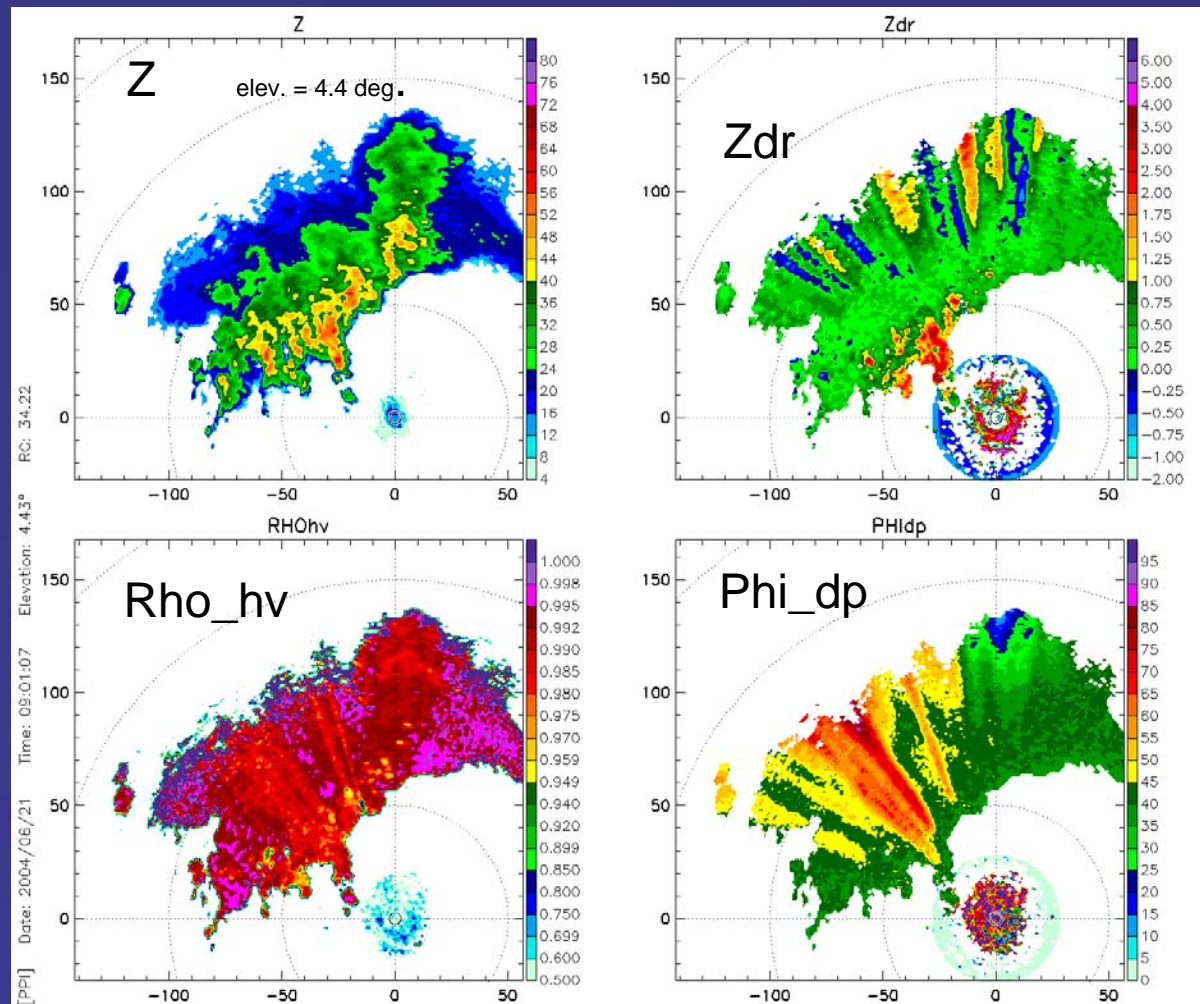
$$E_r = A^T P^T S P A E^t$$

See Hubbert and Bringi 2003: Studies of the Polarimetric Covariance Matrix. Part II: Modeling and Polarization Errors, JTECH



# Non-zero Mean Canting Angle induced Errors

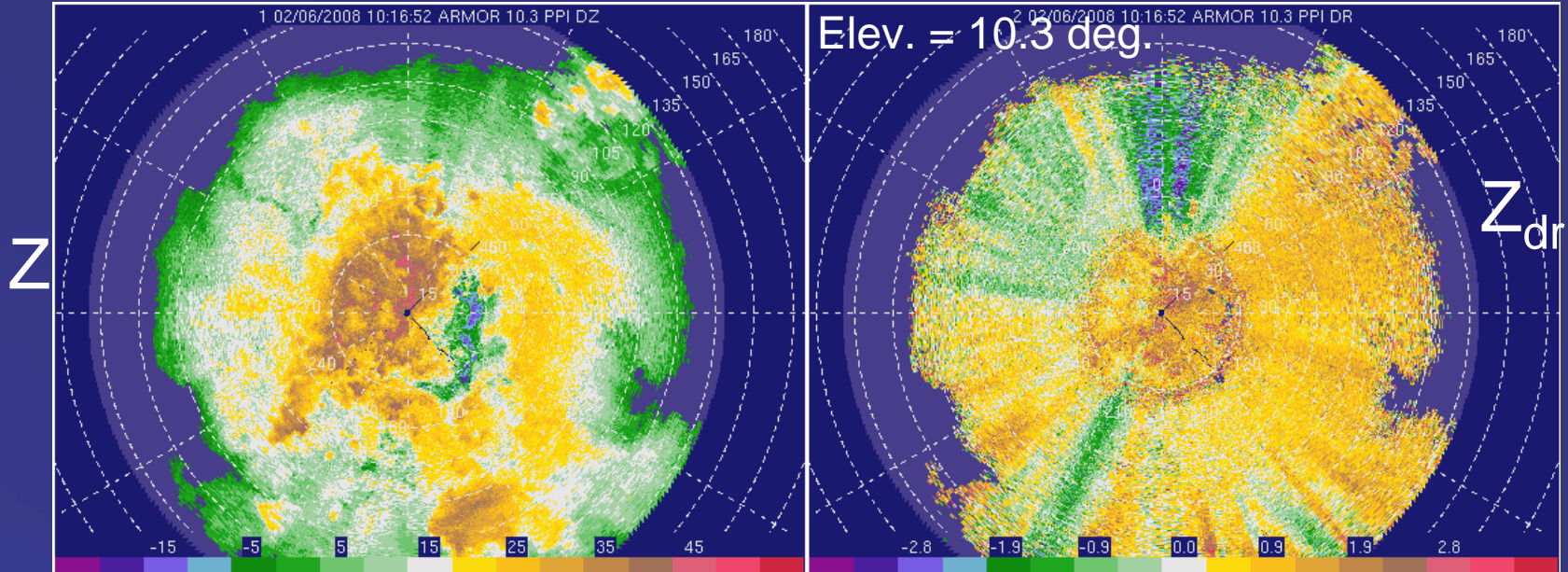
- From Ryzhkov et al, 2006. KOUN Data



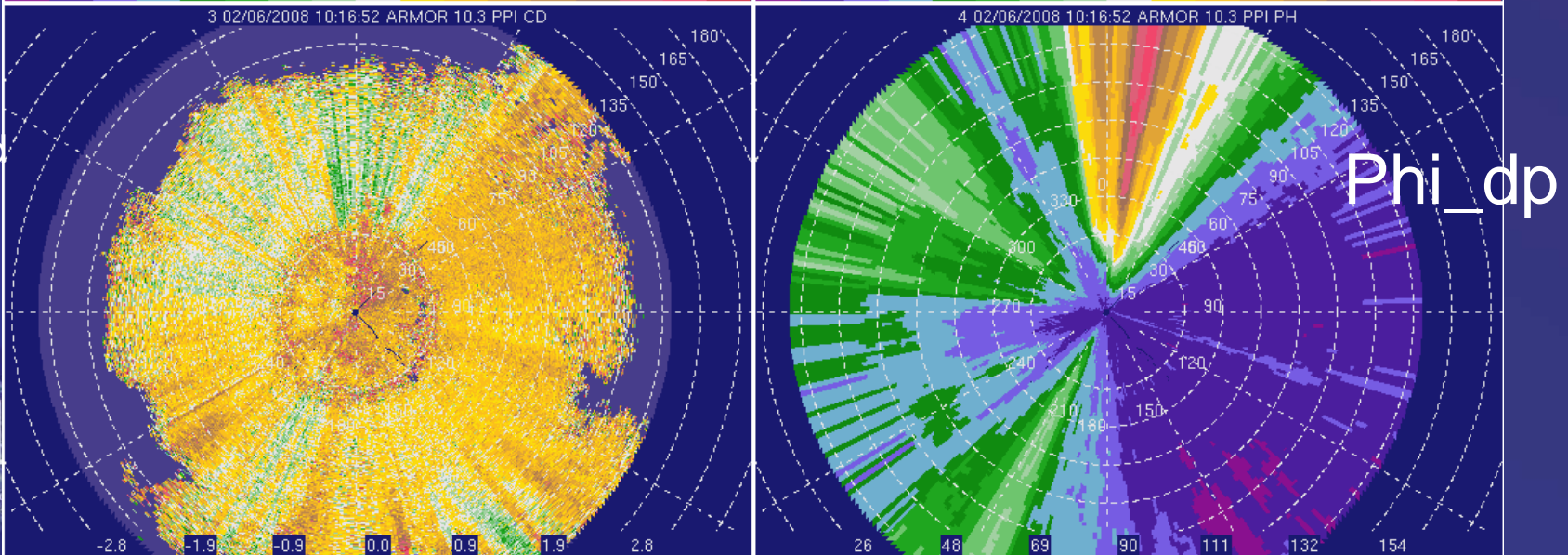
# Data from Other Simultaneous H and V Transmit Radars

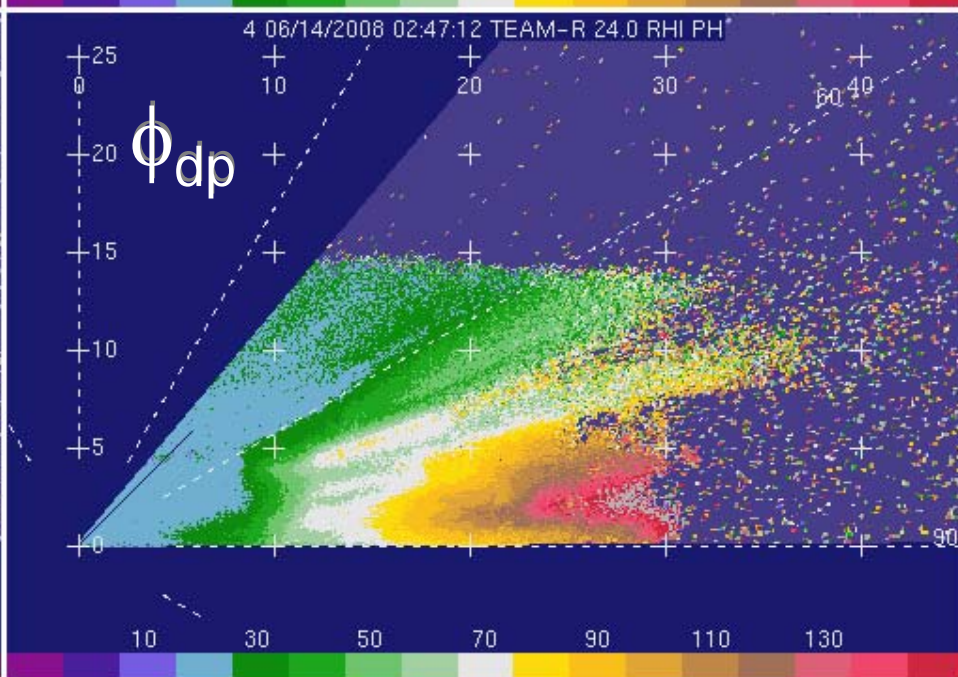
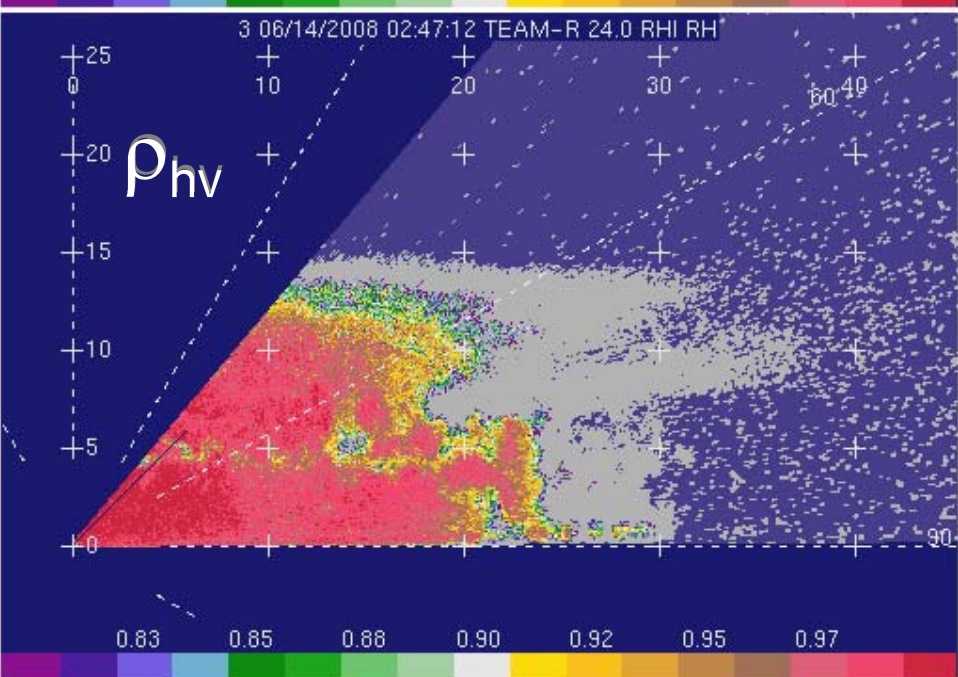
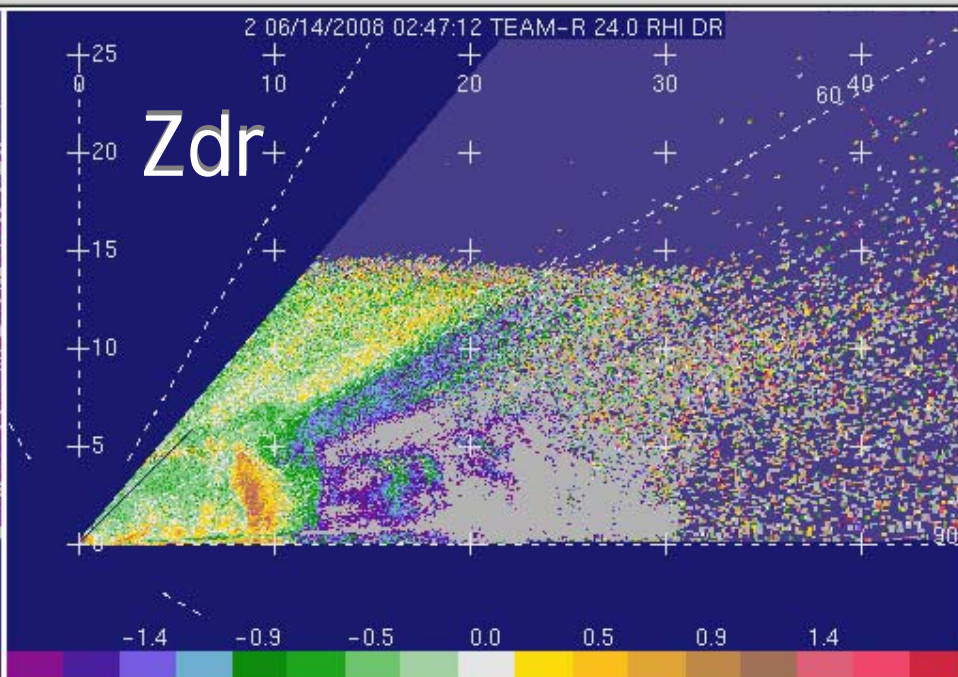
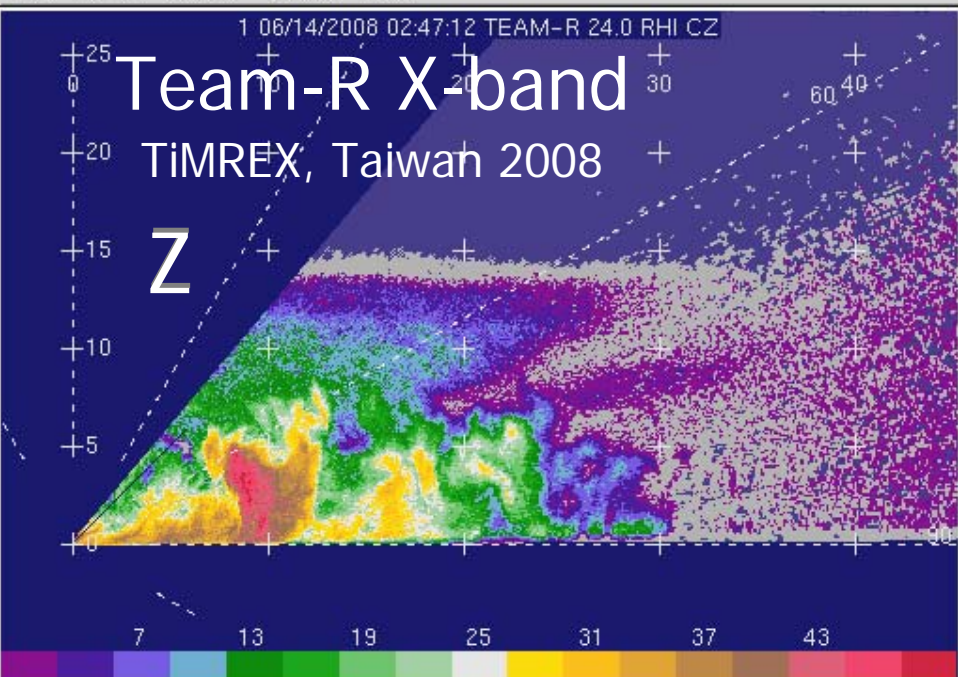
University of Alabama Huntsville, ARMOR Radar

