# CMD: Improvements and Transition to Dual Polarization

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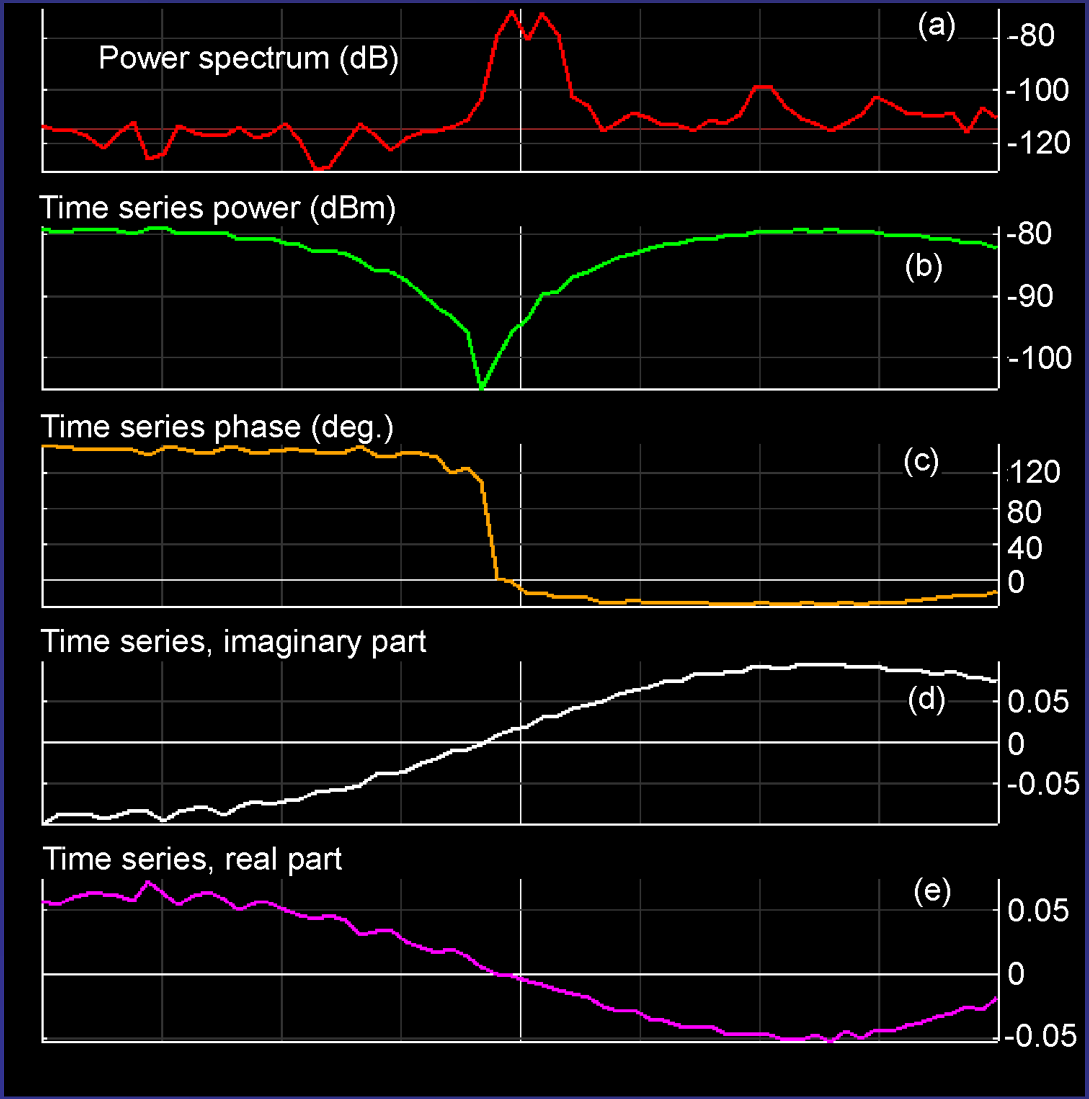
# Presentation Overview

1. Doubled peaked clutter spectra
2. Modified infill and spike filter
3. The addition of dual-polarization fields

# KMEX Anomalous Ground Clutter

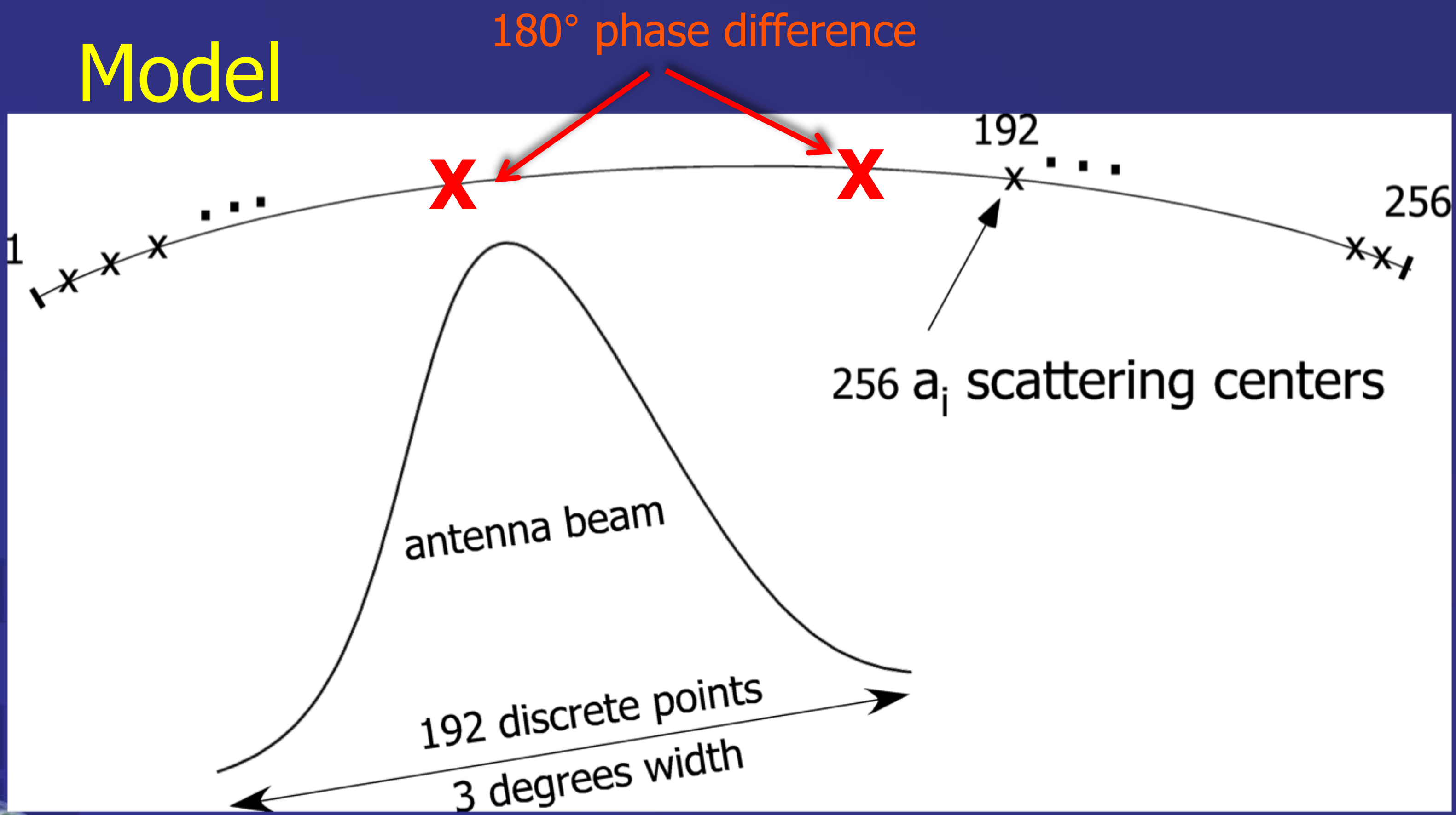


# Doubled Peaked Spectra

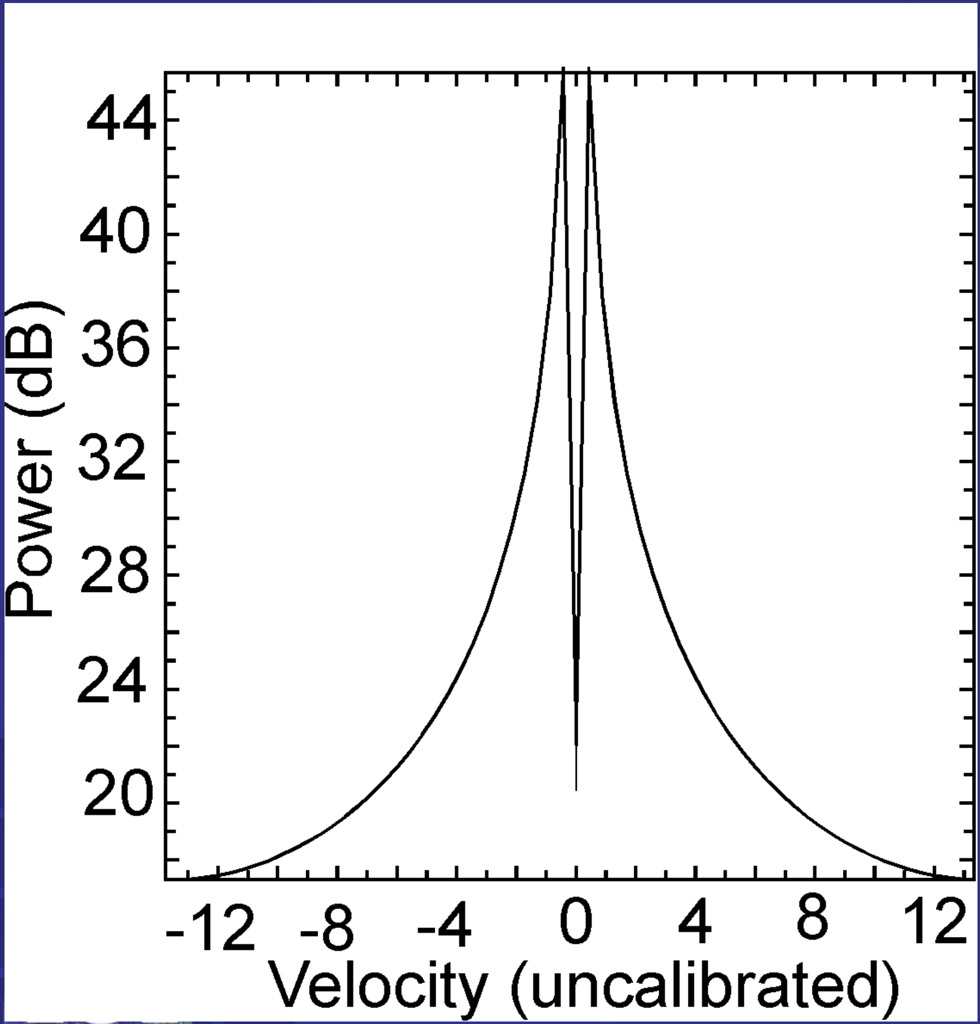
- What type of ground clutter target would cause a “null” at zero velocity?

# Two Dominant Clutter Targets

Model

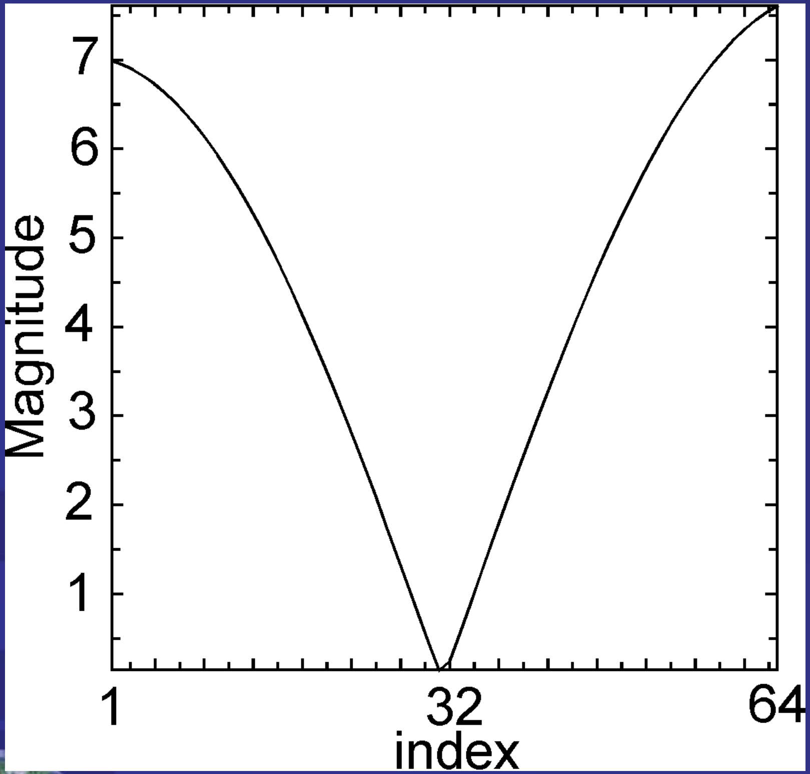


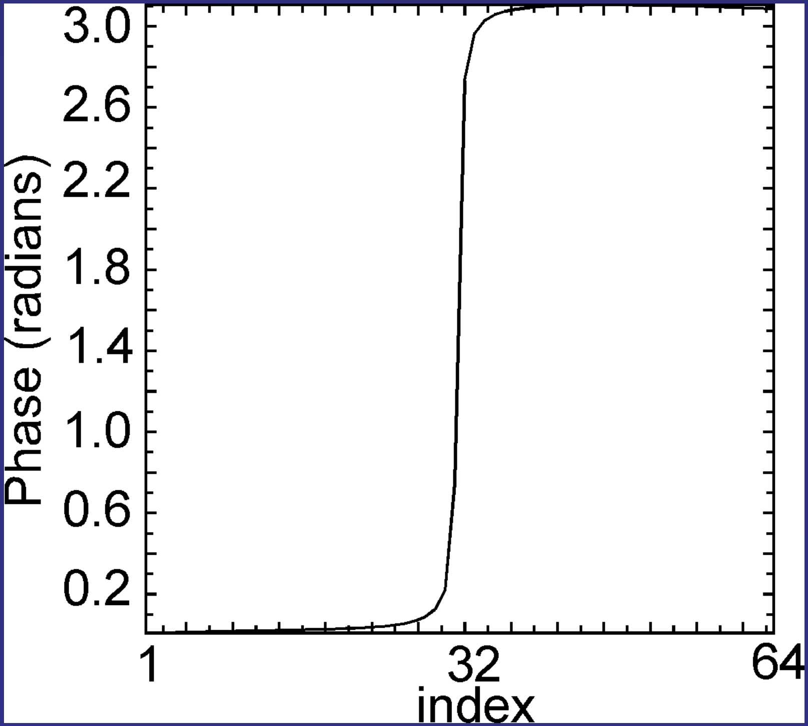
# Simulated Double Peaked Spectrum




- Quite rare
- Two dominant targets
- 180 degree phase shift difference between the two targets