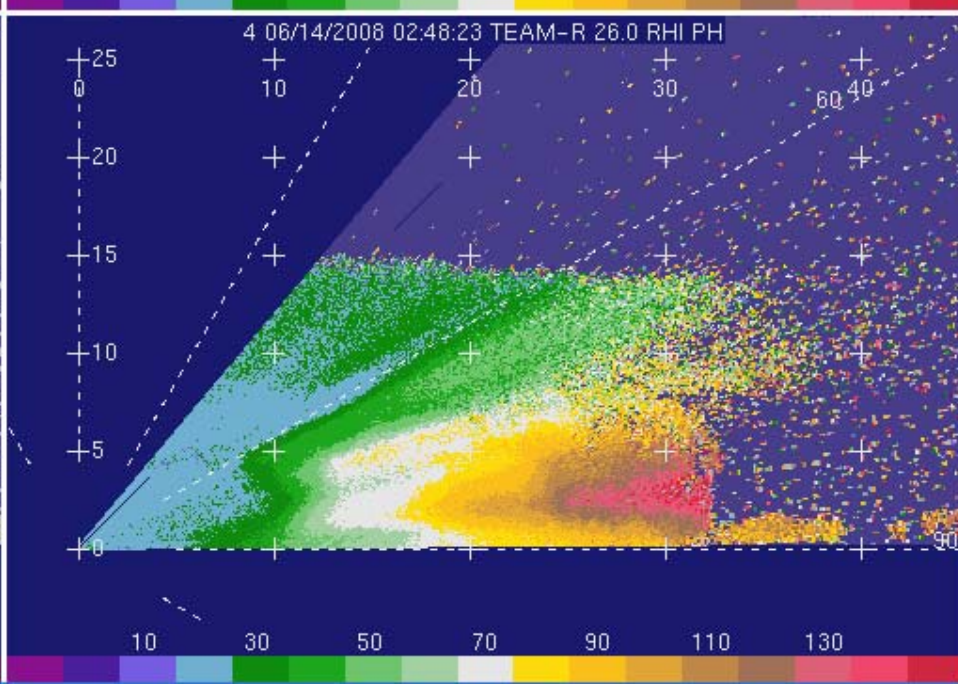
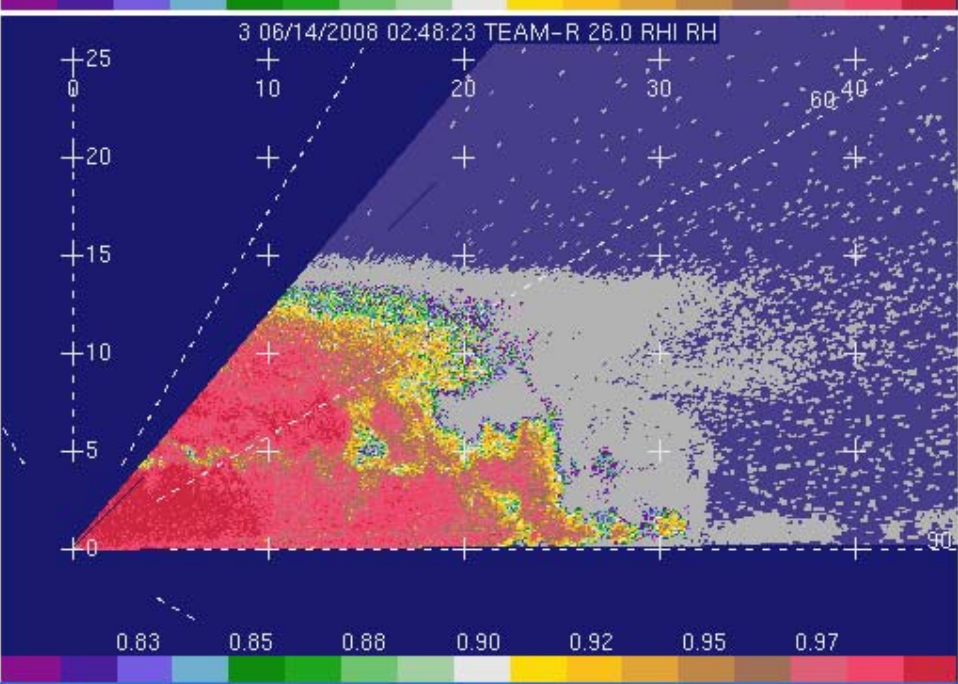
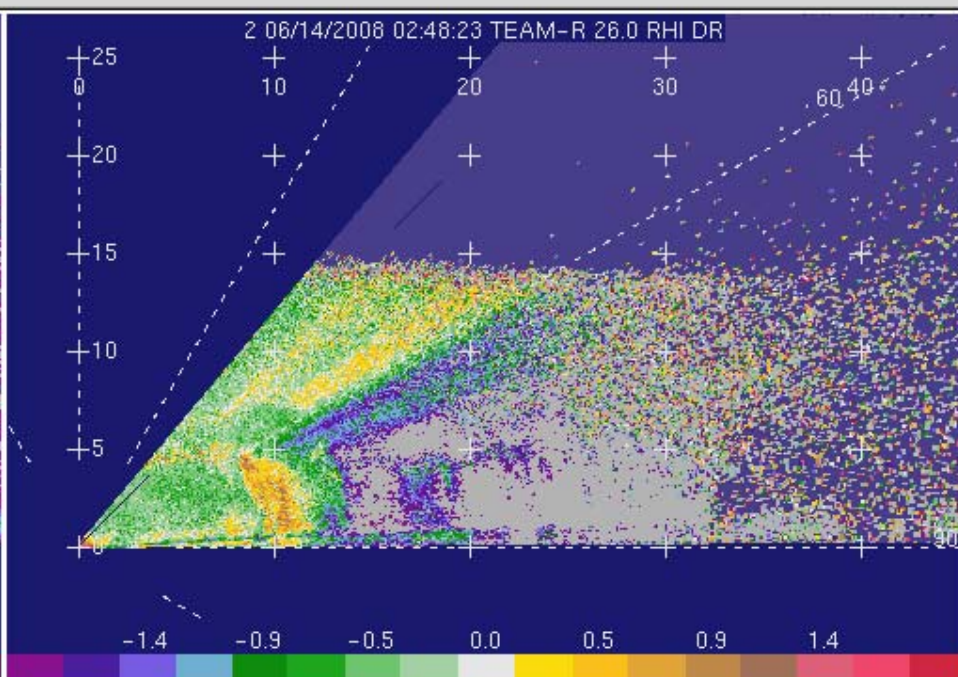
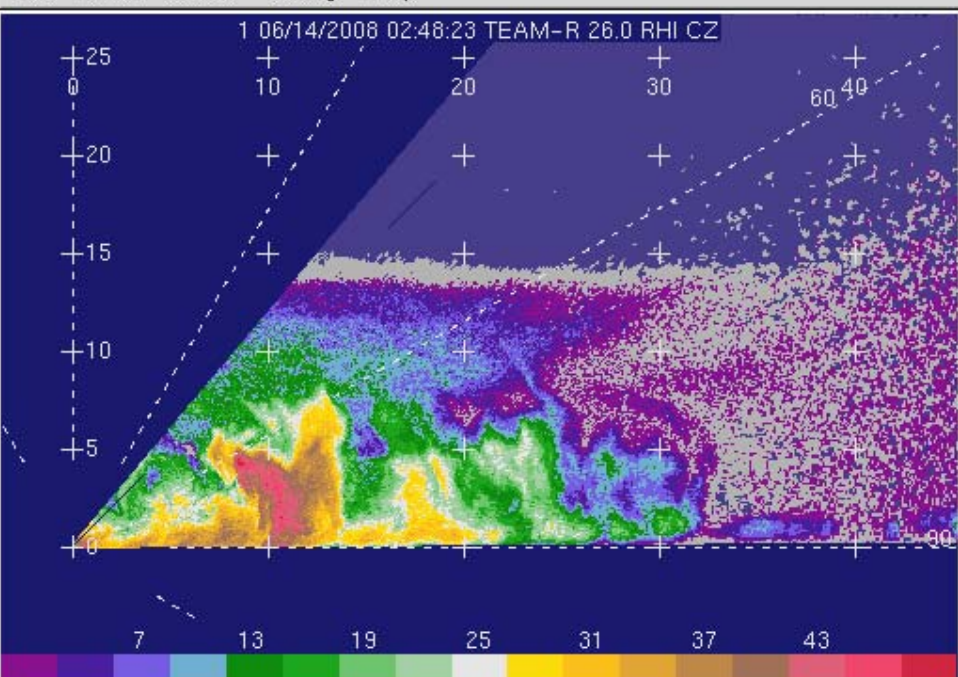
Elev. = 10.3 deg.

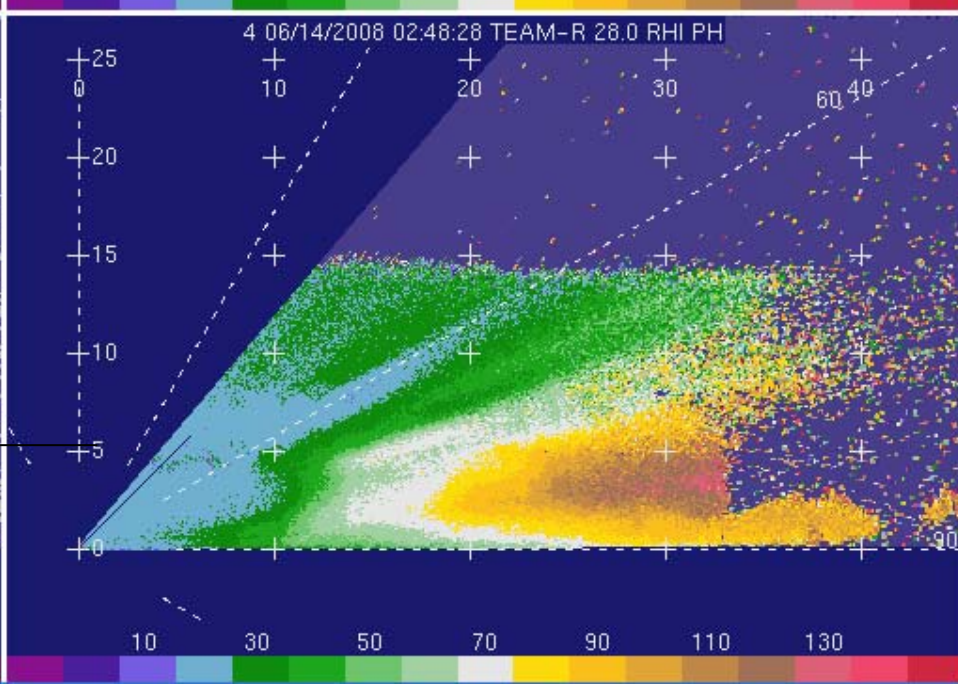
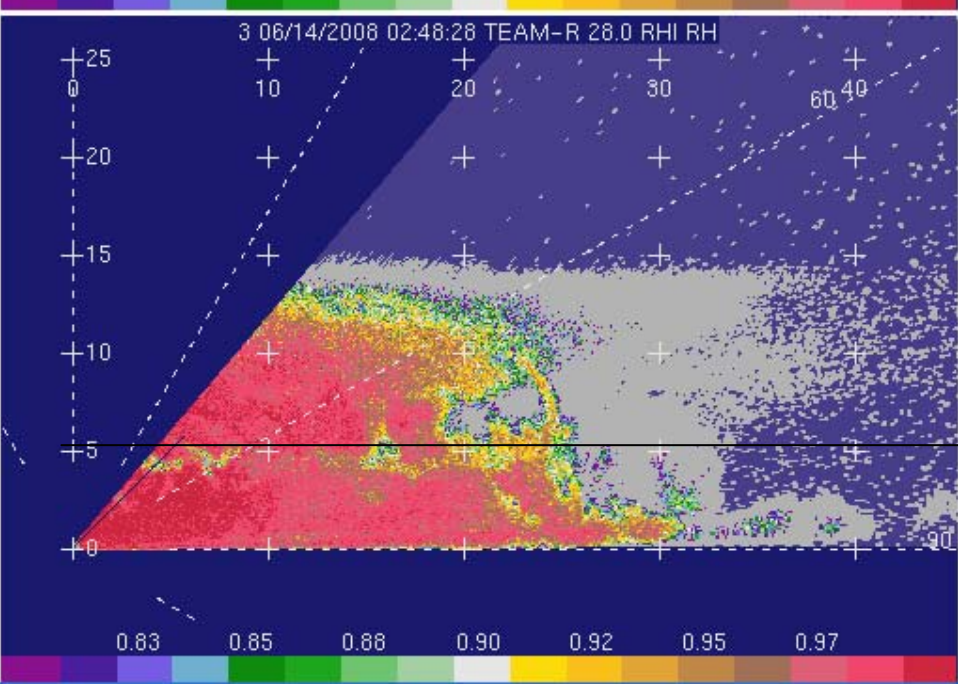
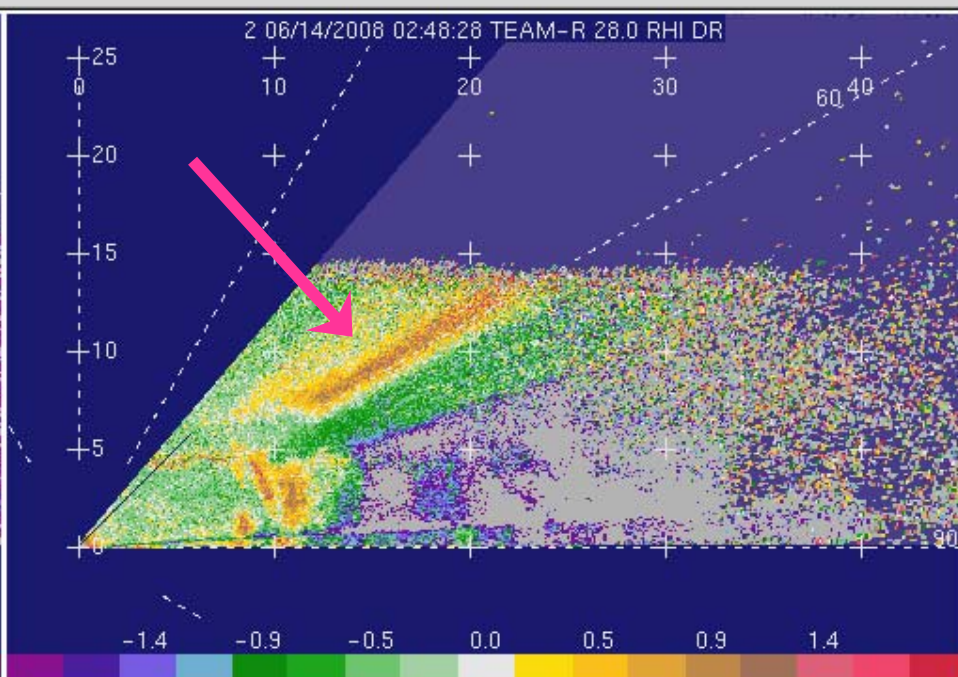
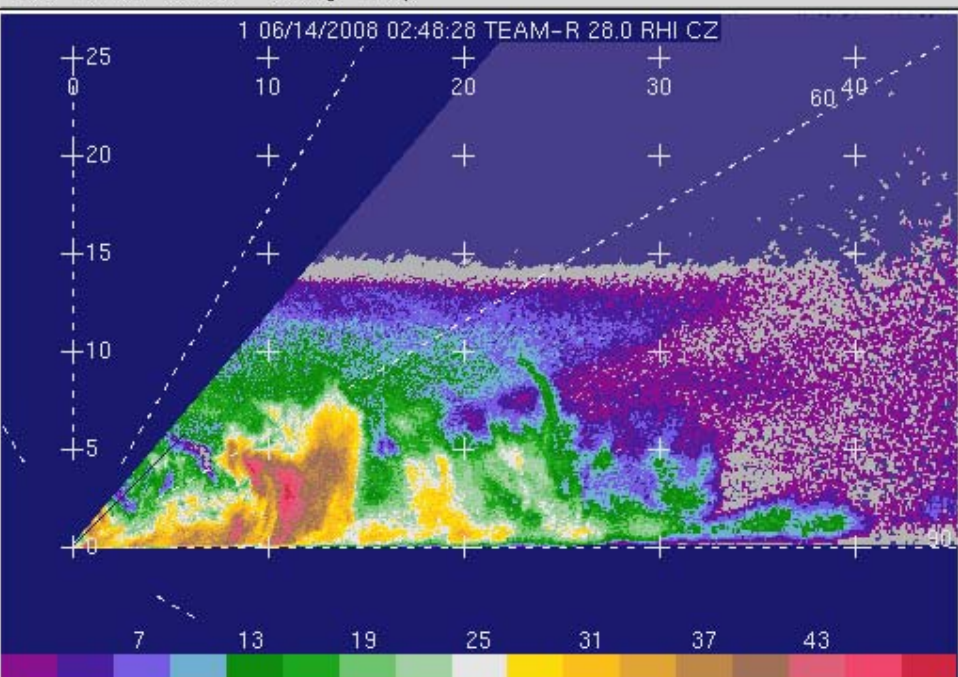


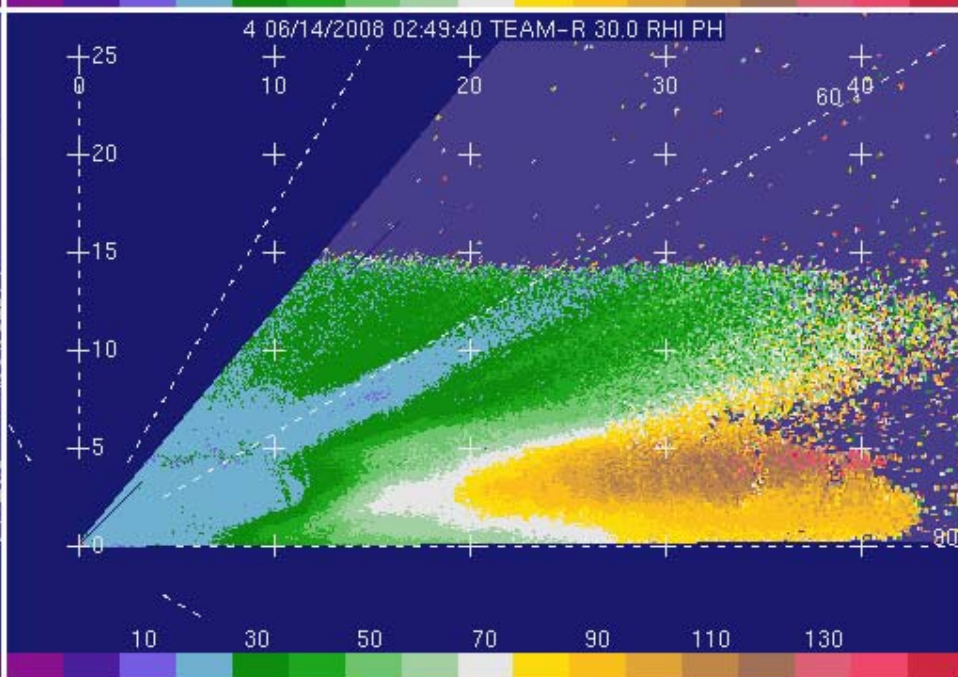
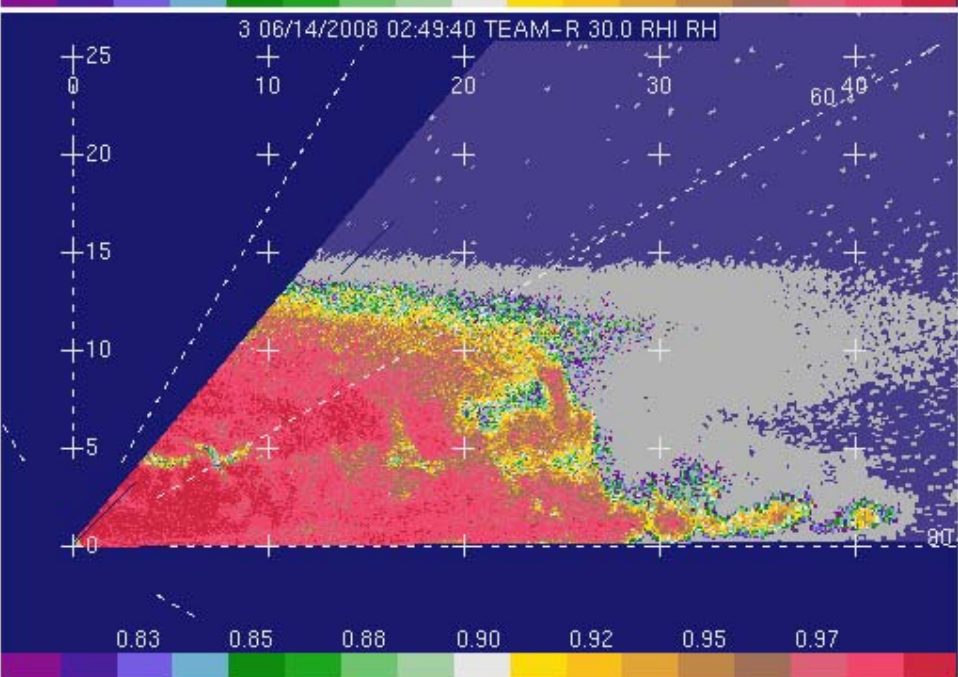
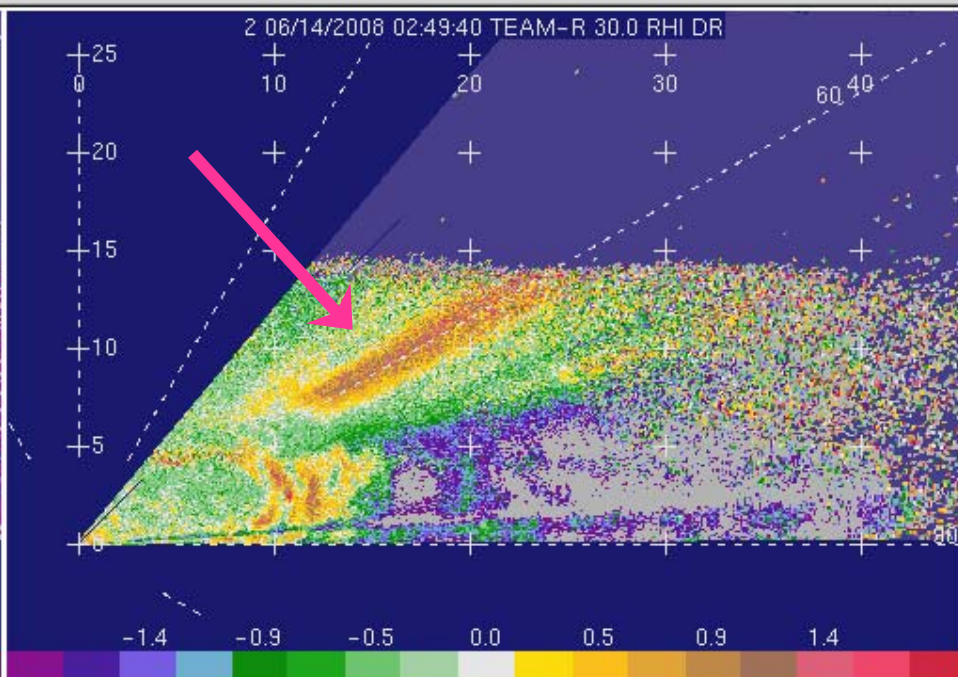
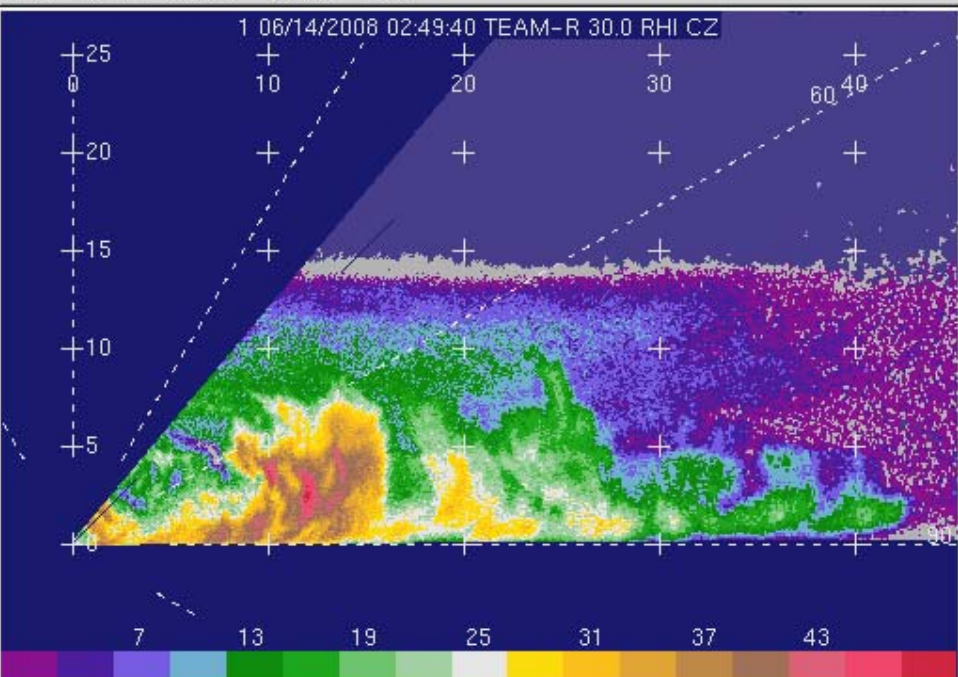
$Z_{dr}$   
corrected