# Time Series
# Magnitude and Phase



# How to Identify Such Targets as Clutter?

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# Doubled Peaked Spectrum

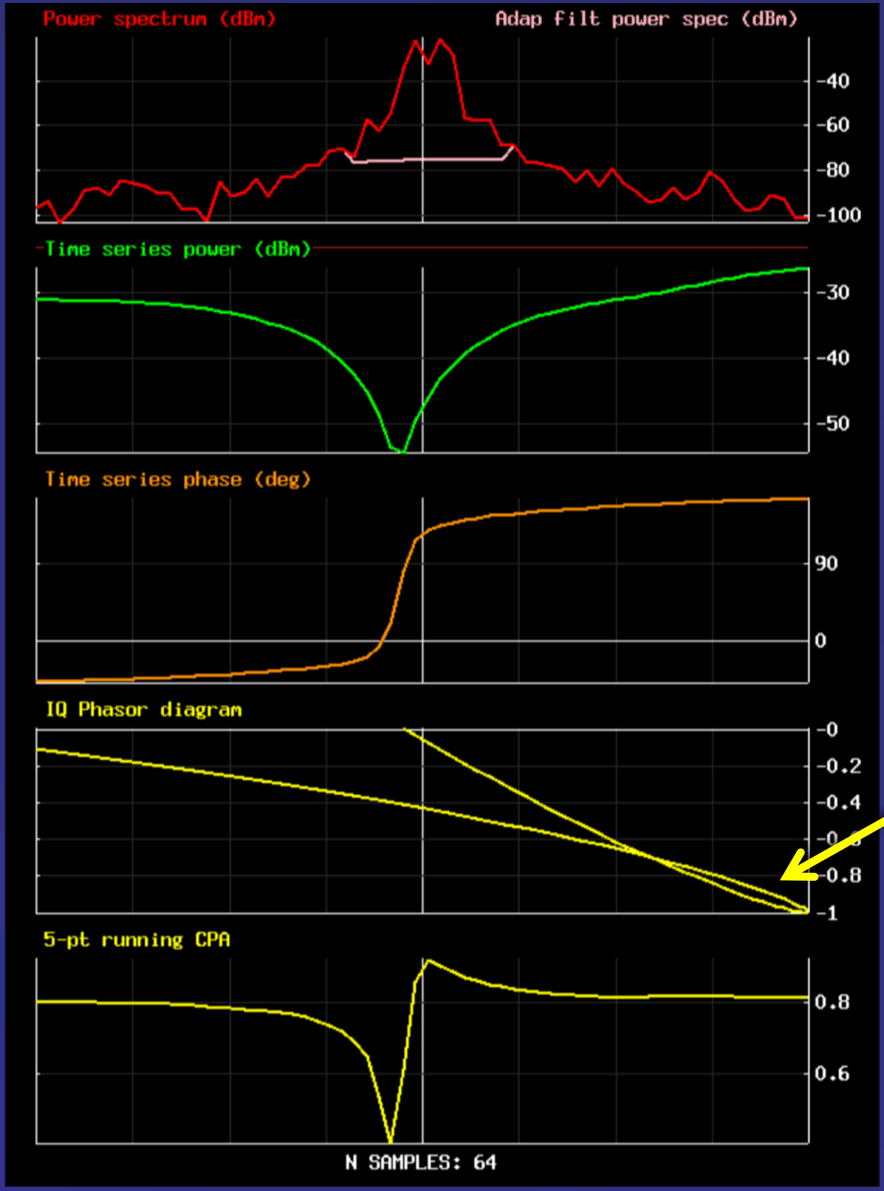
Power spectrum

Time series:Power

Time series:Phase

Phasor diagram

5 point average CPZ



# How to Identify Such Targets as Clutter?

- Identify spectra with a large mimima in the time series magnitude accompanied by a large phase change
- Calculate CPA over the two new segments
- Calculate the weighted mean CPA  from the two segments

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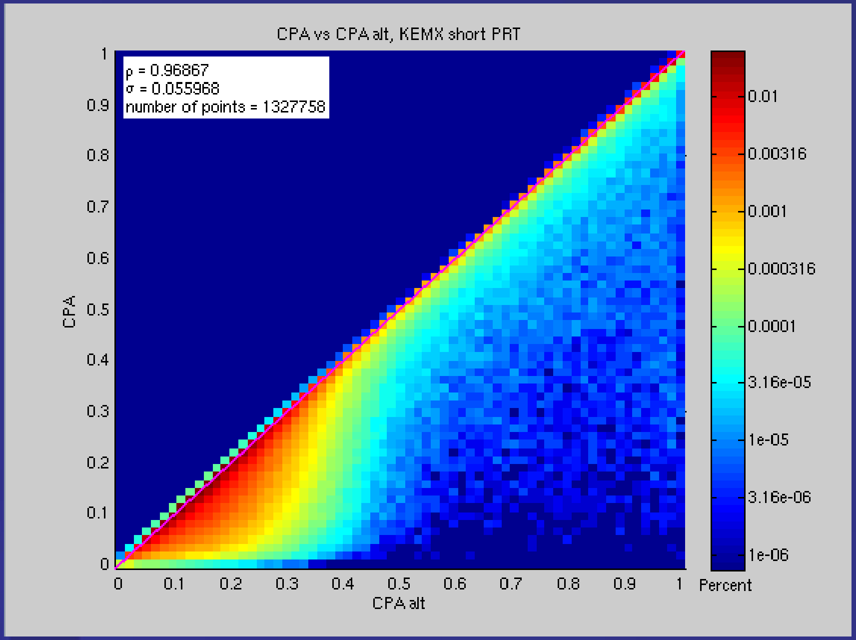
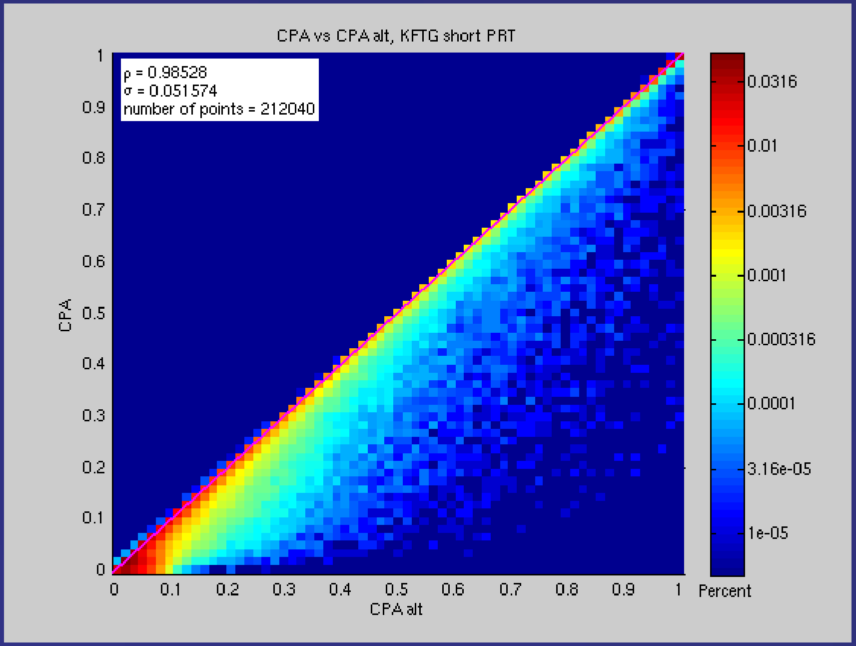
# Comparison of original and modified CPA values Short PRT



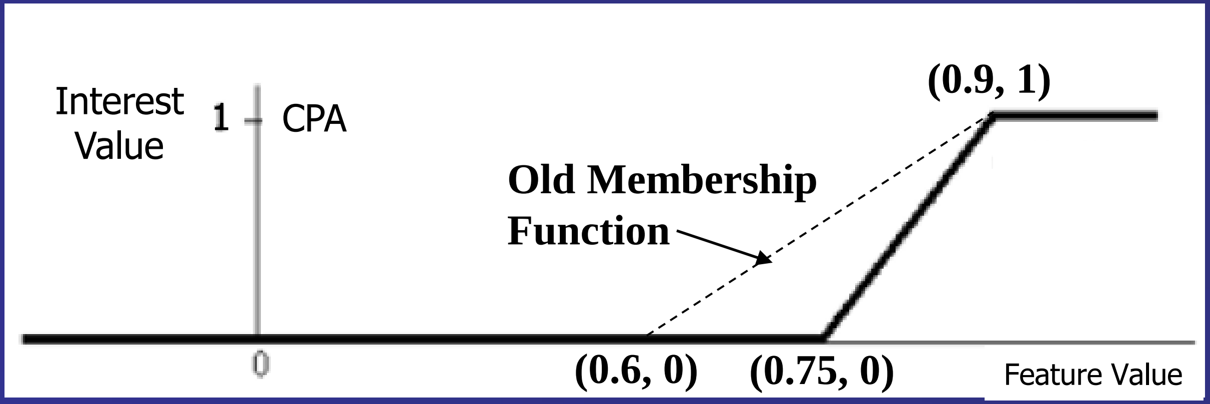

KEMX



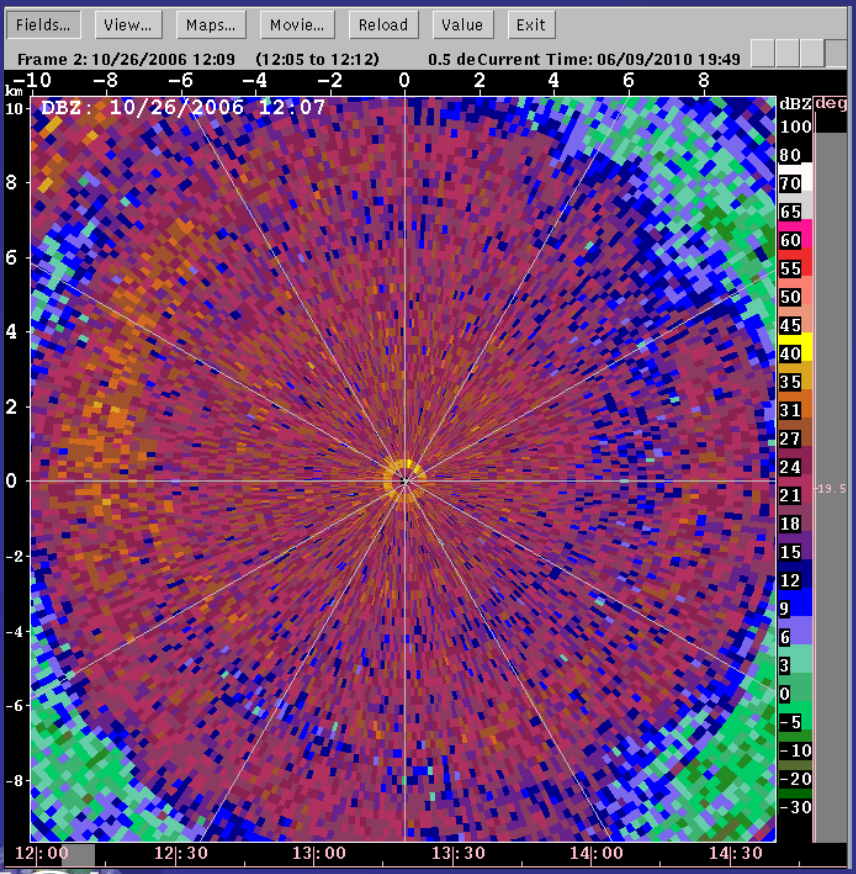

KFTG

# New CPA membership

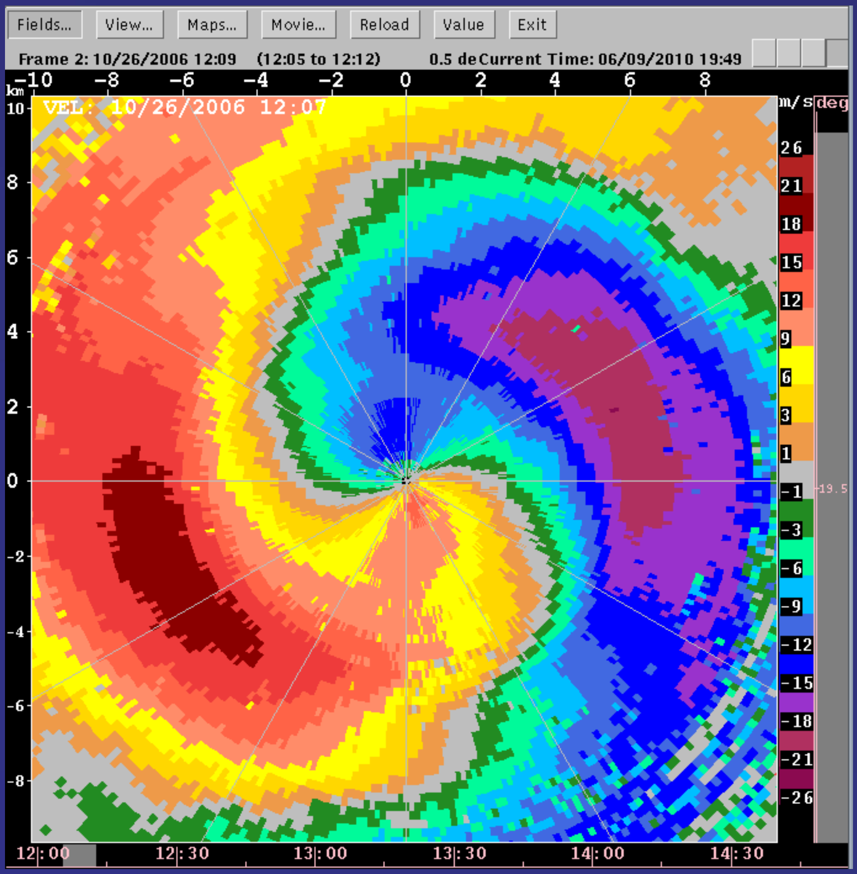
- New CPA computation prevents low CPA values in clutter
- Modified the CPA membership function accordingly