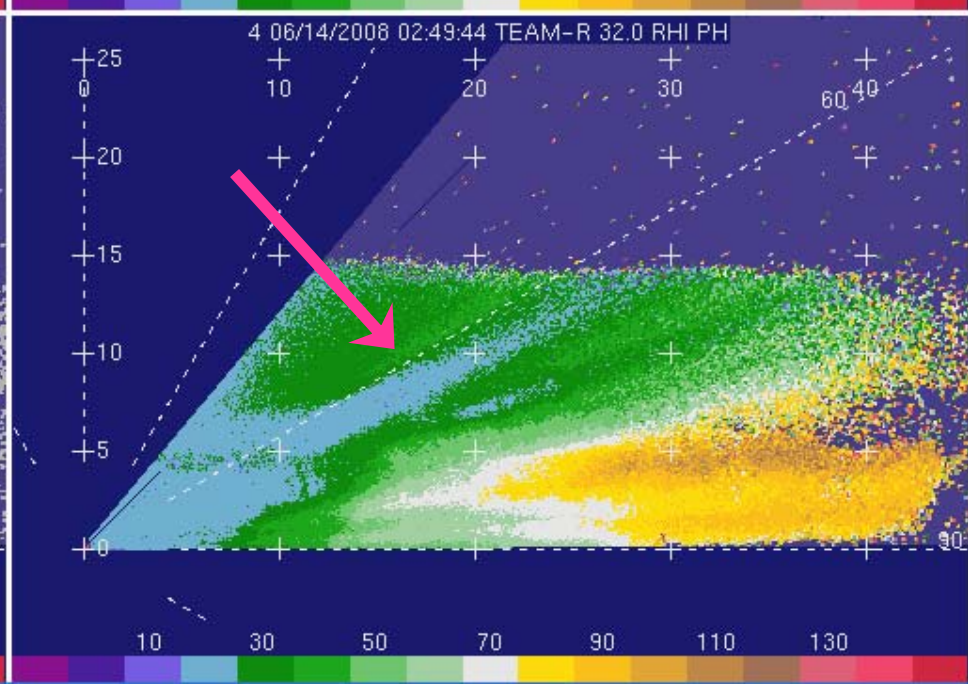
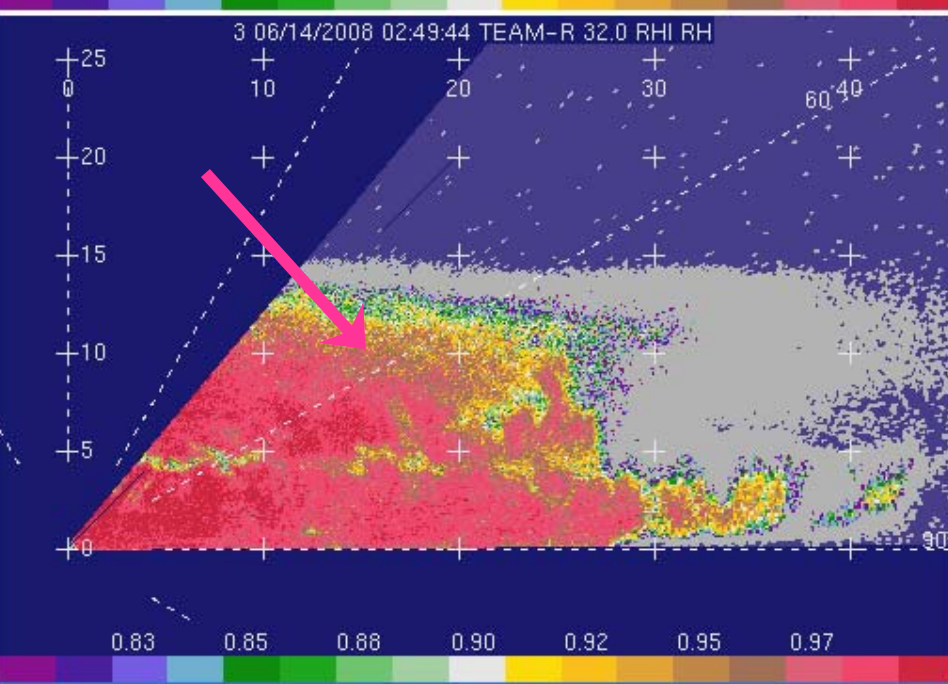
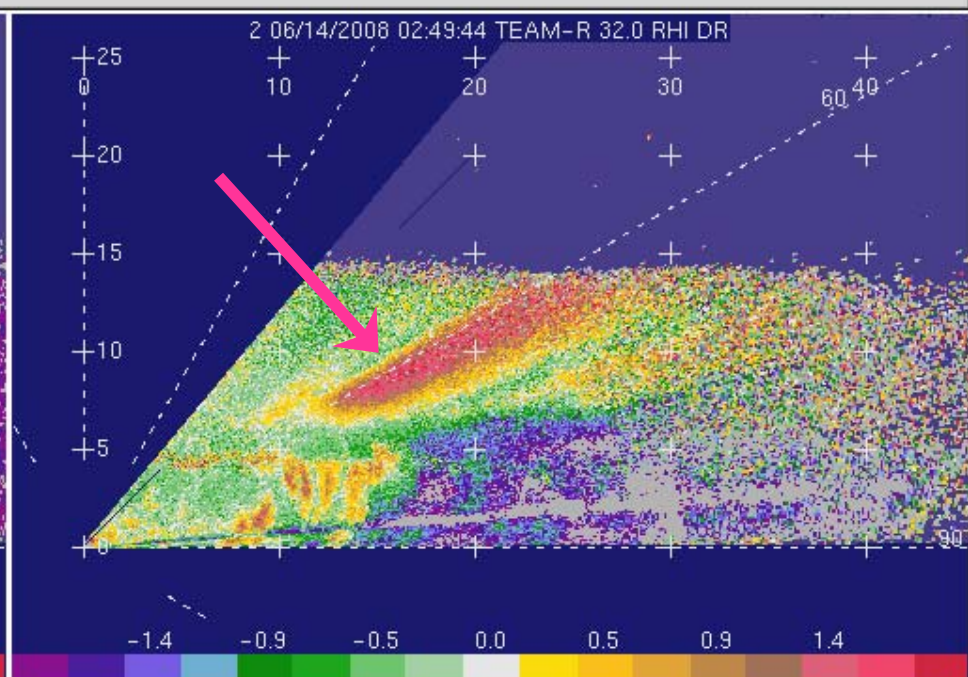
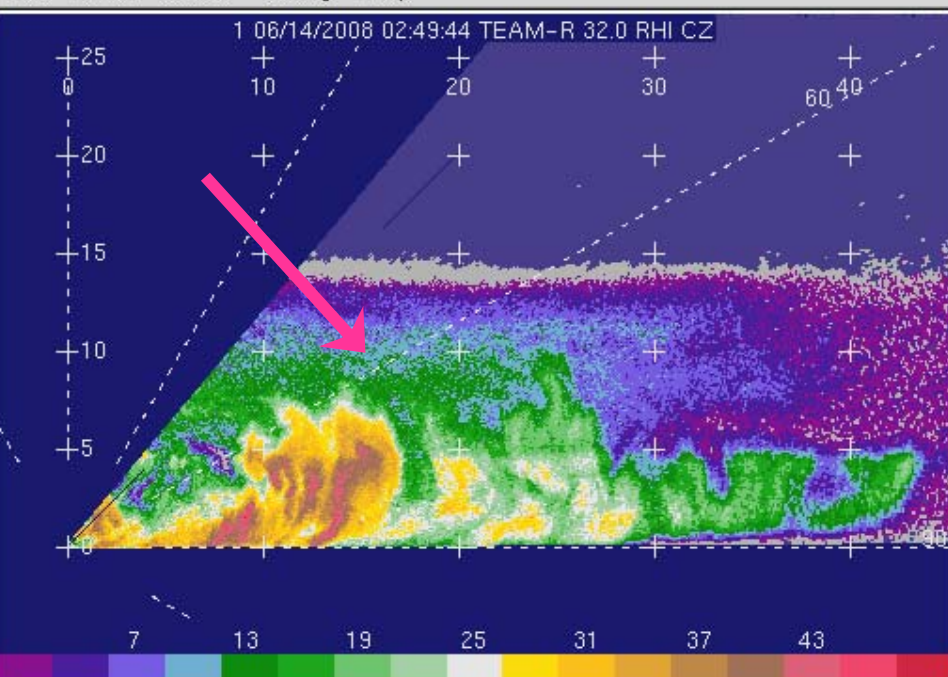


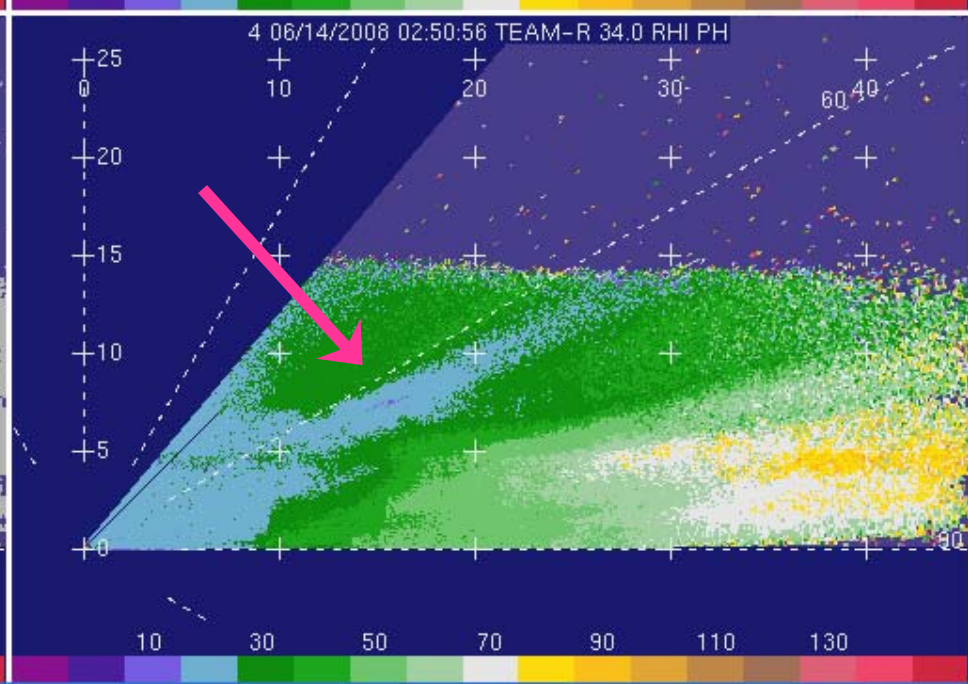
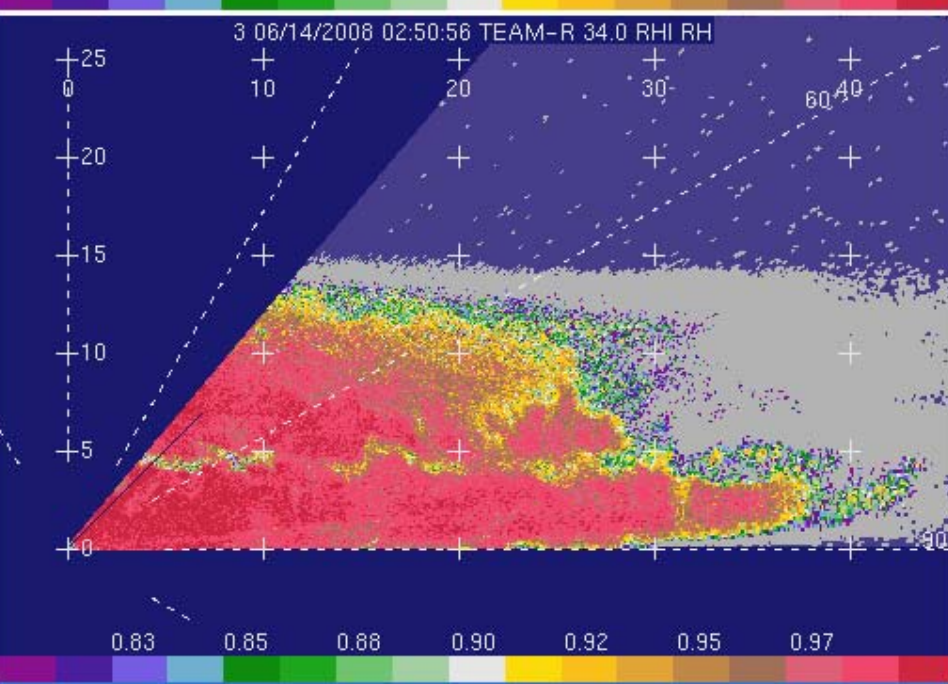
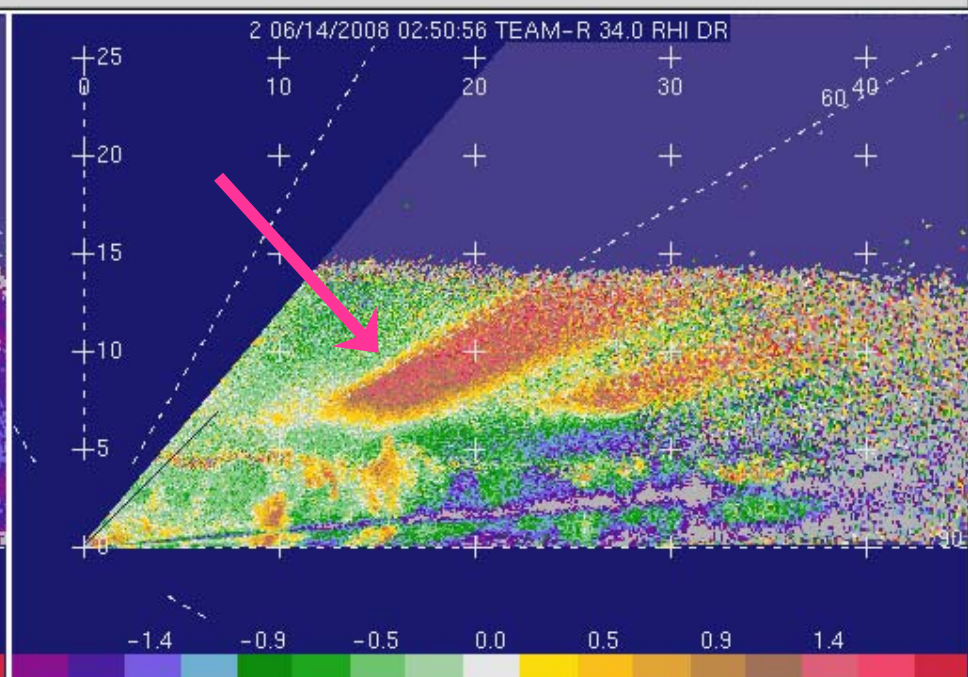
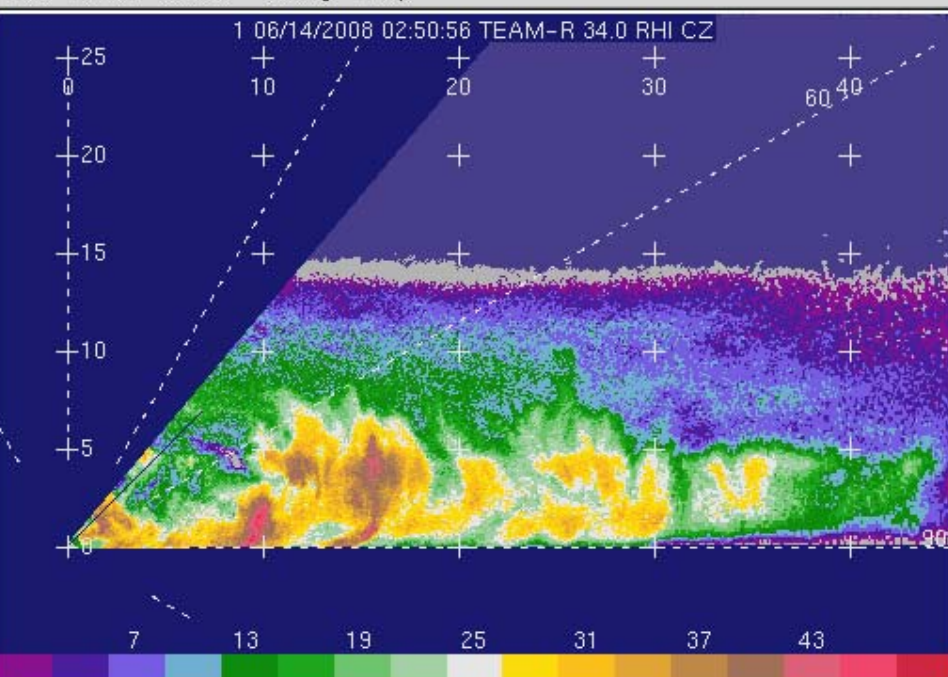








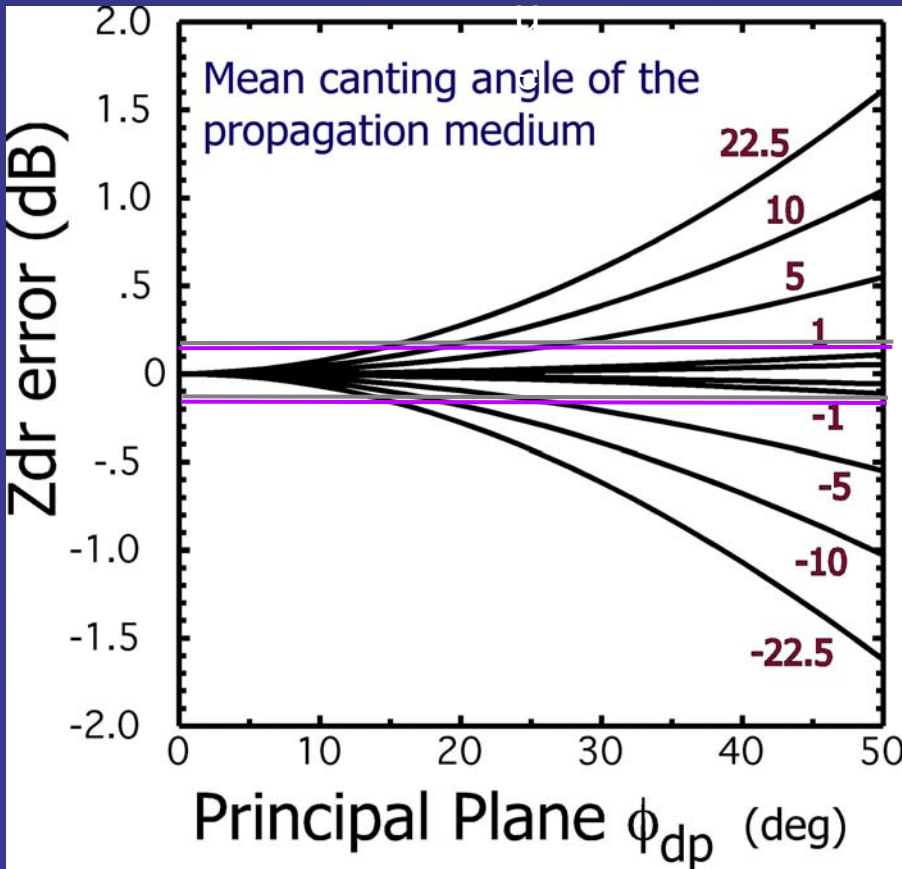




# Modeled Zdr Bias

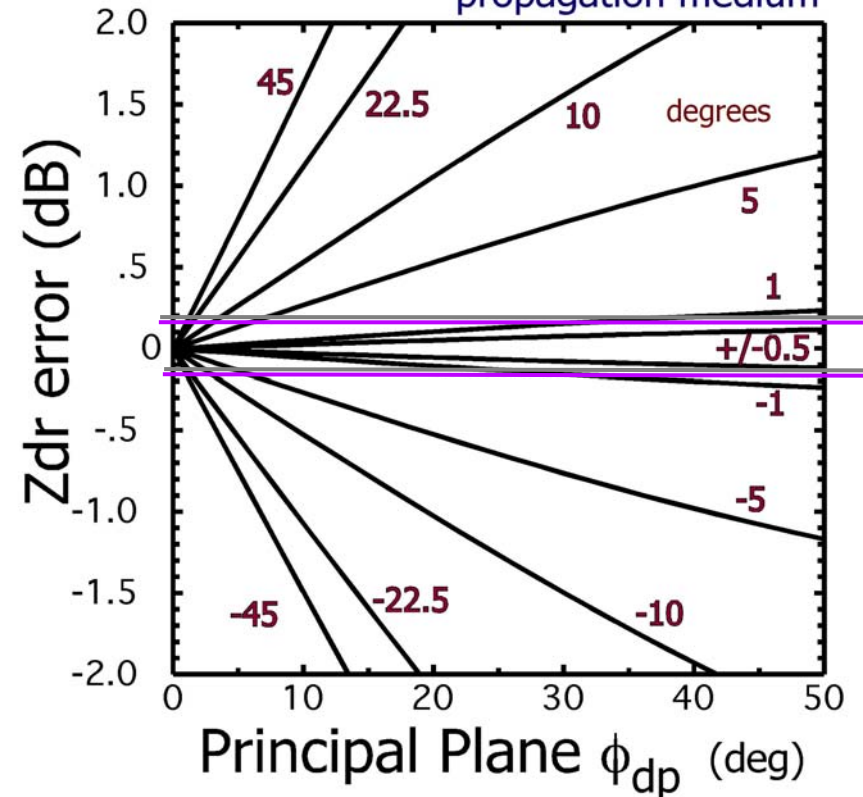
Due to canted ice crystals

Slant 45° transmit D



Circular pol. transmit

Mean canting angle of the propagation medium



- *Very little differential phase needs to accumulate before significant SHV  $Z_{dr}$  bias is observed.*

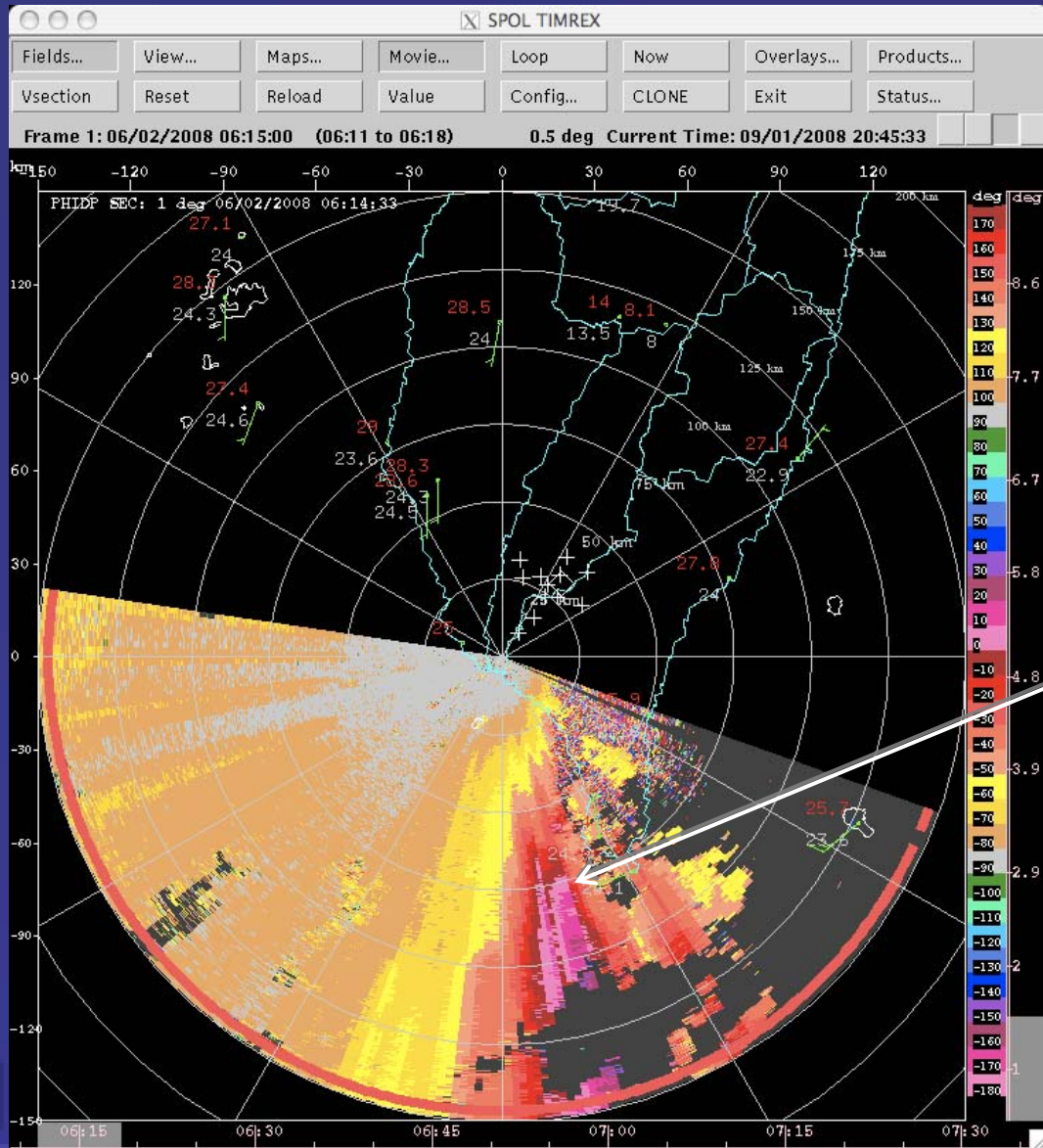
# Antenna Polarization Errors

- TiMREX: Terrain-influenced Monsoon Rainfall Experiment. Taiwan, May-June 2008
- Both fast alternating H&V (FHV) and simultaneous H&V (SHV) data sets gathered within minutes of each other.



First analysis of such data (to our knowledge)

# S-Pol TIMREX $\phi_{dp}$



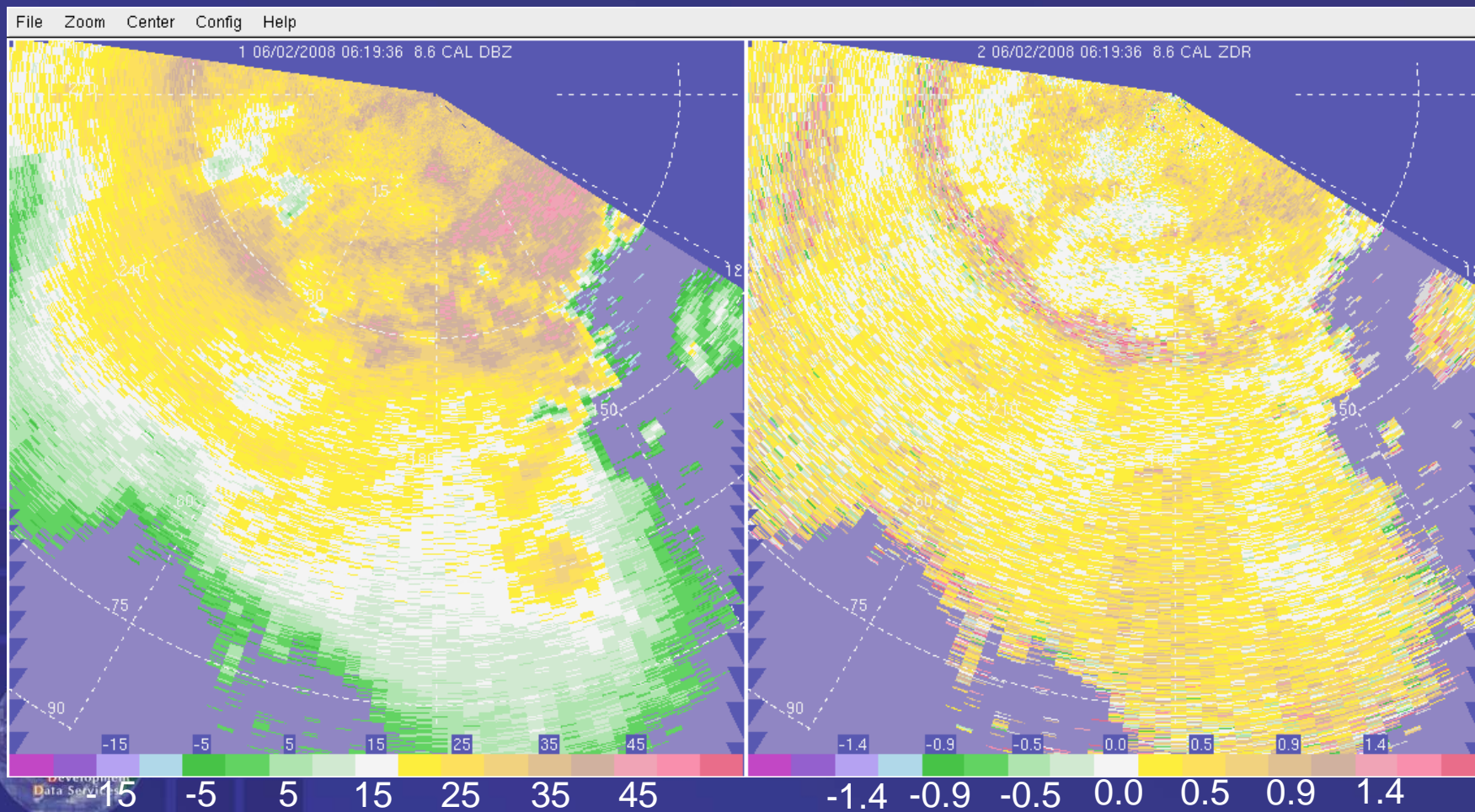
Over 100 degrees of phase shift



# Fast Alternating H&V Transmit at 8.6 deg elevation 06:19:36

Reflectivity (dBZ)

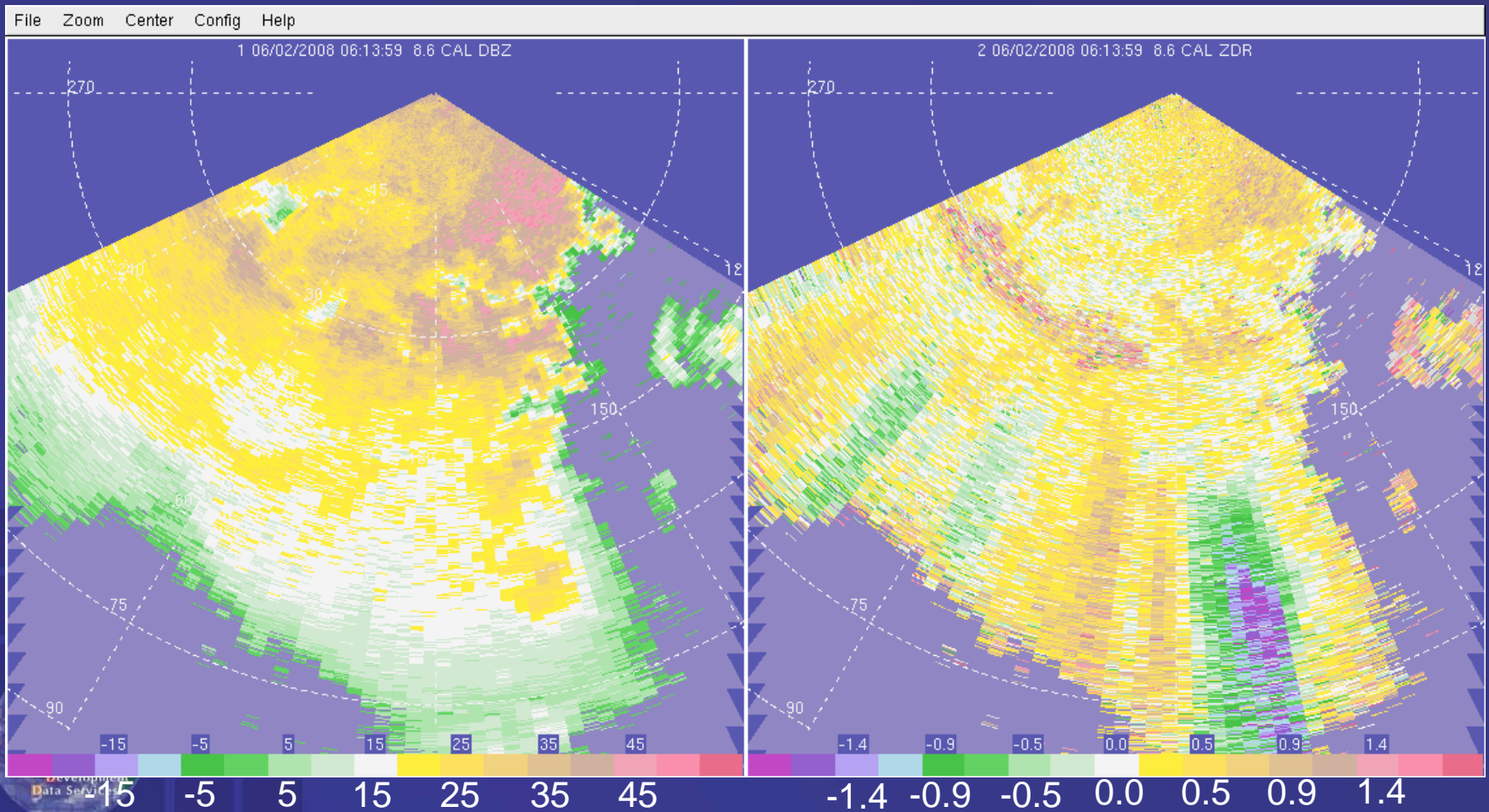
Differential Reflectivity (dB)



# Simultaneous H&V Transmit at 8.6 deg elevation. 06:13:59

Reflectivity (dBZ)