# KFTG – high level tilt with weather

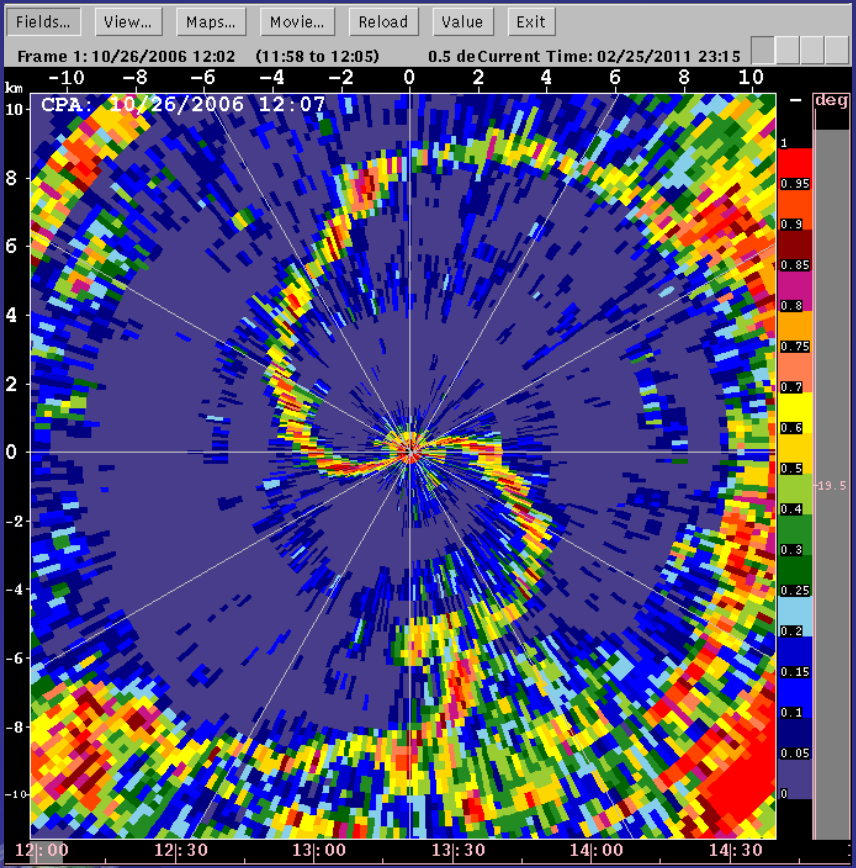



DBZ

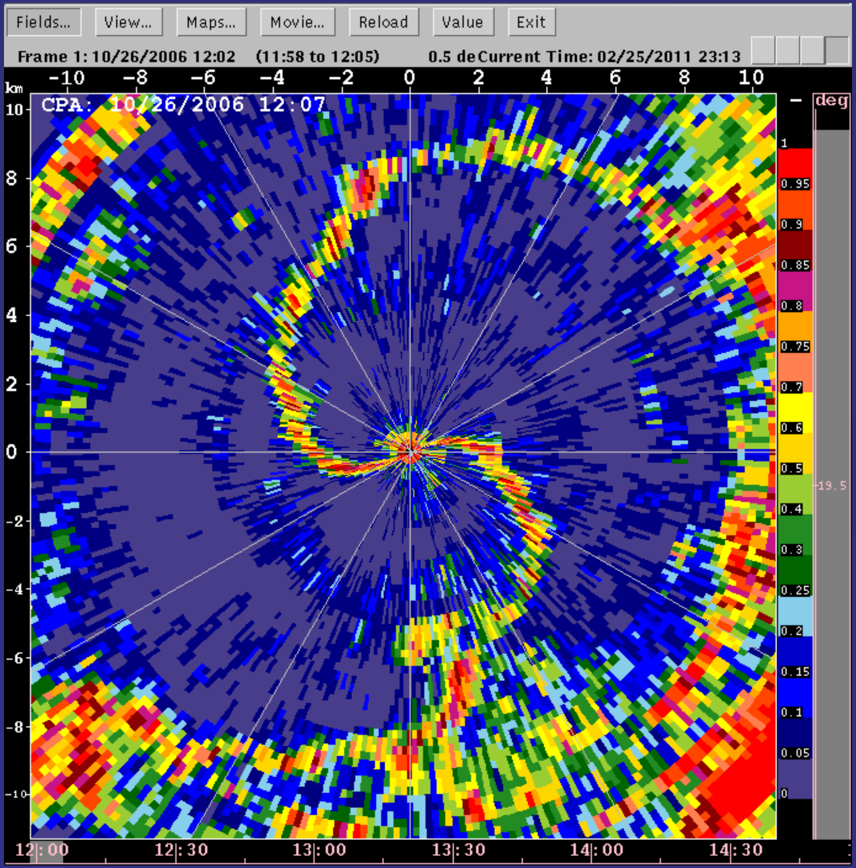



VEL

# KFTG – high level tilt CPA original and modified
# Note: signature is larger in area, but not higher in value



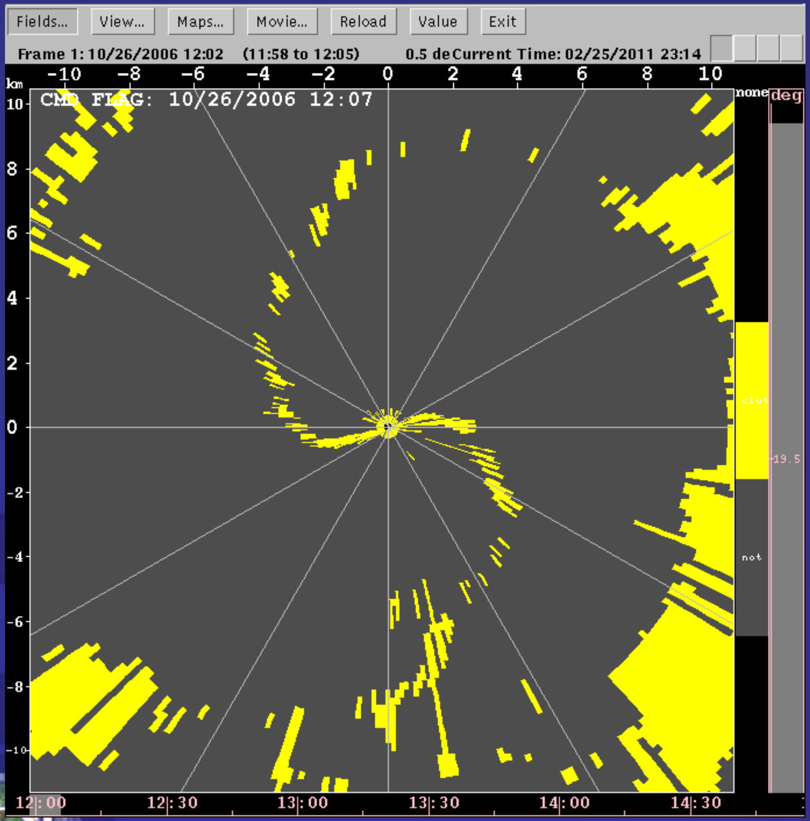

Original CPA



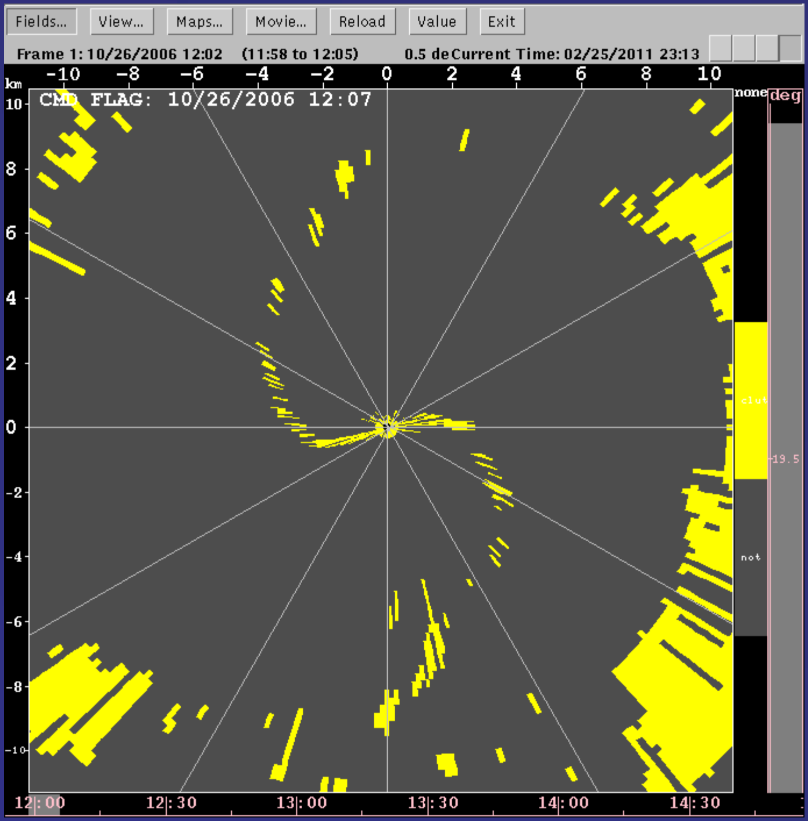

modified CPA

# CMD Flag: Old versus New

With legacy CPA calculation




New CPA calculation

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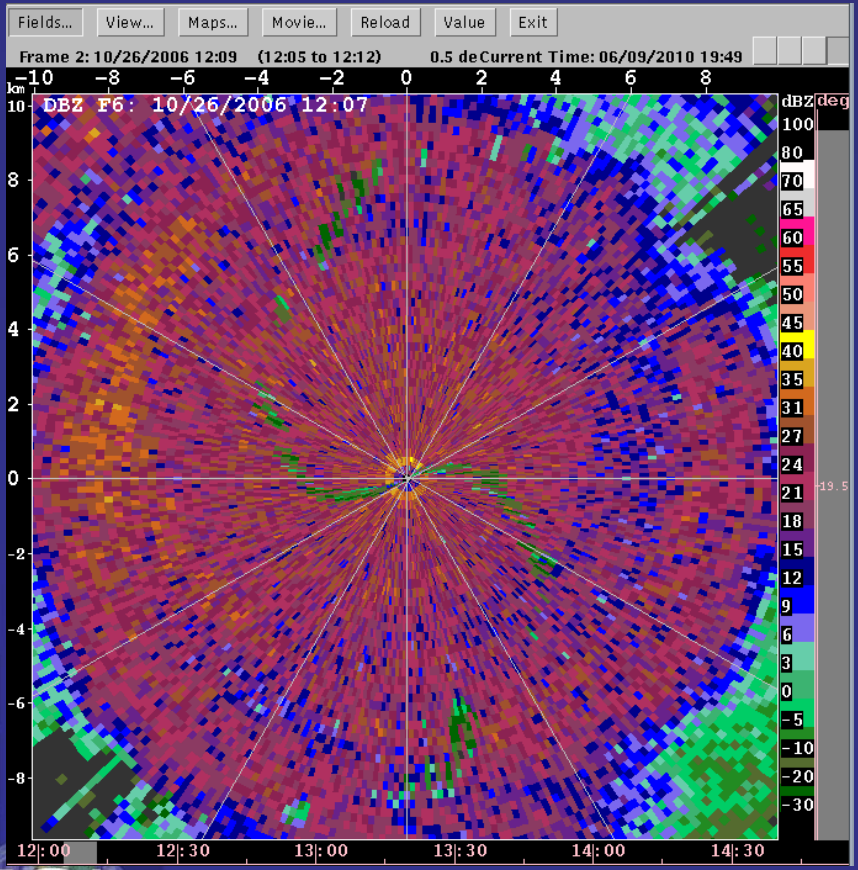
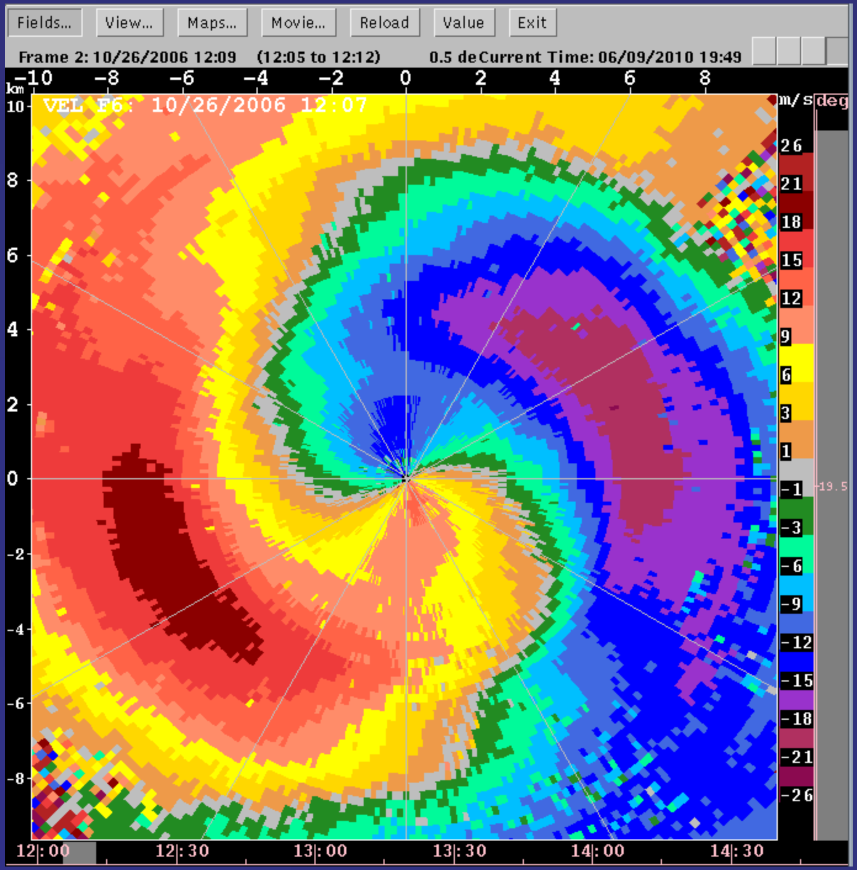
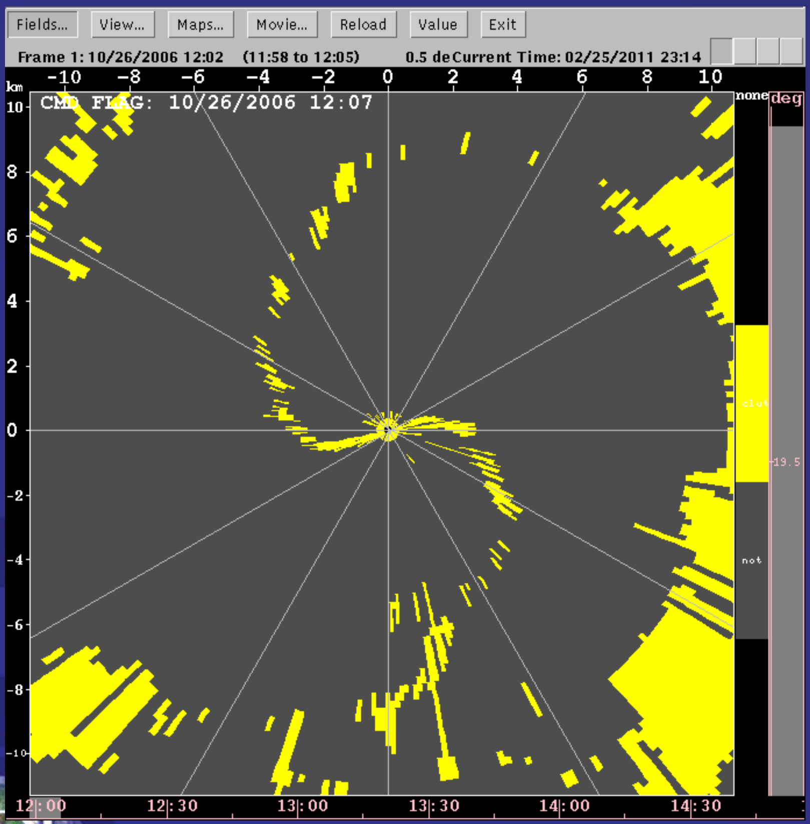
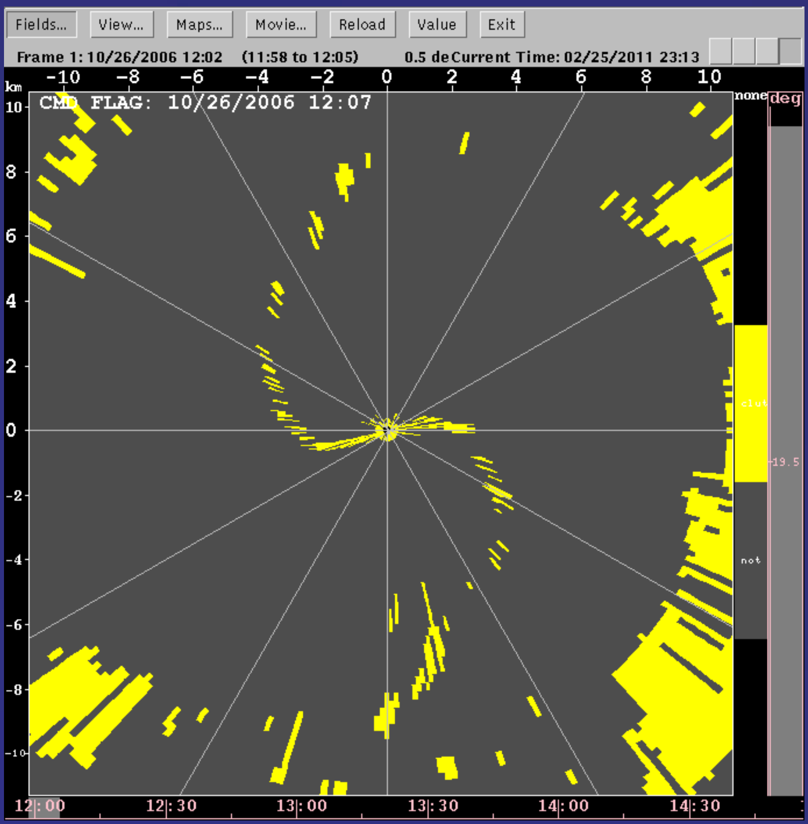
# KFTG – Filtered DBZ and VEL with latest CPA