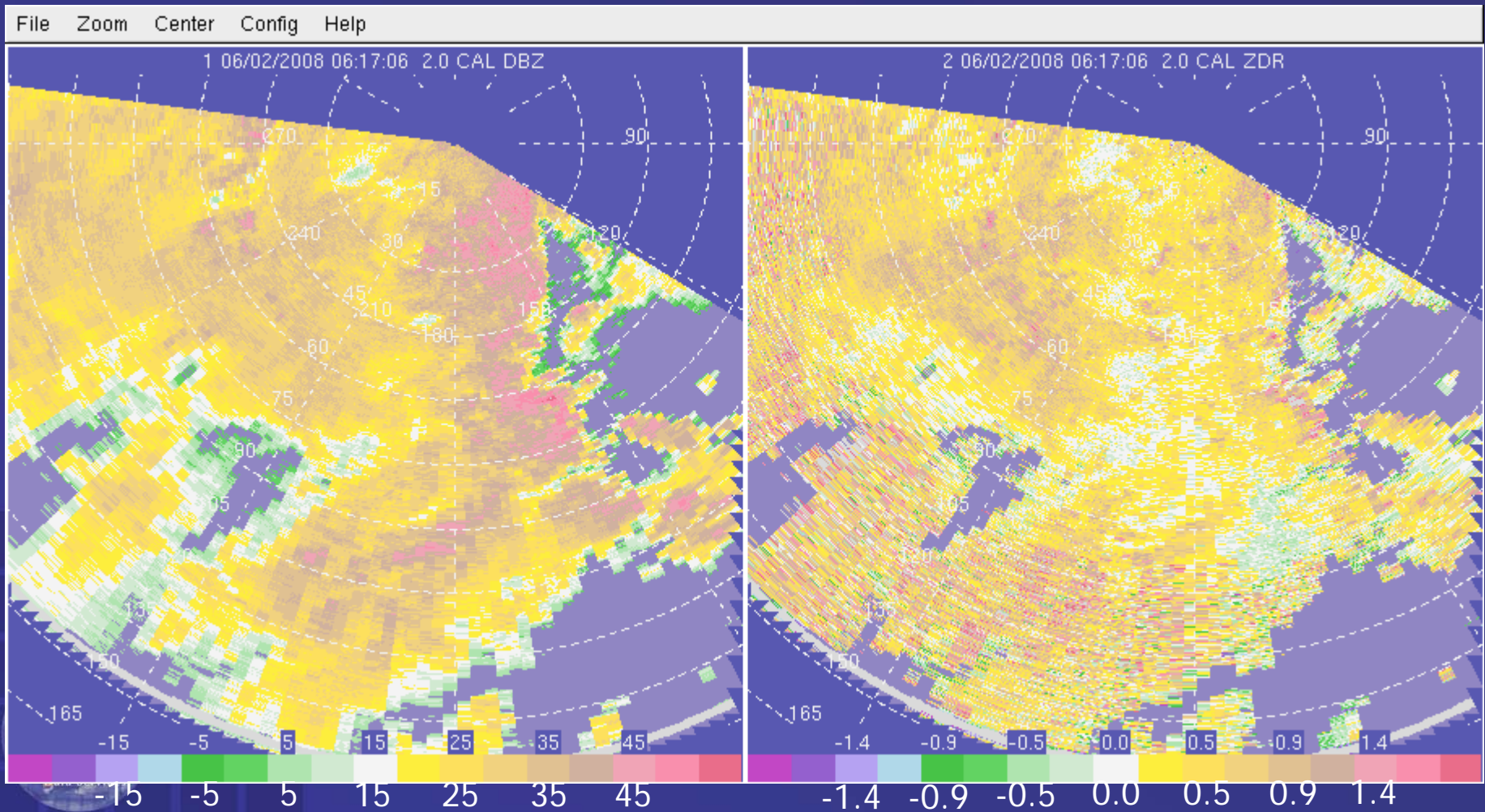
Differential Reflectivity (dB)



# Fast Alternating Transmit at 2.0 deg elevation

Reflectivity (dBZ)

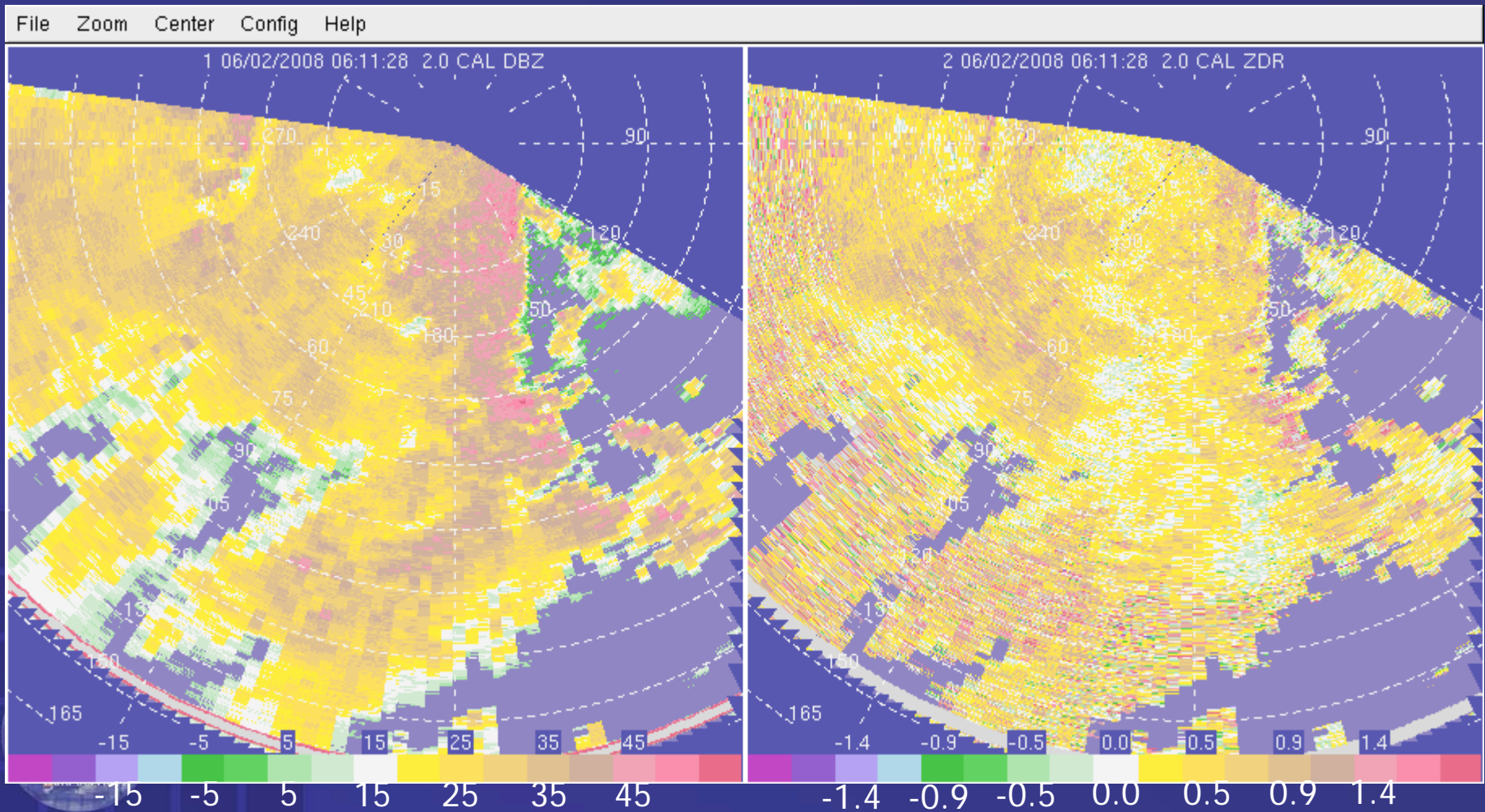
Differential Reflectivity (dB)



# Simultaneous Transmit at 2.0 deg elevation

Reflectivity (dBZ)

Differential Reflectivity (dB)



# Compare SHV and FHV Zdr

For  $20 \text{ dBZ} < Z < 25 \text{ dBZ}$

Total $\phi_{dp}$	Mean Zdr (dB)	
	FHV	SHV
between 20 and 40 deg	0.17	0.16
between 40 and 70 deg	0.15	0.26
between 70 and 100 deg	-0.07	0.20

As  $\phi_{dp}$  increases SHV data incurs positive Zdr bias  
(no attenuation correction)



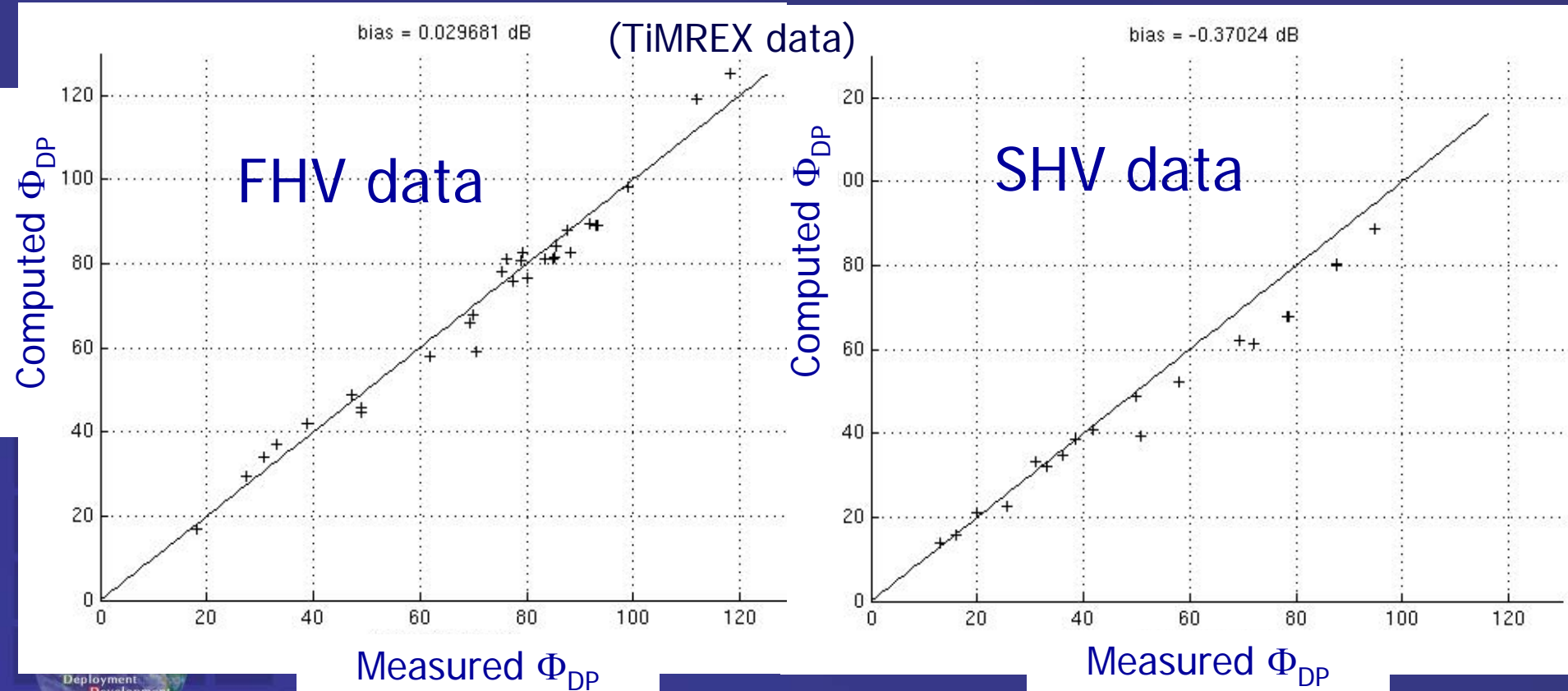


# Power Calibration: Self-Consistency

- Compare  $\phi_{dp}$  as estimated by  $Z$ ,  $Z_{dr}$  with  $\phi_{dp}$  estimated directly from radar data
  - Requires approximate knowledge of DSD
  - Technique of Vivekanandan, et al., 2003 based on Gorgucci et al.
  - Caveats
    - Avoid areas of hail, clutter, etc.
    - Correct for  $Z_{dr}$  bias, first
  - *But also can use to detect  $Z_{dr}$  bias*

# Self Consistency Technique

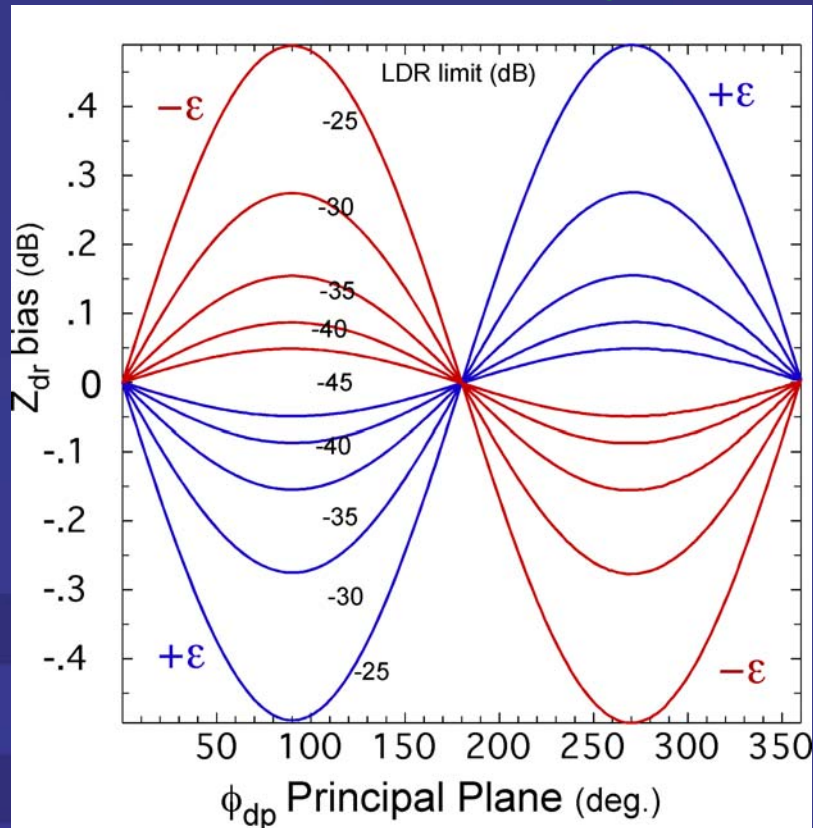
For rain DSDs,  $K_{dp}$ ,  $Z_{dr}$  and  $Z$  have a predictable relationship. In this technique, measured  $Z_{dr}$  and  $Z$  are used to predict  $\phi_{dp}$  and judge if there is any  $Z_{dr}$  bias.



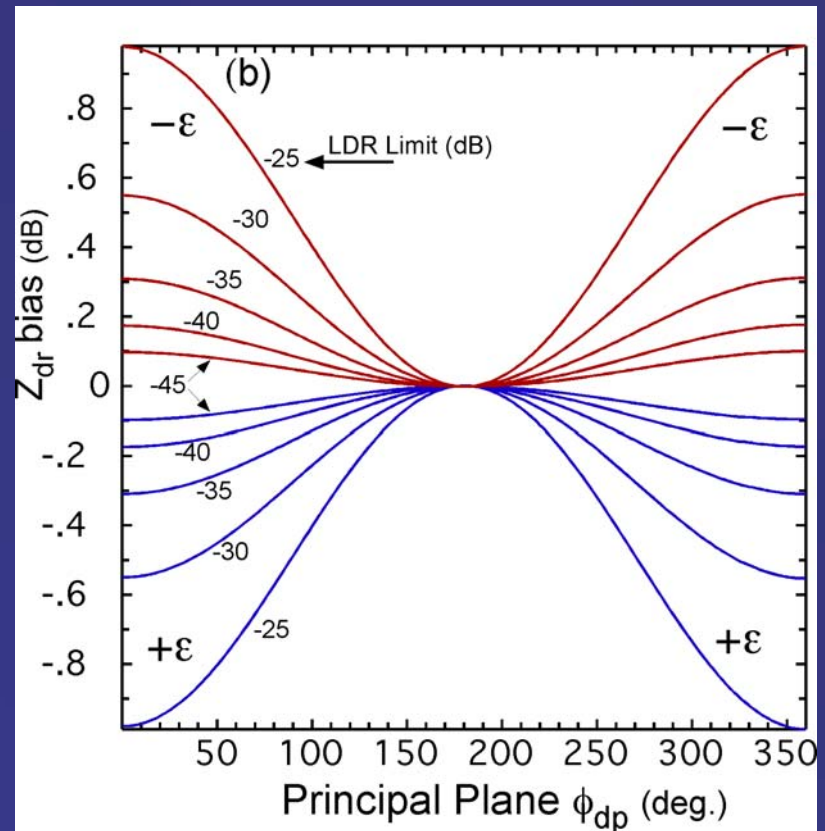
# SHV $Z_{dr}$ Bias Curves

The antenna errors can be equivalently expressed in terms of the LDR system limit, i.e., LDR measured in drizzle.