NOTE – need to modify CPA interest map for use with latest version


Fields... View... Maps... Movie... Reload Value Exit
Frame 1: 10/26/2006 12:02 (11:58 to 12:05) 0.5 deCurrent Time: 02/25/2011 23:14
CMD FLAG: 10/26/2006 12:07
km
none
deg
not
12:00 12:30 13:00 13:30 14:00 14:30


Fields... View... Maps... Movie... Reload Value Exit
Frame 1: 10/26/2006 12:02 (11:58 to 12:05) 0.5 deCurrent Time: 02/25/2011 23:13
CMD FLAG: 10/26/2006 12:07
km
none
deg
not
12:00 12:30 13:00 13:30 14:00 14:30

# Improving the infill filter and speckle filter

- The existing infill filter is not aggressive enough.
- A modified infill filter is proposed.
- Also, an alternative to the NEXRAD speckle filter is proposed.

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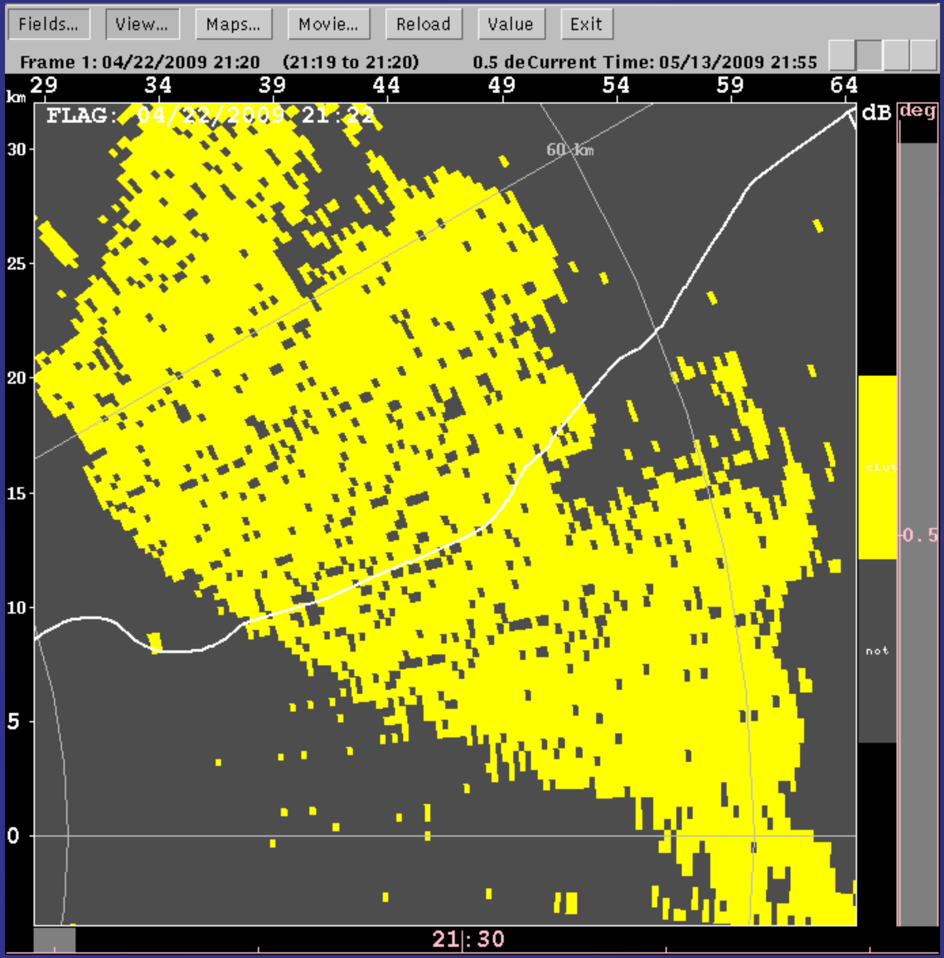
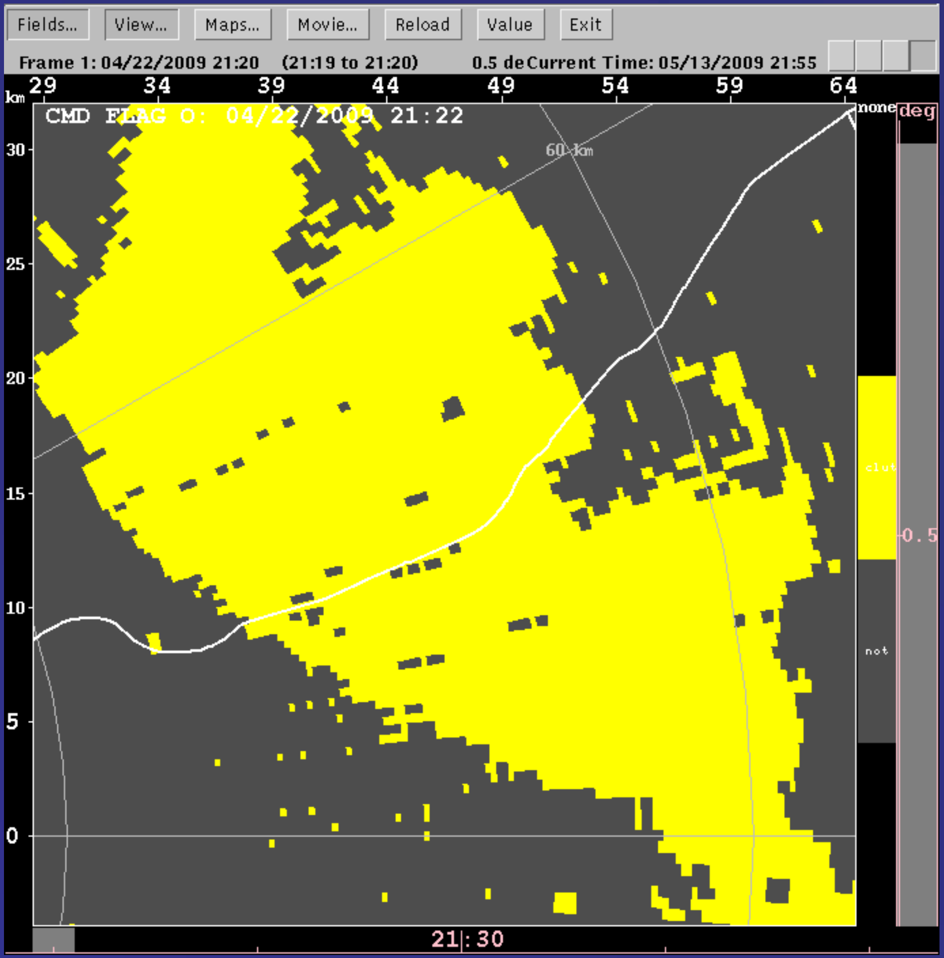
# KEMX Example
# CMD flag field before applying the infill filter

Clutter only



# KEMX Example
# CMD flag field after applying version 4 infill filter

Clutter only



# Version 5 CMD flag infill filter

Forward → ← Reverse

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight | 1/6 | 1/5 | 1/4 | 1/3 | 1/2 | 1/1 | ? | 1/1 | 1/2 | 1/3 | 1/4 | 1/5 | 1/6 |
| CMD flag | 1 | 1 | | | 1 | | | | 1 | | 1 | | |
| CMD val | 0.95 | 0.85 | 0.45 | 0.33 | 0.60 | 0.33 | 0.40 | 0.45 | 0.65 | 0.49 | 0.80 | 0.48 | 0.25 |

- One each side of the gate in question, construct a computational kernel with weights decreasing with distance from the gate.
  - In the forward direction, if the CMD flag is set, sum up (weights * CMD val) at that gate
  - In the reverse direction, if the CMD flag is set, sum up (weights * CMD val) at that gate
- IF forward_weight >= threshold AND reverse_weight >= threshold, set CMD_flag at center gate to TRUE (Threshold = 0.35)
  - IF not, set CMD_flag at center gate to FALSE

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# Proposed CMD flag speckle filter

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMD flag | | 1 | 1 | 1 | | | 1 | 1 | | | | 1 | |
| CMD val | 0.25 | 0.56 | 0.61 | 0.57 | 0.40 | 0.48 | 0.70 | 0.66 | 0.45 | 0.49 | 0.33 | 0.80 | 0.25 |

- Consider speckle to be CMD flags over only 1 or 2 consecutive gates.
- In these cases, use a higher CMD threshold to determine the CMD flag.
- If the CMD value is less than this higher value, set the CMD flag to false to remove the speckle.
- Speckle thresholds:

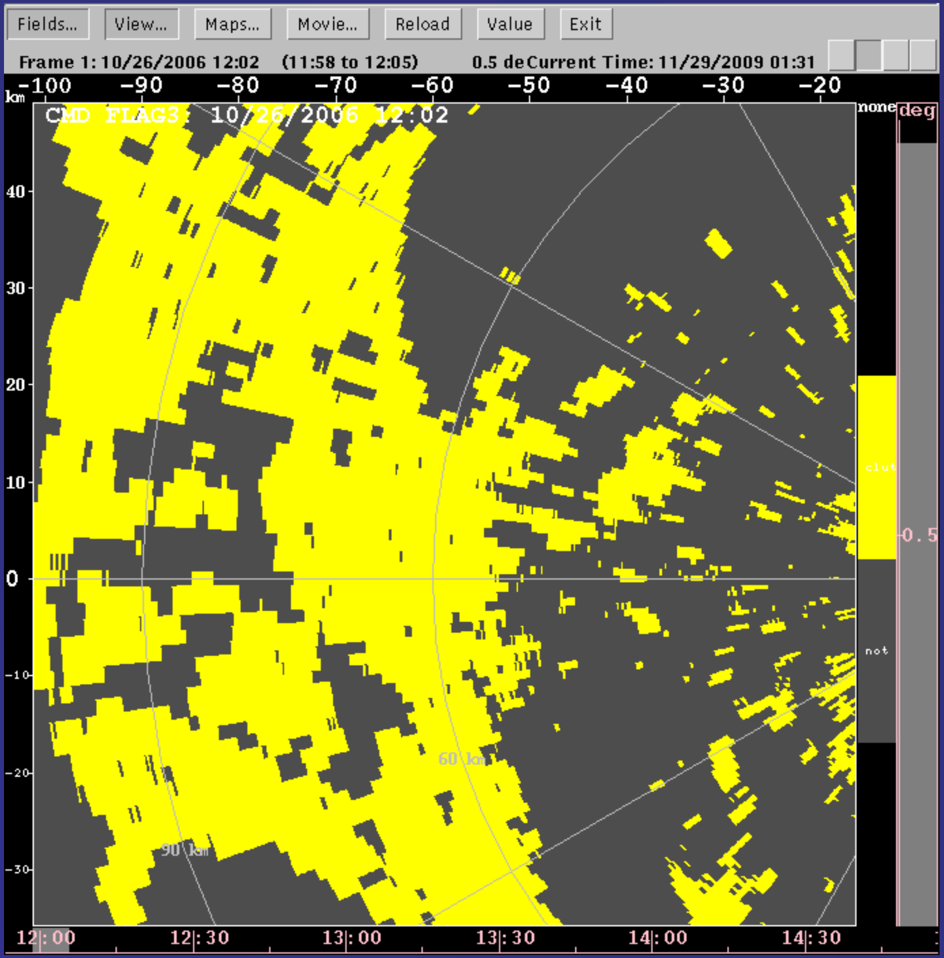
1 isolated point: use 0.75

2 isolated points: use 0.65

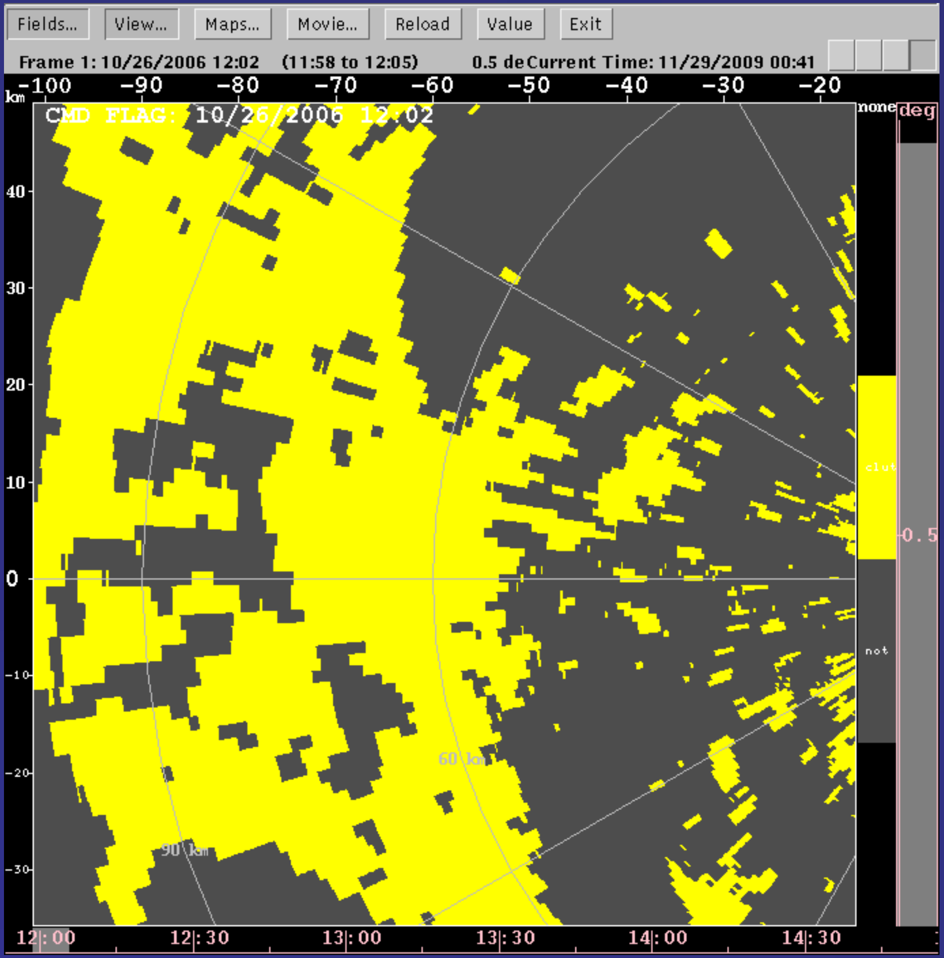
3 isolated points: use 0.55

Otherwise use 0.5

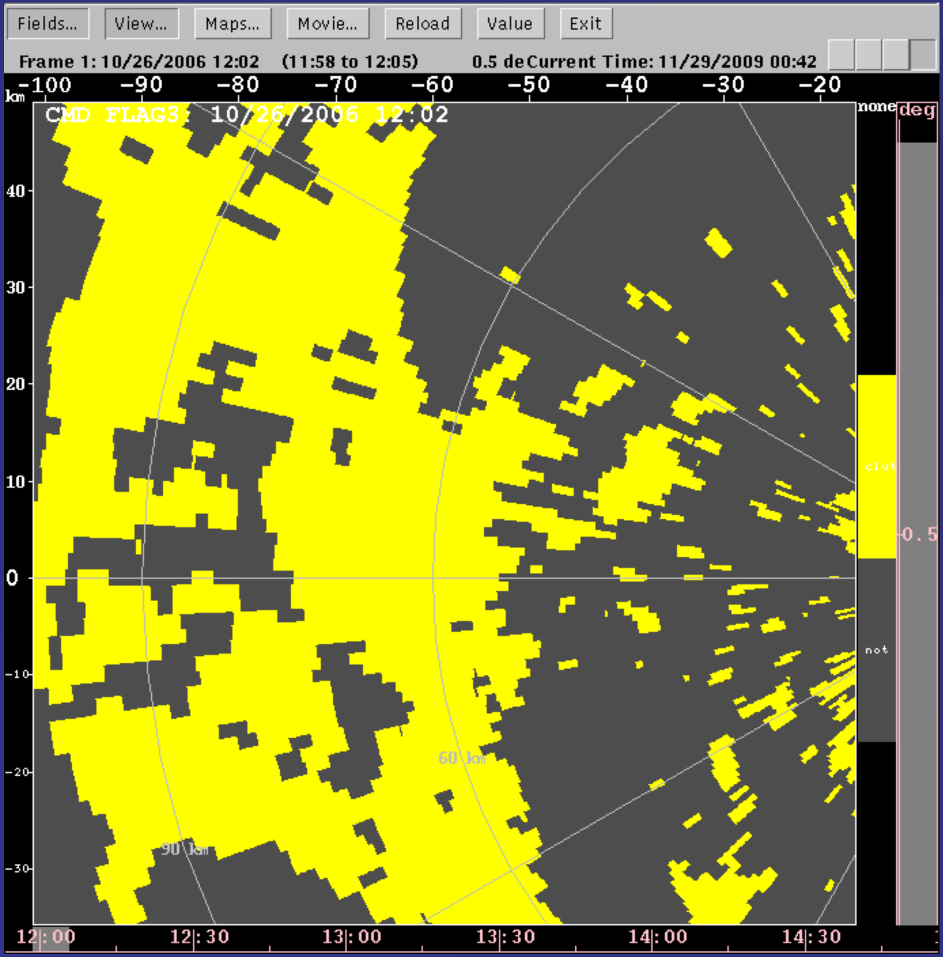
# KFTG example - No infill filter



# KFTG example - Version 4 infill filter



# KFTG Example - Version 5 infill filter and speckle filter



# Addition of Dual-pol Variables to CMD

- Dual-pol version of CMD has been developed for WSR-88D dual-pol upgrade
- Two additional fuzzy logic inputs
  - SD (ZDR)
    - Standard deviation of $Z_{DR}$ using 5 gates in range
  - SD (PHIDP)
    - Standard deviation of $\Phi_{DP}$ using 5 gates in range
- Dual-pol CMD running on
  - S-Pol since 2008
  - KOUN since beginning of this year

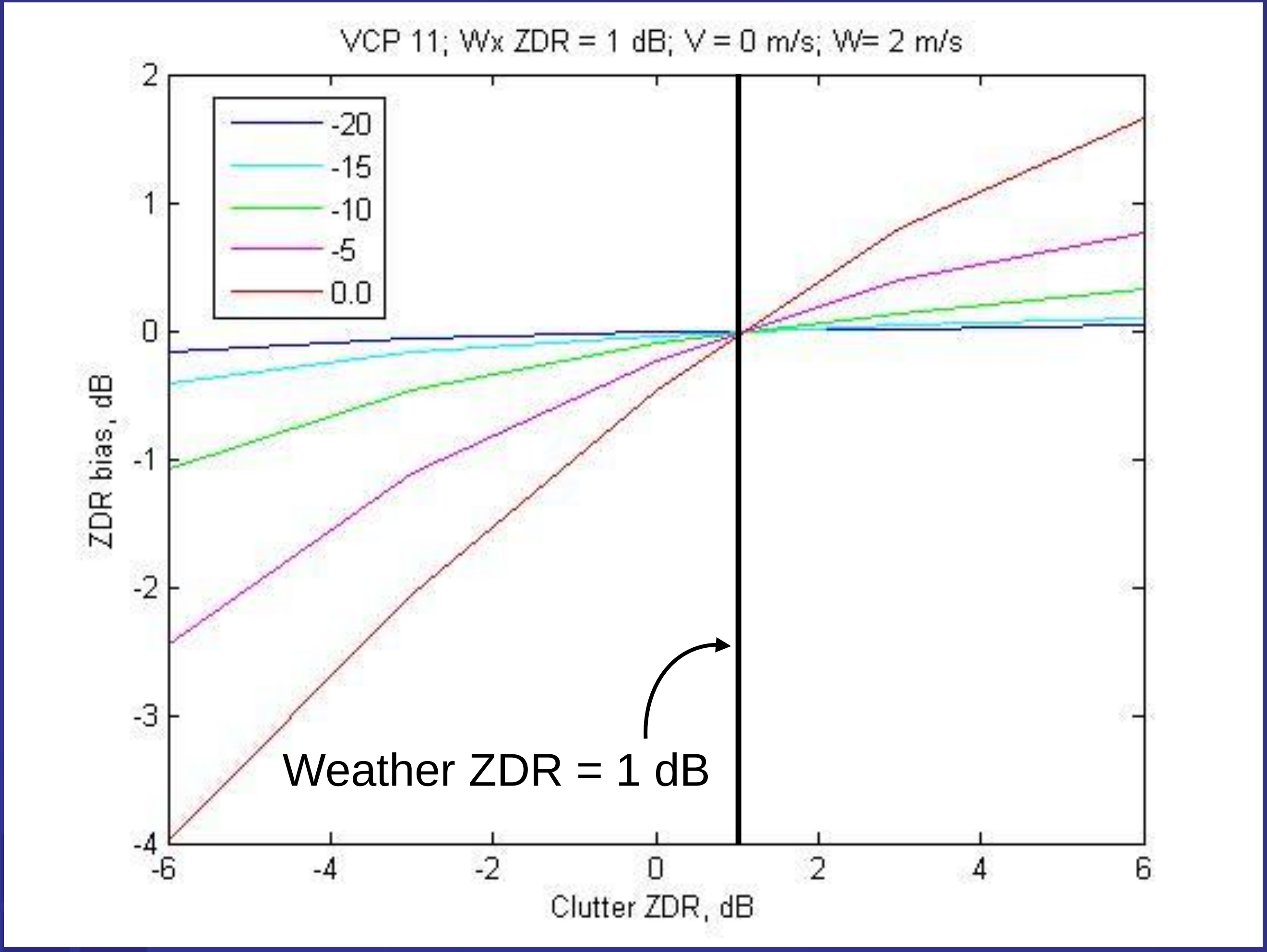
# Addition of Dual-pol Variables to CMD: Goals

- Investigate errors of dual-pol variables (ZDR) due to clutter overlaid with weather echoes
- Investigate the characteristics of the new CMD dual-pol feature fields
  - Pure Clutter and pure weather
  - Mixed clutter and weather
- Determine CSR values the CMD algorithms identify for filtering
  - Can approximate CSR using existing data sets
  - Compare performance of single and dual pol algorithms
- Demonstrate improvement of dual-pol CMD over single-pol CMD

# Dual-pol Errors Due to Clutter: Simulated Dual-Pol data

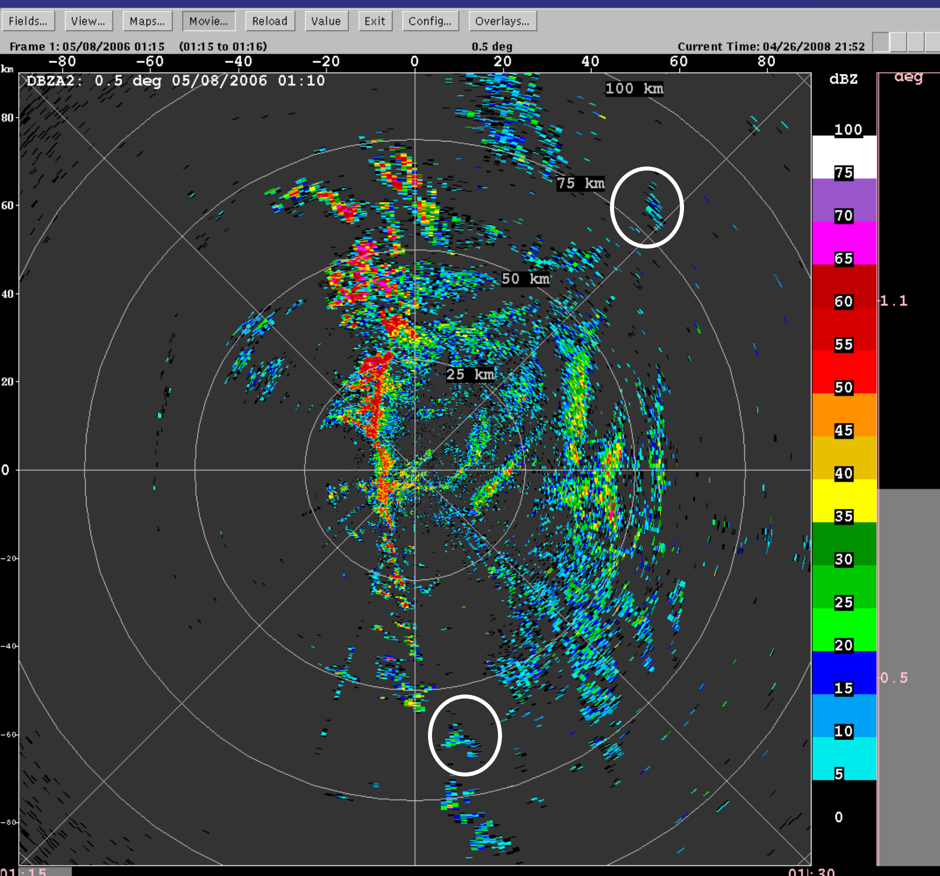
- Used I&Q simulator as detailed by R. Frehlich and M. J. Yadlowsky
  - Frehlich, R. and M. J. Yadlowsky, 1994: Performance of mean-frequency estimators for Doppler radar and LIDAR. *Journal of Atmospheric and Oceanic Technology*, 11, 1217-1230; corrigenda, 12, 445-446.
- Adapted for dual-pol following Chandrasekar et al. 1986
  - Chandrasekar, V., Bringi, V.N., Brockwell, P.J., " Statistical properties of dual polarized radar signals". Proc. 23rd conference on radar meteorology, pp193-196, Snowmass, Colorado,Sep 1986.
- VCP 11
- 1000 range bins per simulation
- Combined weather (wx) and clutter signals
- Clutter W = 0.25, V = 0
- Varied: CSR, clutter ZDR, wx ZDR, wx Vr, wx W
- Specified high SNR