Transmit linear 45 degree



Transmit Circular



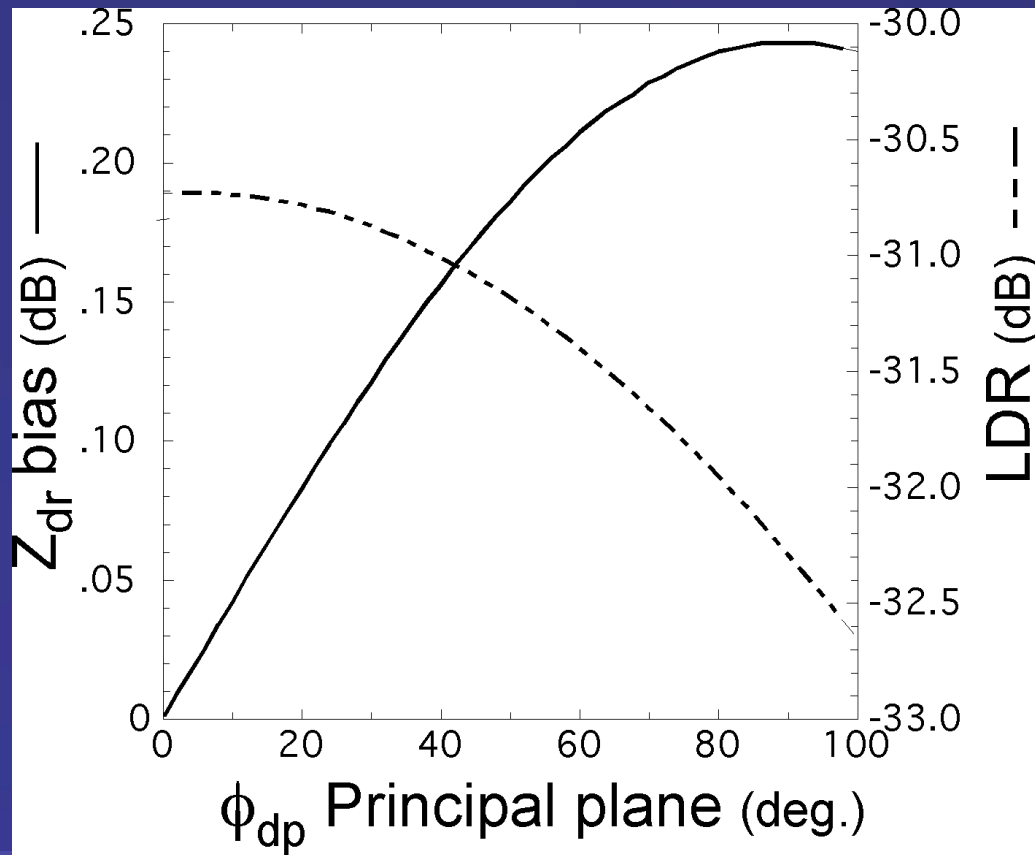
For SHV  $Z_{dr} < 0.2\text{dB}$ , LDR system limit  $< -40\text{dB}$

# Correcting S-Pol SHV Zdr

Using solar scan and LDR limit values, can calculate:

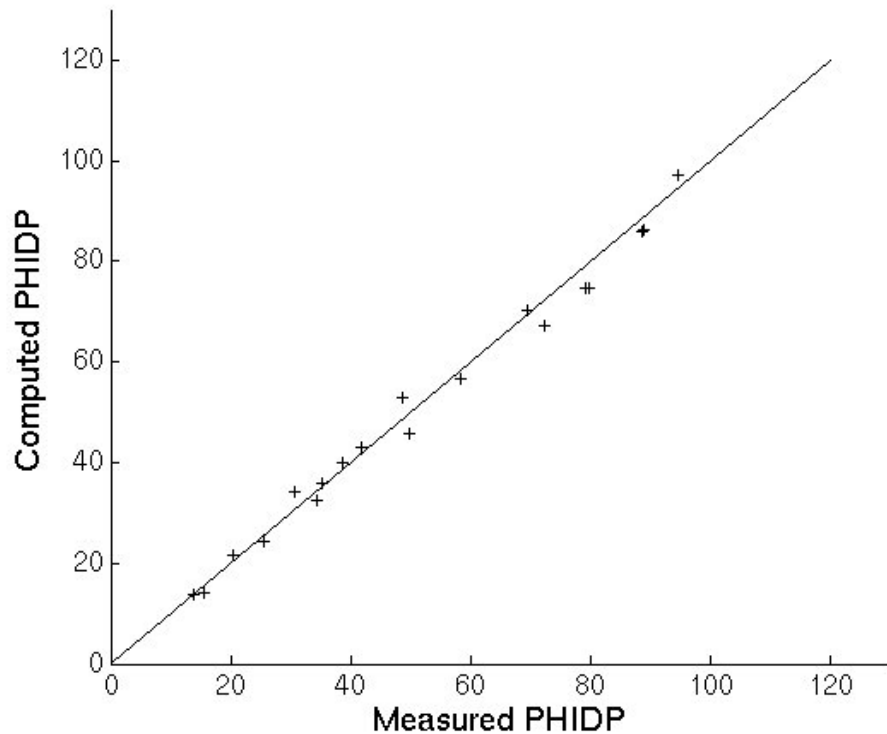
Tilt H =  $0^\circ$  , ellip H =  $0.91^\circ$  and tilt V =  $90^\circ$  , ellip V =  $-0.69^\circ$

From the model

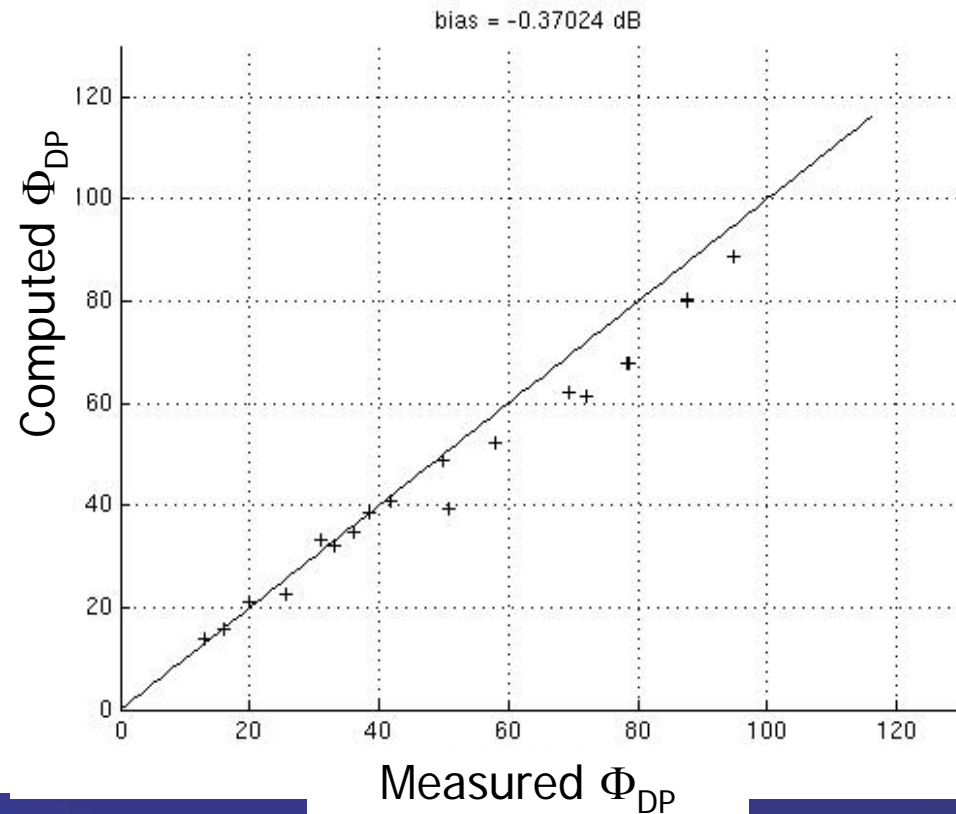


# Corrected SHV Data

Corrected SHV data



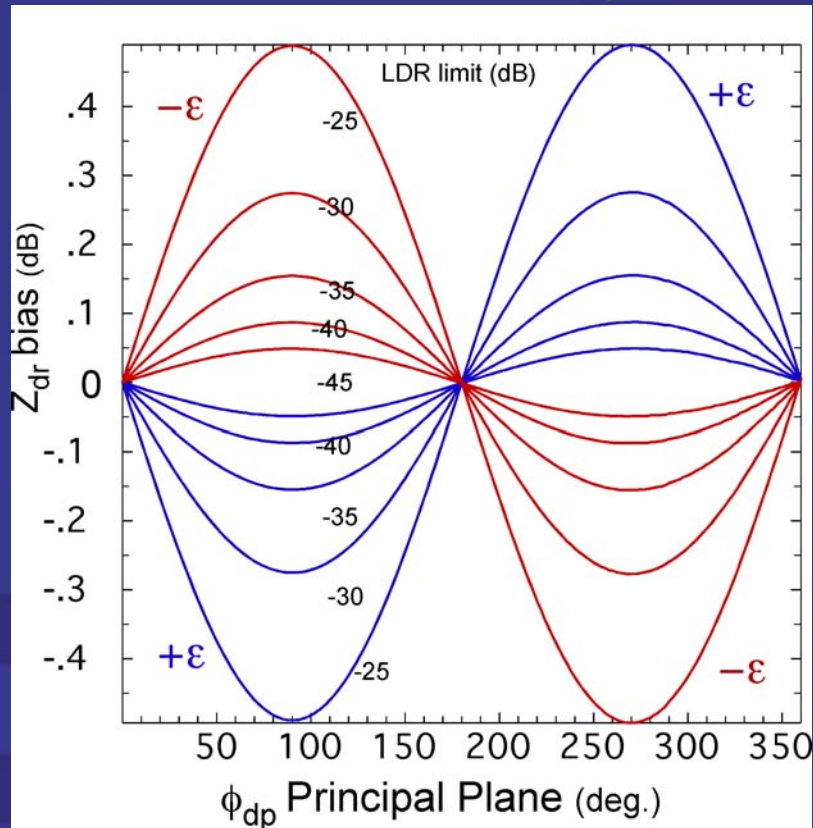
Uncorrected SHV data



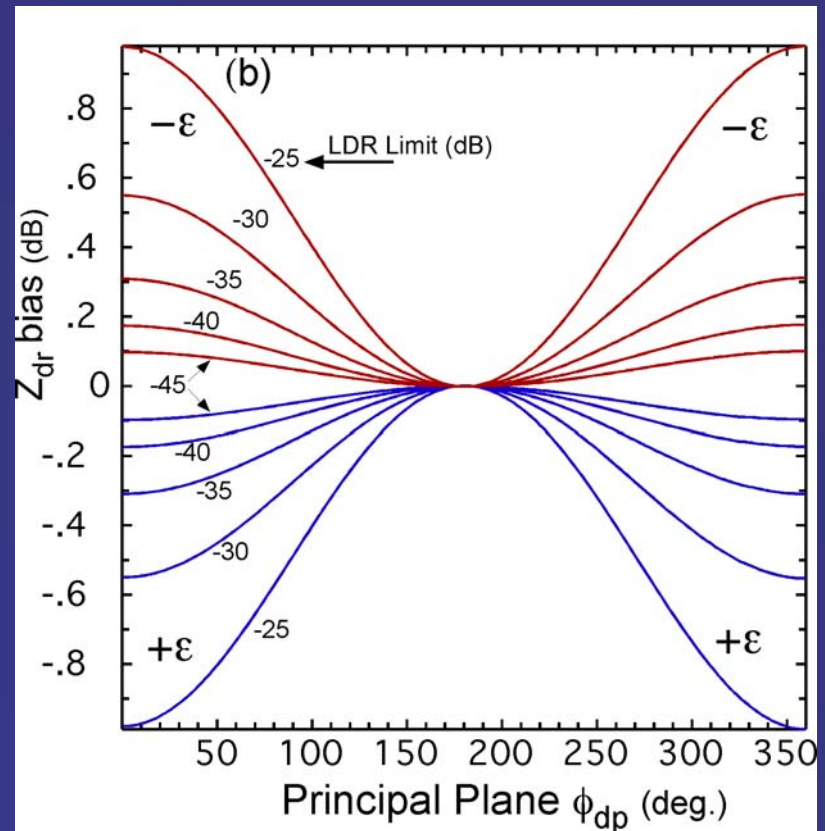
# SHV $Z_{dr}$ Bias Curves

The antenna errors can be equivalently expressed in terms of the LDR system limit, i.e., LDR measured in drizzle.

Transmit linear 45 degree



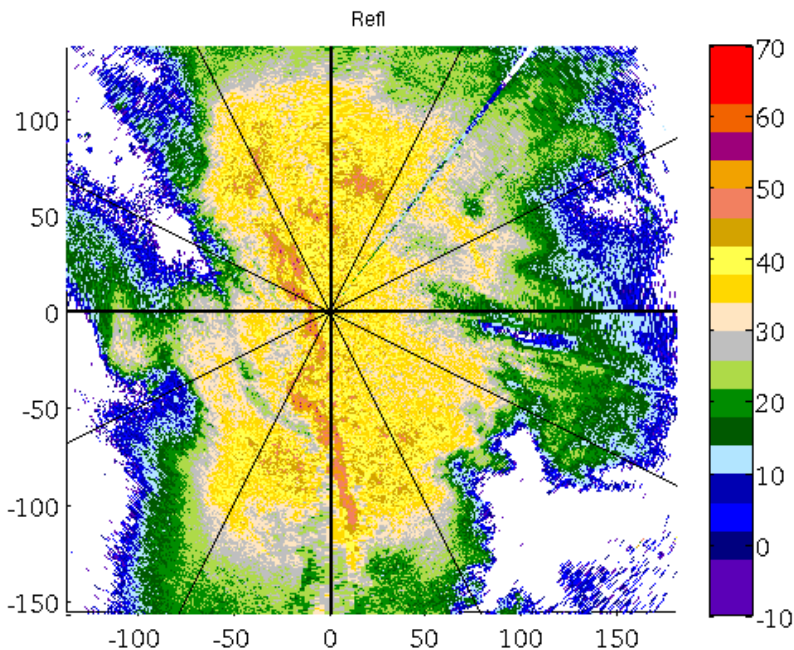
Transmit Circular



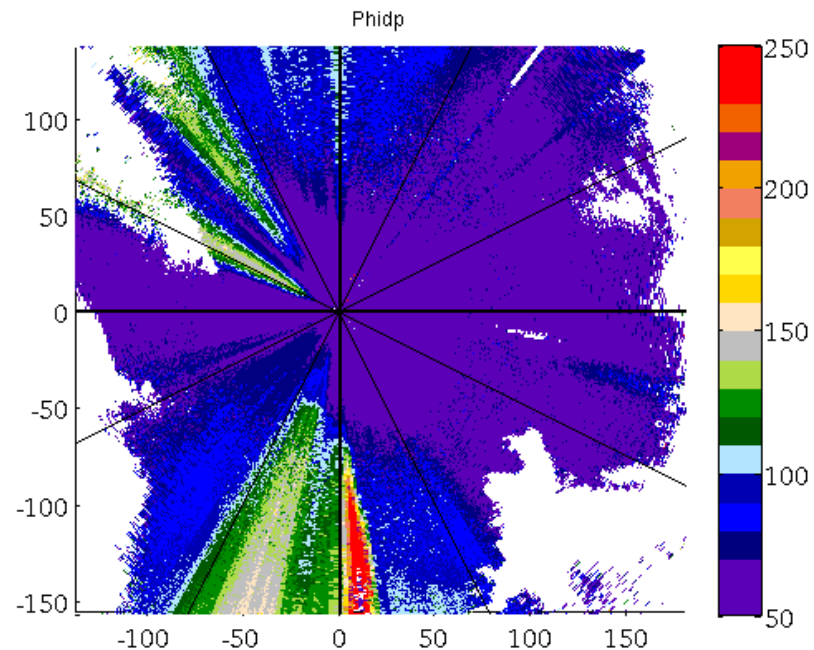
# KOUN Data, 30 March 2007

- Large  $\phi_{dp}$  case in rain: 300 degrees!
- Reported as more “tropical” in nature (few large drops)
- No hail reports from NWS or the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)
- sounding data for the time period shows a moist profile through a deep layer, low vertical wind shear, and relatively low convective available potential energy (CAPE = 834 J)