# Simulated $Z_{DR}$ bias versus clutter $Z_{DR}$ for various CSR

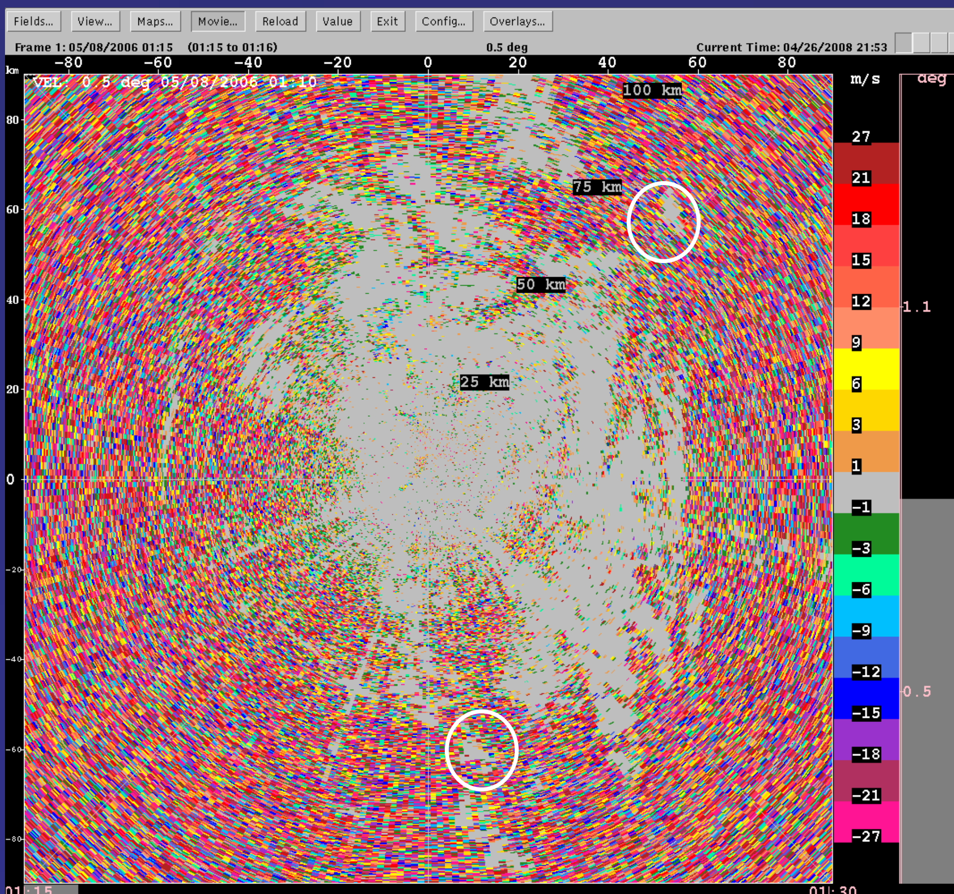


# New Dual-Pol Inputs: S-Pol Clear Scan

**Reflectivity (dBZ)**




**Radial Velocity (m/s)**

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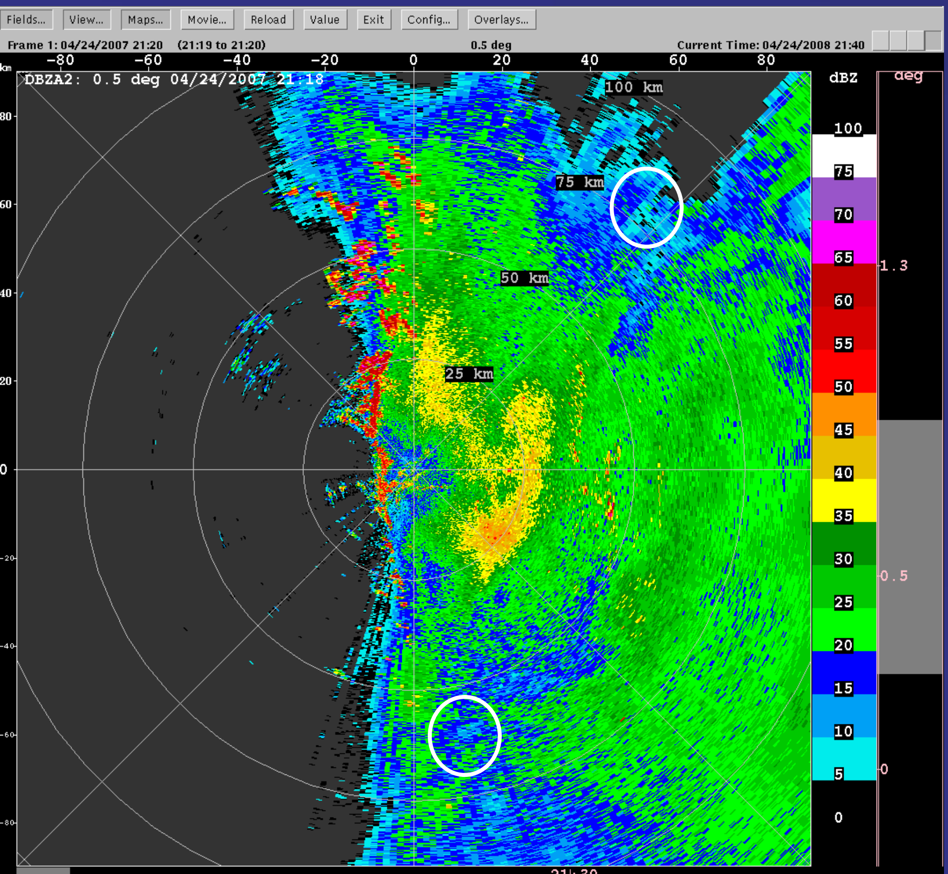
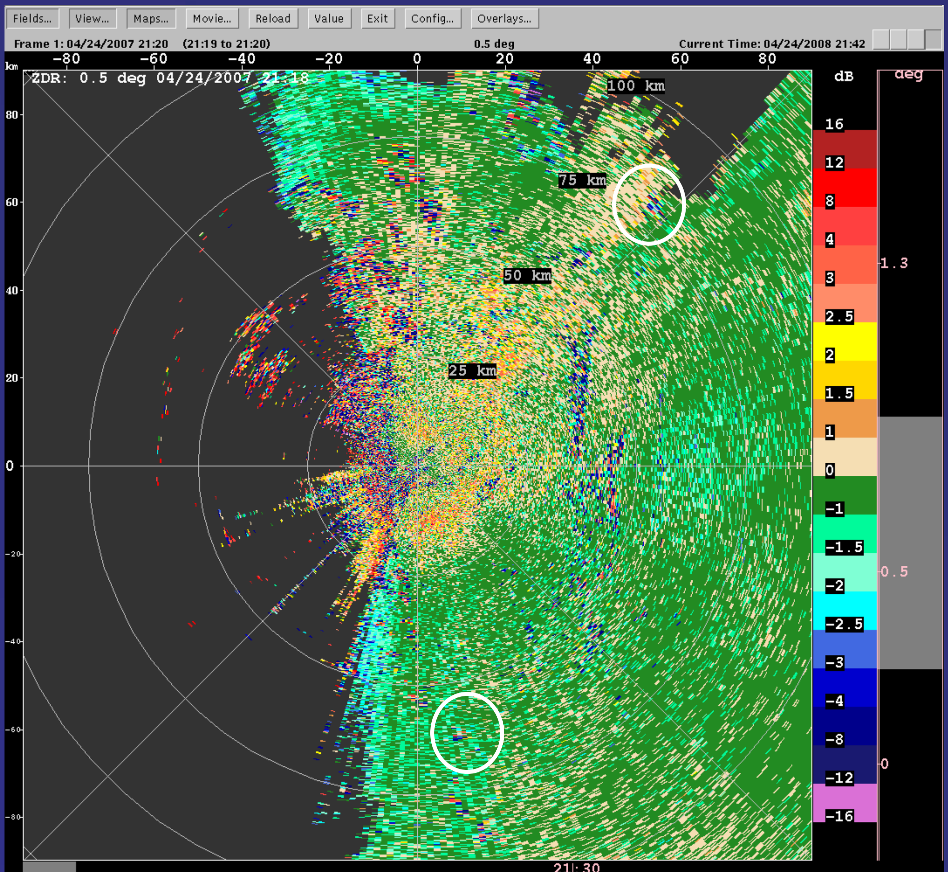
# S-Pol Clutter/Weather Mixed

## Reflectivity (dBZ)




## Differential Reflectivity (dB)

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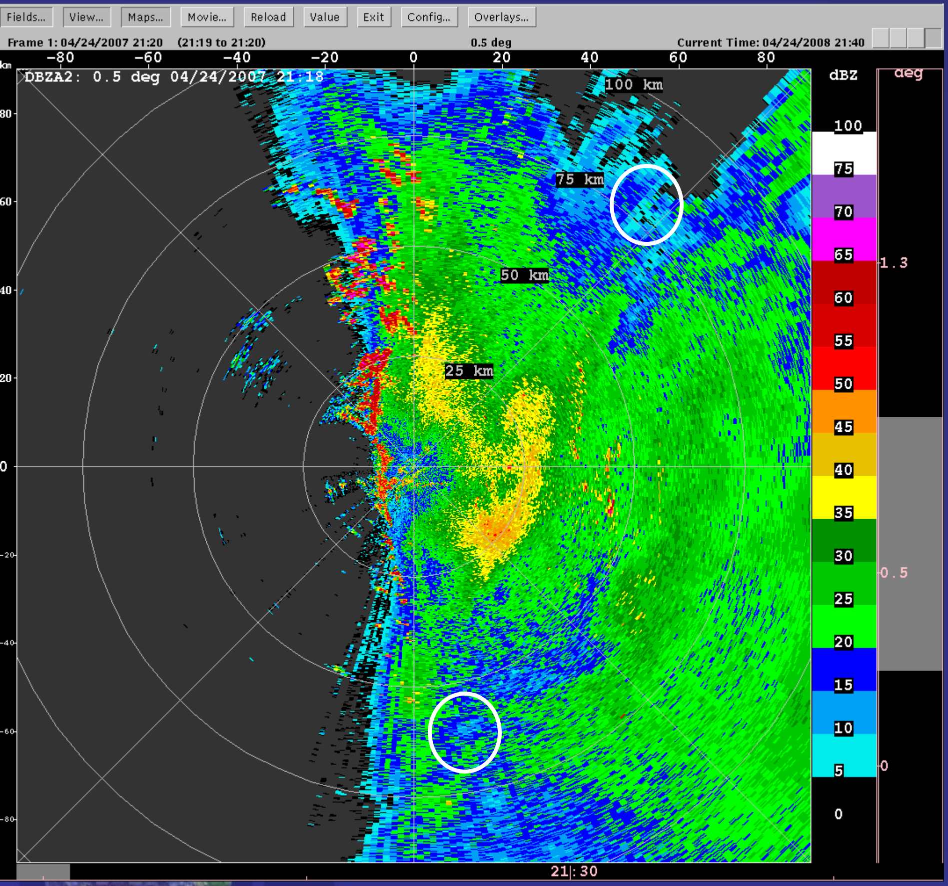
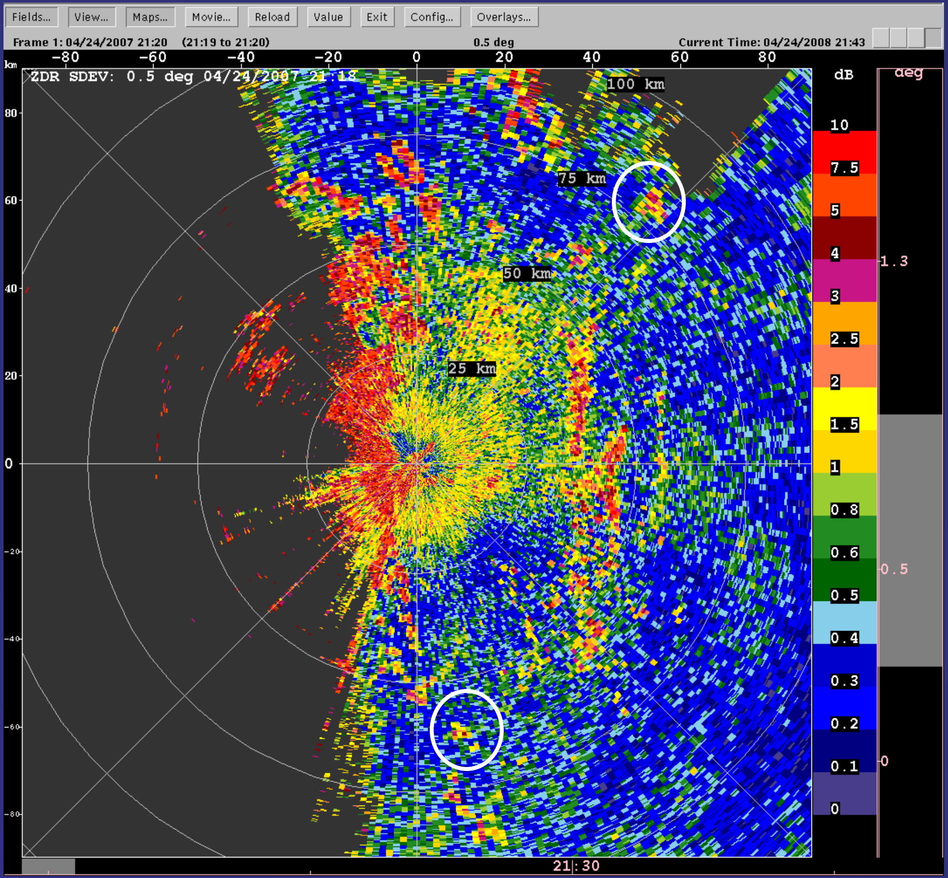
# S-Pol Clutter/Weather Mixed

## Reflectivity (dBZ)

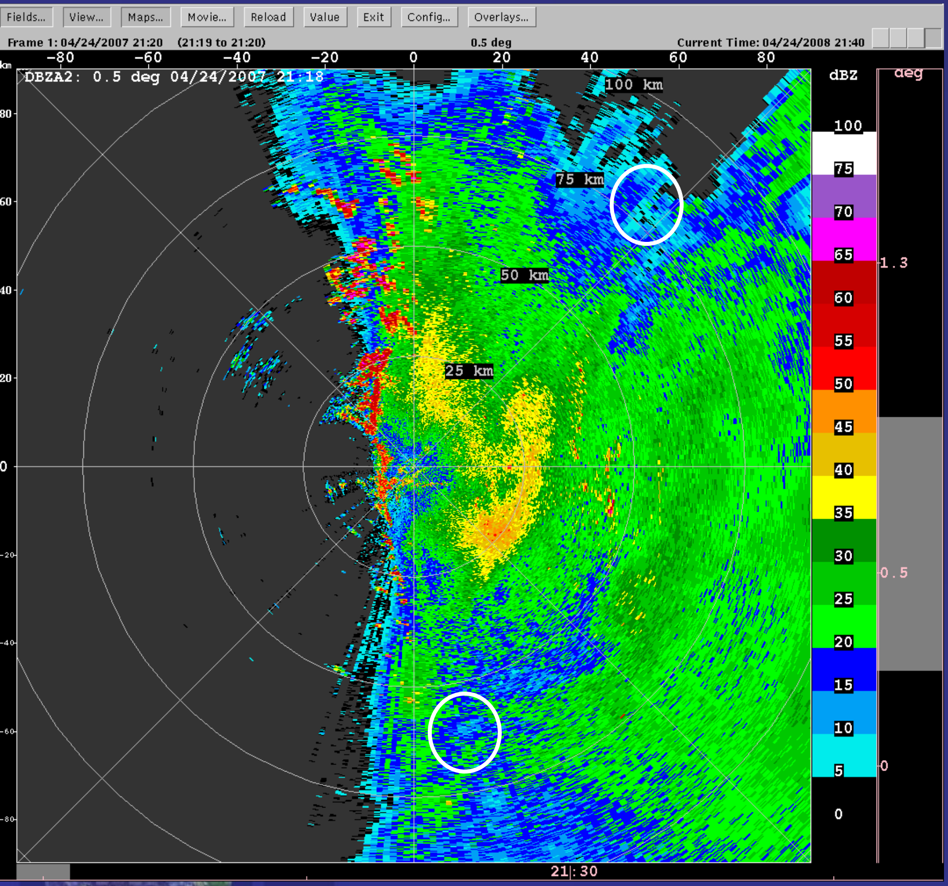



## SD(ZDR)

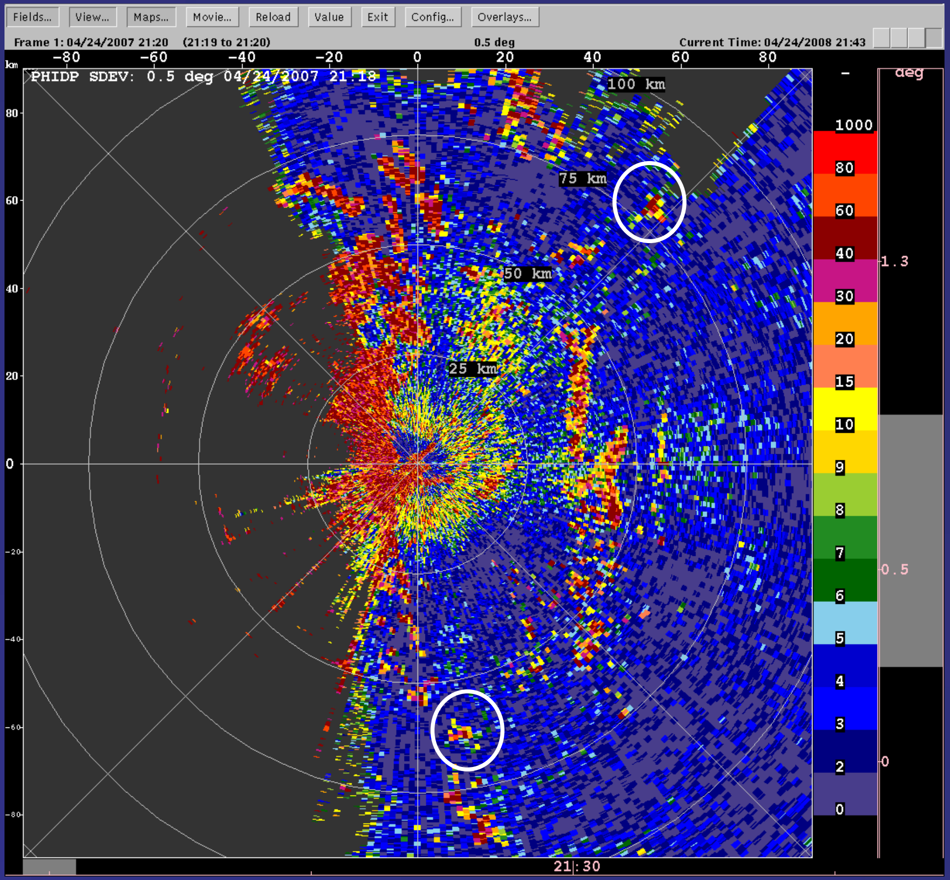


# S-Pol Clutter/Weather Mixed

## Reflectivity (dBZ)




## SD(PHIDP)

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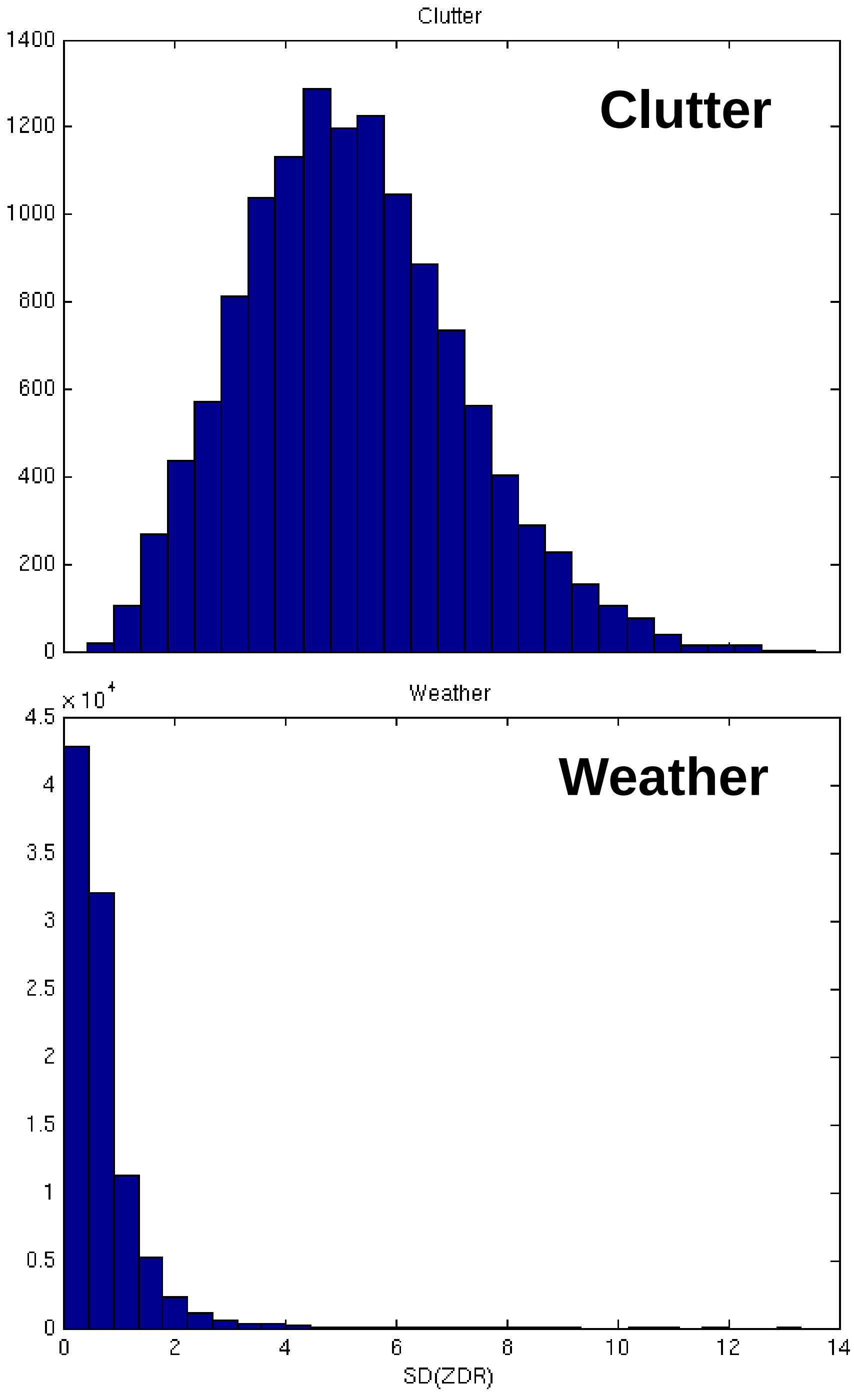
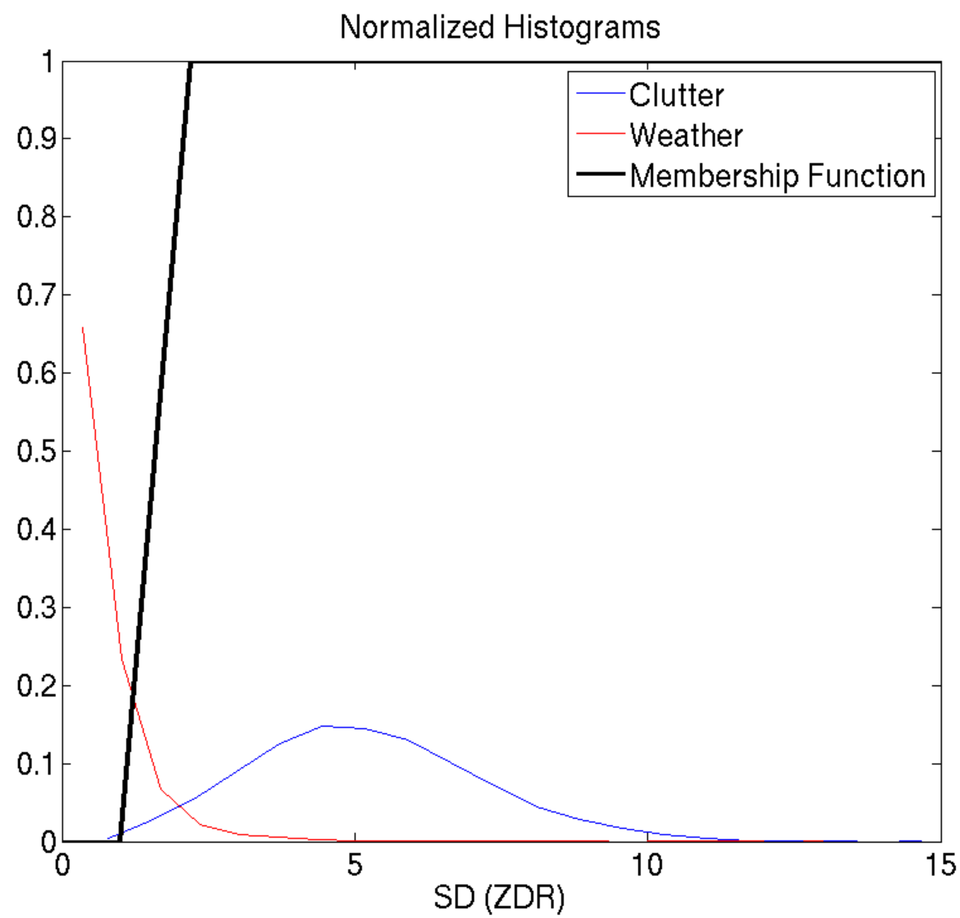
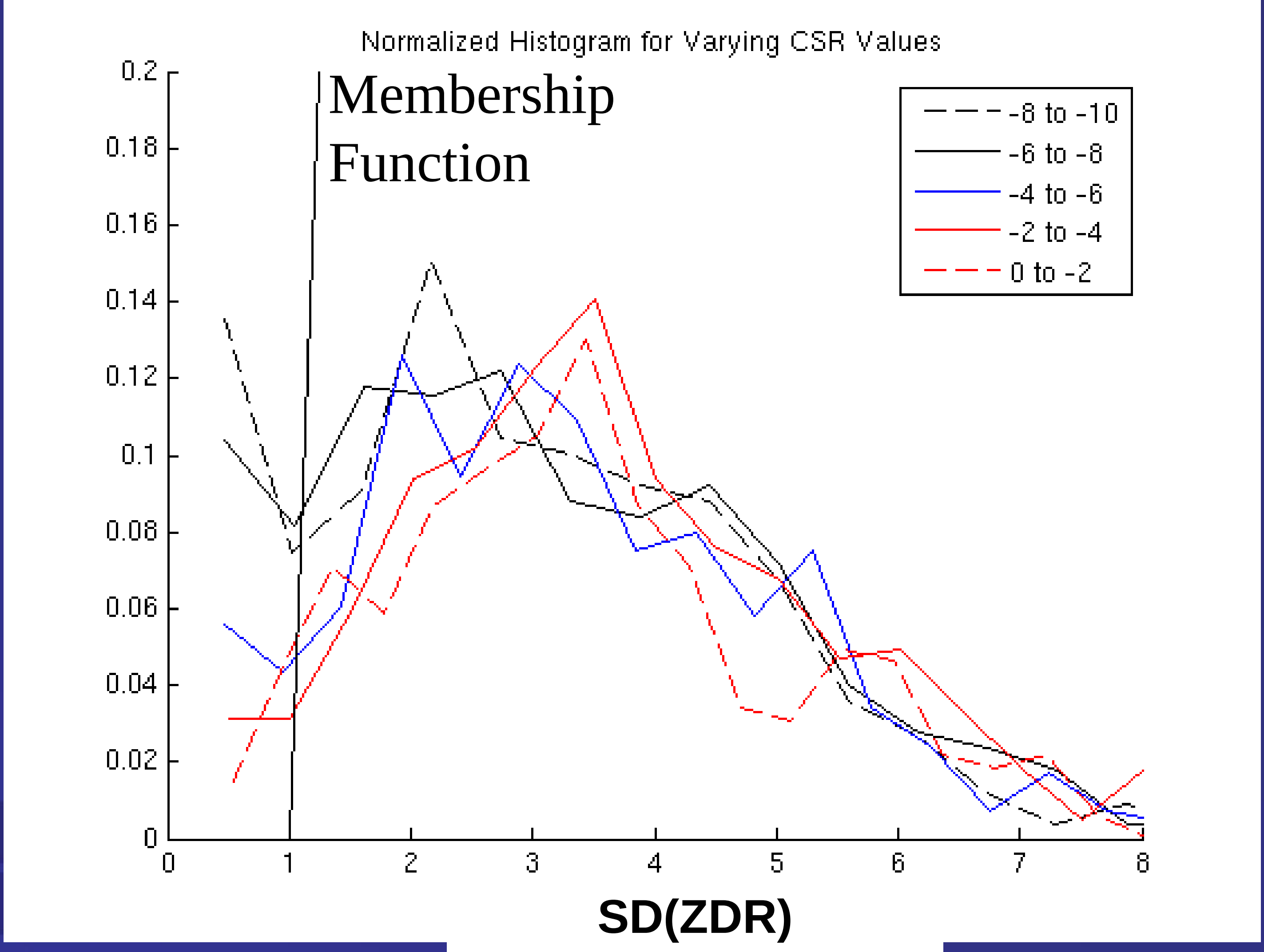
# Histograms of SD(ZDR) in pure weather and clutter