Z

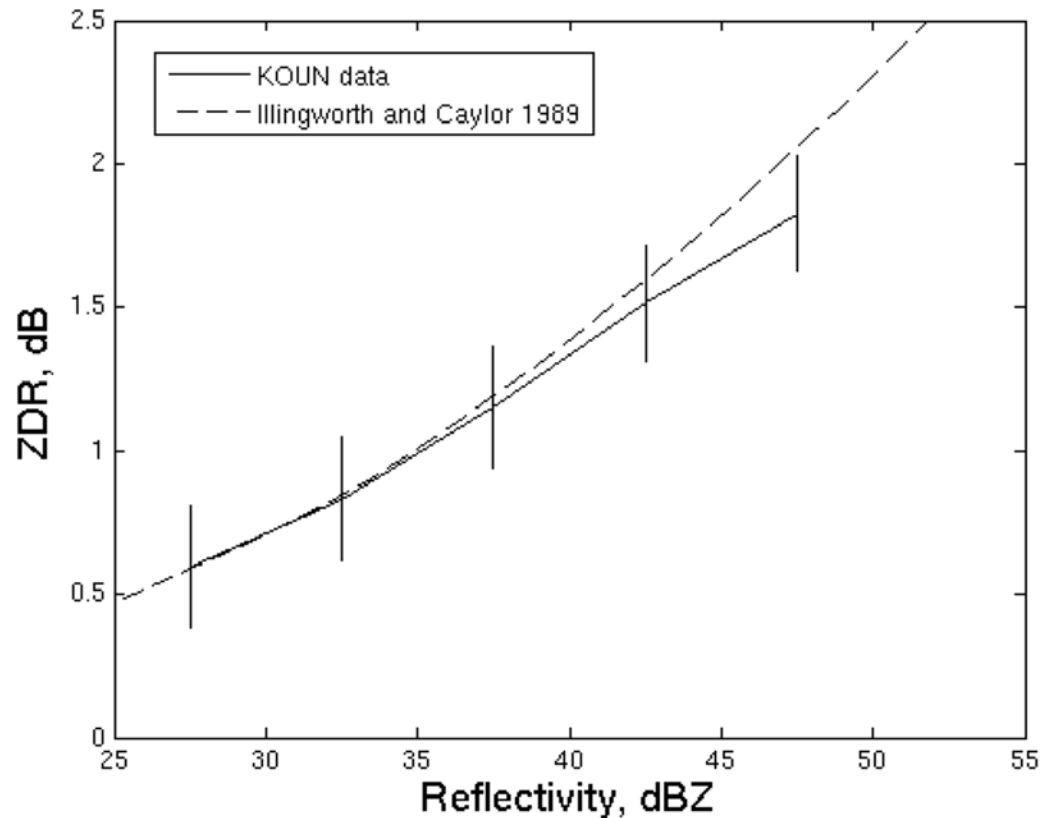


$\phi_{dp}$



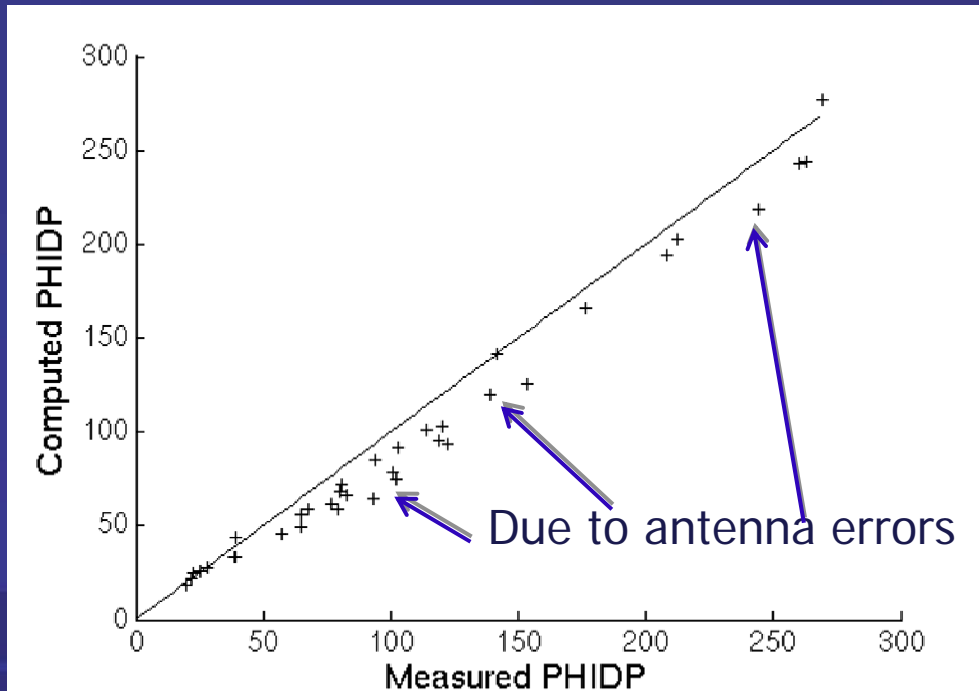
# KOUN Calibration

- Data from rain with less than 30 deg. accumulative  $\phi_{dp}$
- Self consistency

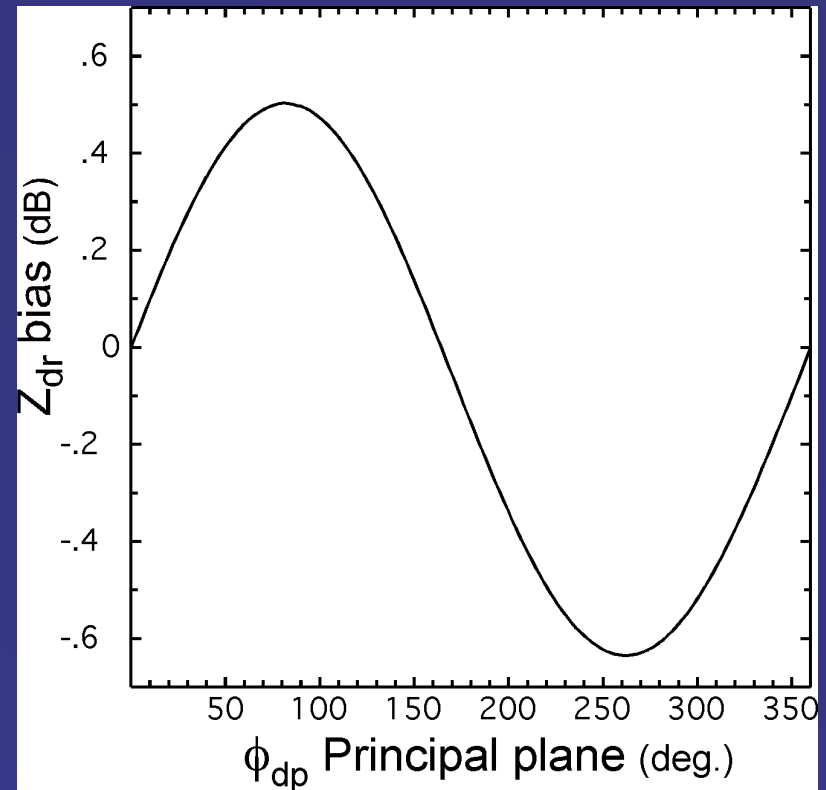


# Koun Calibrated Data

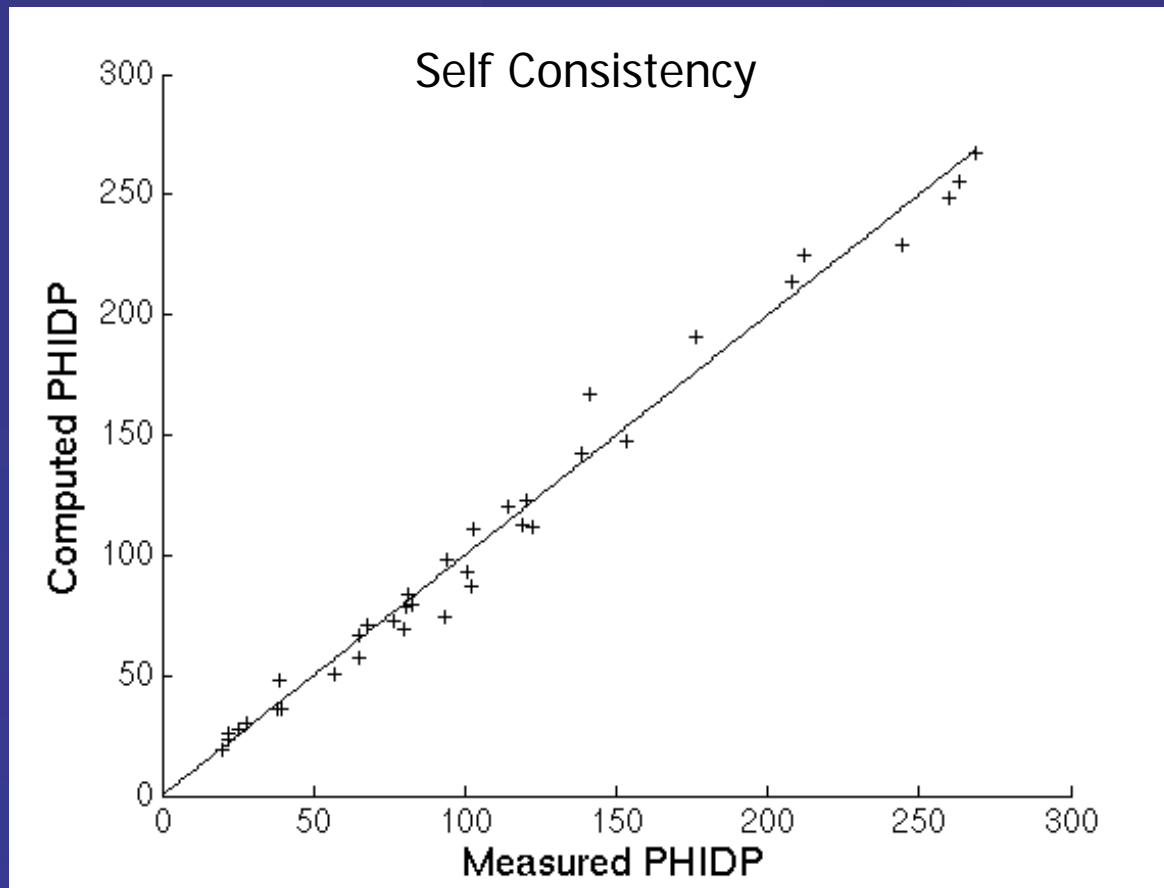
## Self Consistency



## Estimated Antenna Errors

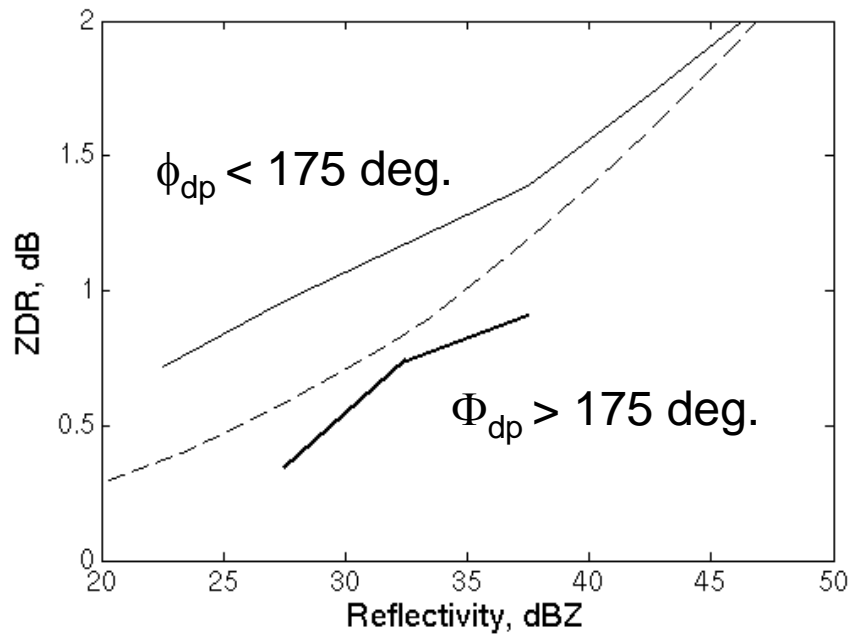


# KOUN Data Corrected for Antenna Errors

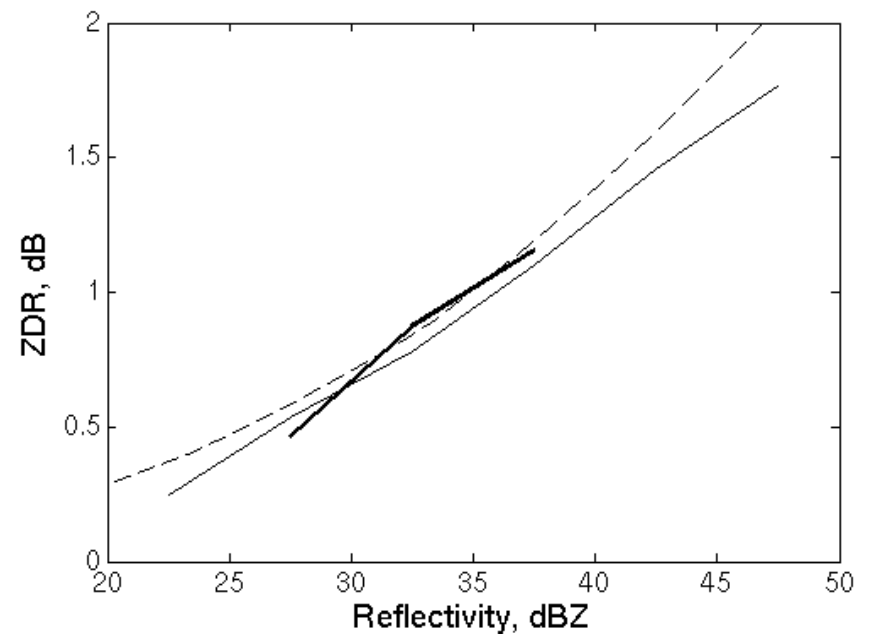


# KOUN $Z_{dr}$ Versus Z

## Uncorrected Data



## Corrected Data



# Physical Polarization Error Sources

- Surface error of the parabolic dish
- Blockage due to support struts and horn
- Feed horn (likely most significant)
- Radome irregularities
- Wetting of the radome



# Implications

- Rainfall estimates using SHV data based on  $Z_{dr}$  are suspect, especially for larger  $\phi_{dp}$
- Differential attenuation correction, even if it is done without error, the corrected data will still contain bias due to antenna errors
  - Better to use only  $\phi_{dp}$



# Conclusions

- Cross Coupling between the H and V simultaneous transmitted signals can occur in ice and mixed phase regions
- All radars have imperfect antennas and therefore polarization errors
- For a radar with a -35 dB LDR limit, Zdr errors still can be from 0.15 to 0.25 dB, max. (function of  $\phi_{dp}$ )
- The Zdr bias is a strong function of the transmit polarization state (H-to-V phase difference).
- *To minimize cross coupling the best strategy is to have an antenna with excellent isolation figure*
- Using self consistency among Z, Zdr and  $\phi_{dp}$ , the Zdr bias can be detected in region with about 100 degrees of  $\phi_{dp}$
- *Differential attenuation should be corrected using  $\phi_{dp}$  only*
- *Zdr bias accumulated in rain propagates into the ice phase.*



# Thanks for your attention

## Questions?

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Modeling, error analysis and evaluation of dual polarization variables obtained from simultaneous horizontal and vertical polarization transmit radar.

Part I: Modeling and antenna errors

Part II: Experimental data

J.C. Hubbert, S. M. Ellis, M. Dixon and G. Meymaris

**JTECH, October 2010**