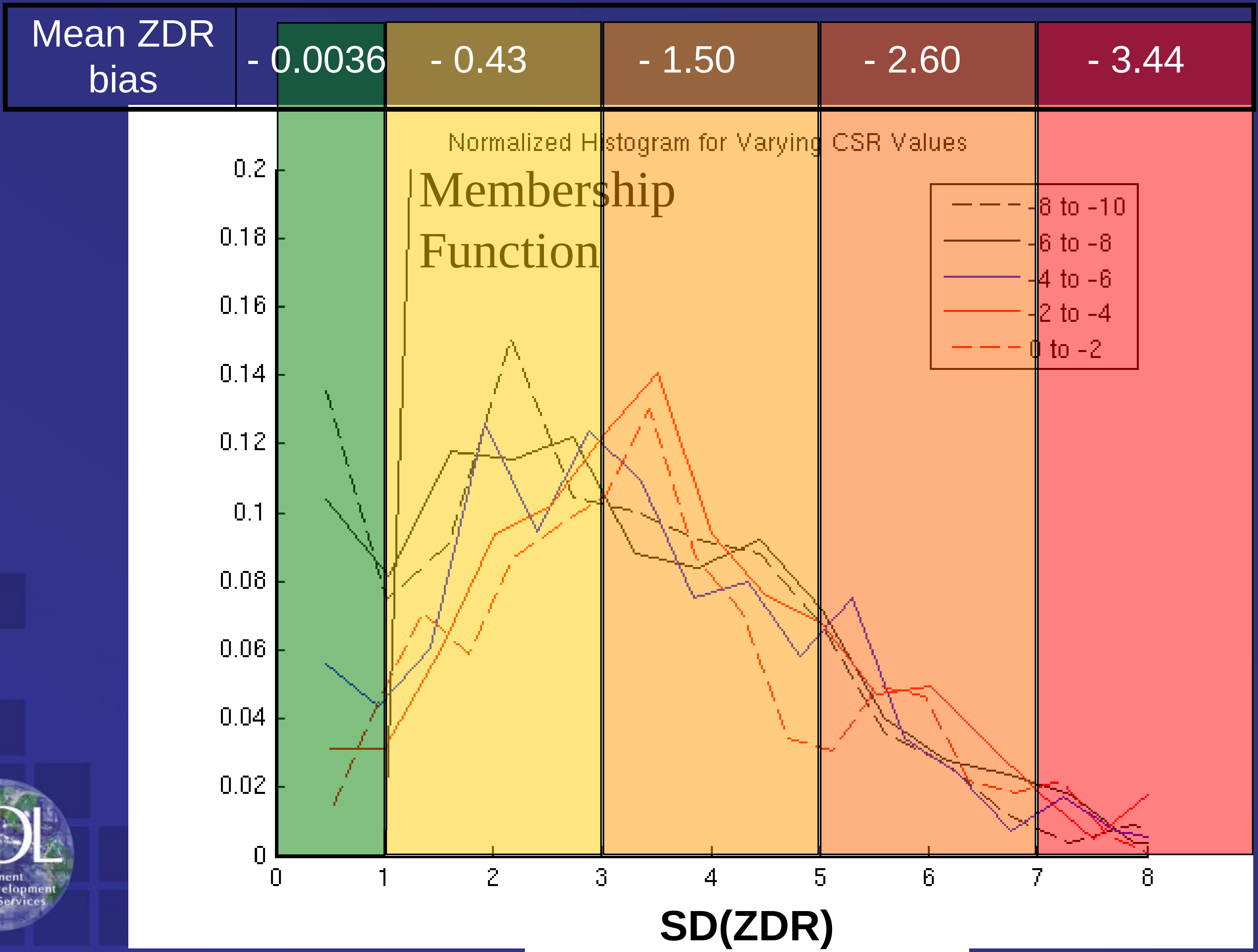


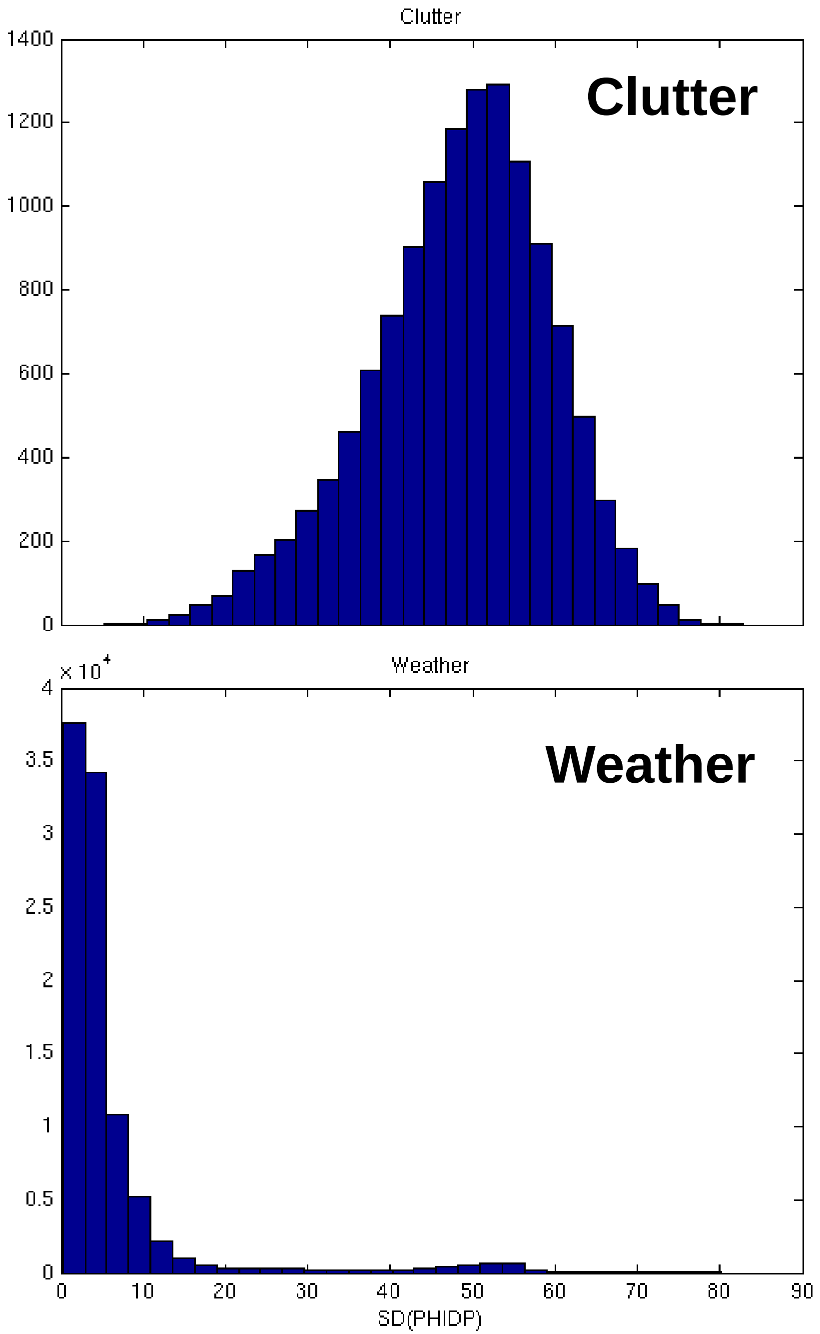
# Normalized Histograms of SD(ZDR) in Clutter Mixed with weather at various CSR values

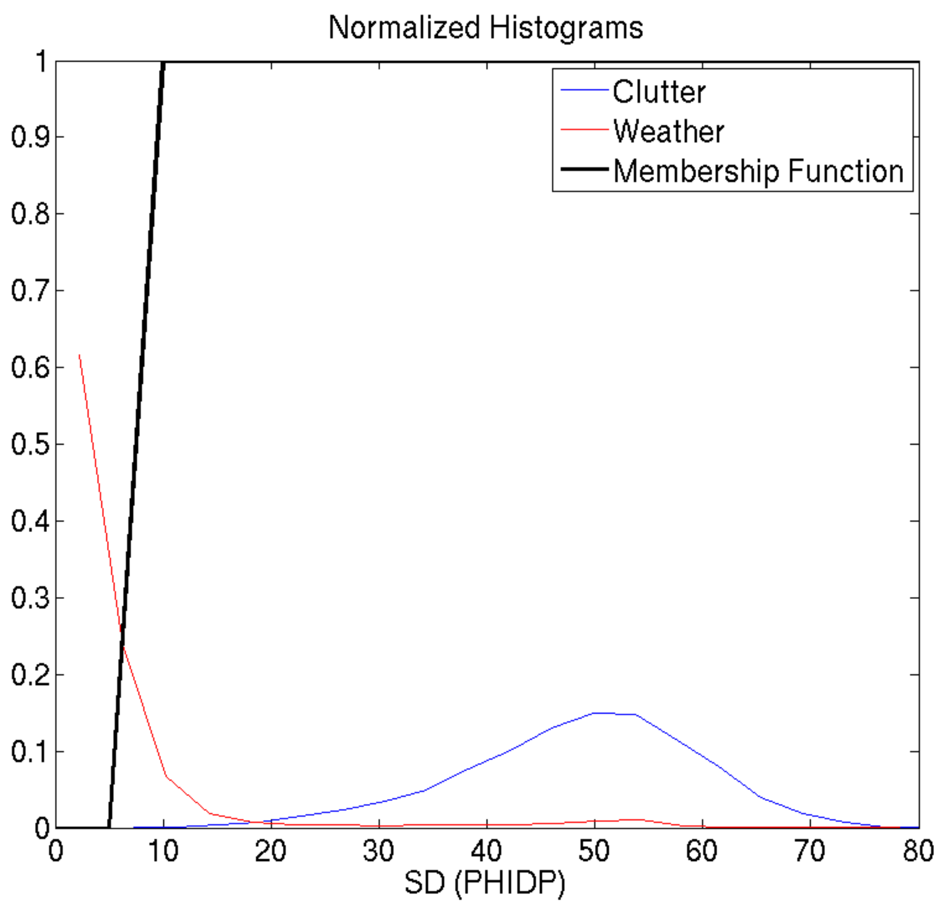


# Mean ZDR bias (dB) in mixed weather and clutter: -8 > CSR > -10 (dB)

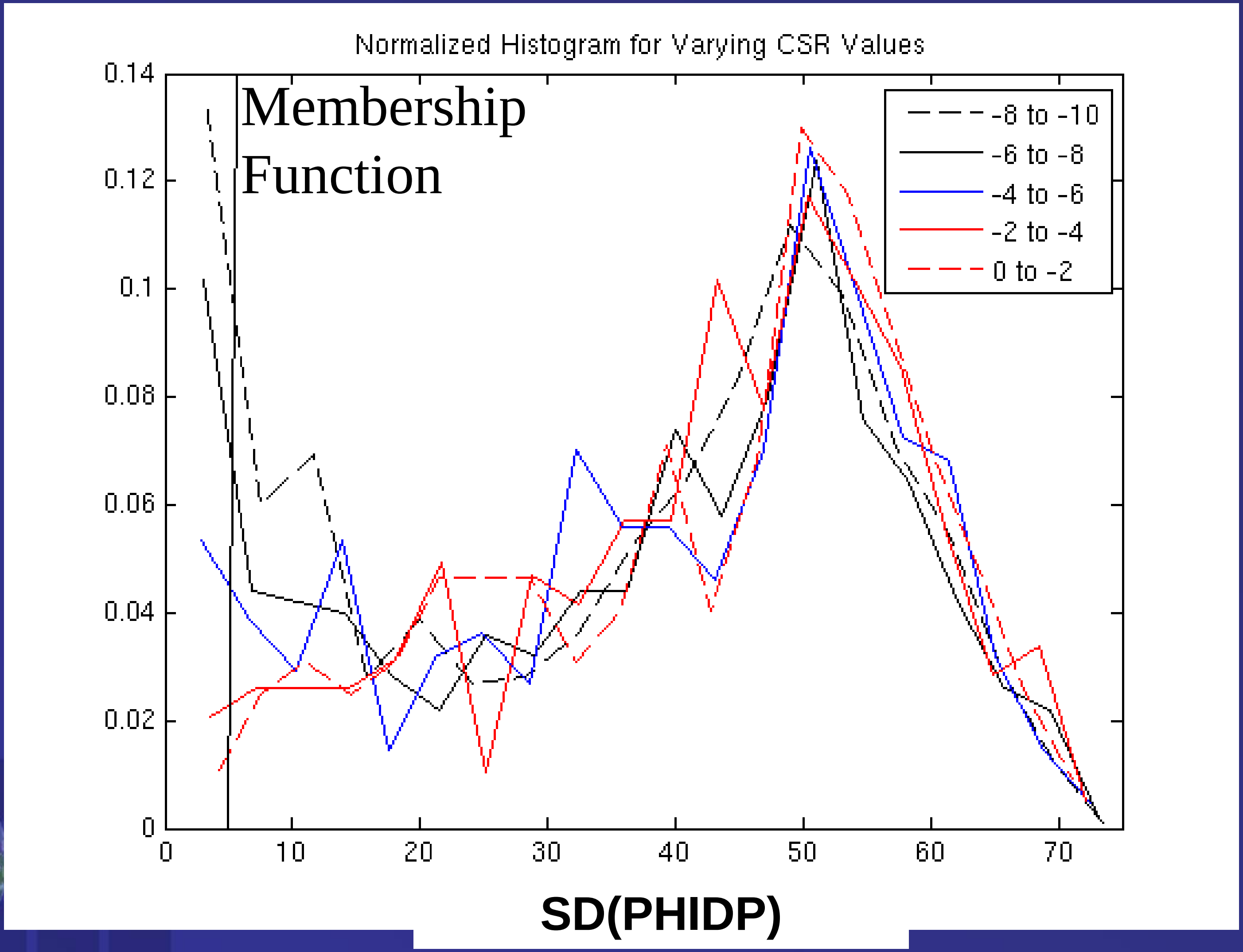


# Histograms of SD($\Phi_{DP}$) in pure weather and clutter



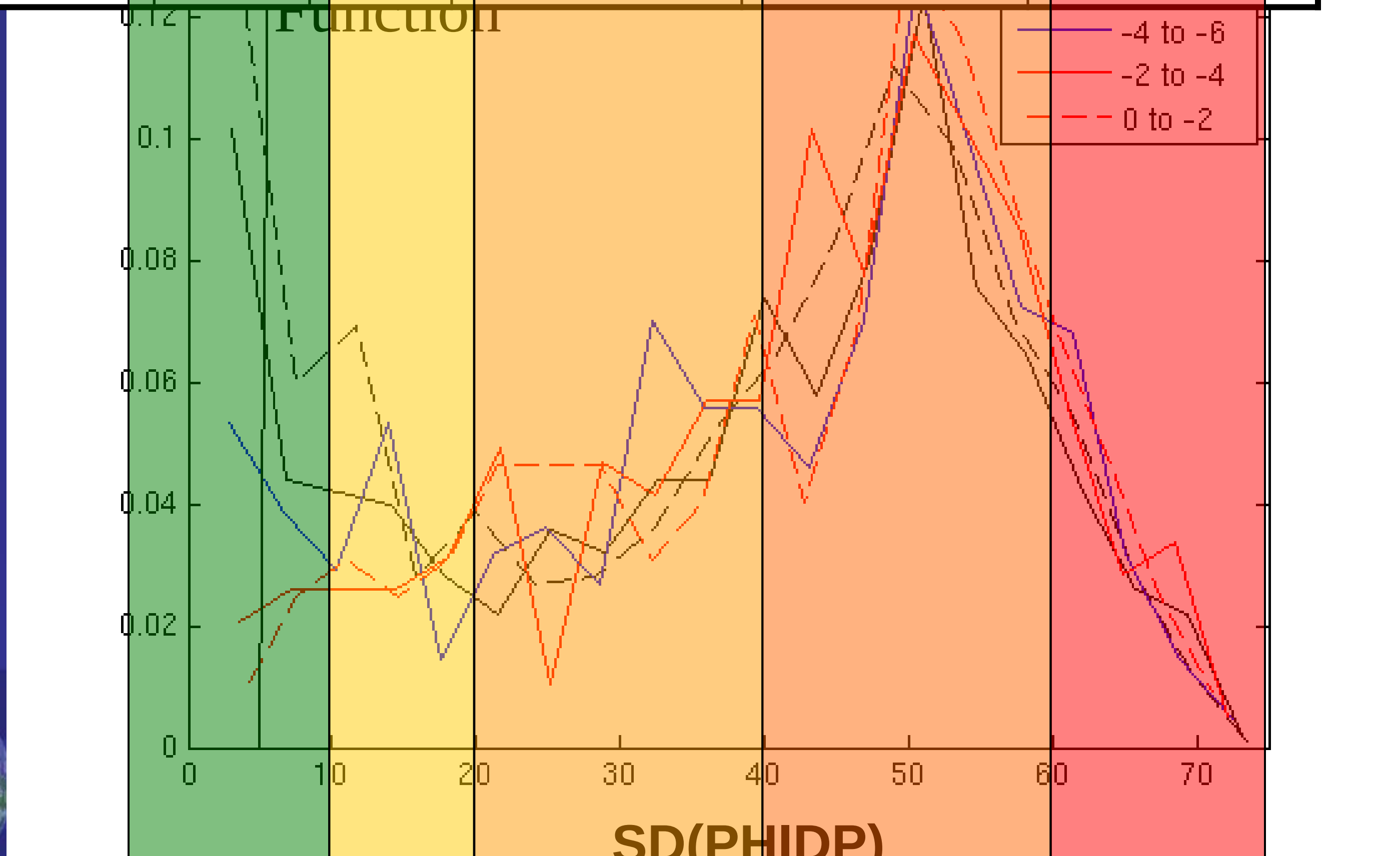



# Normalized Histograms of SD(PHIDP) in Clutter Mixed with weather at various CSR values

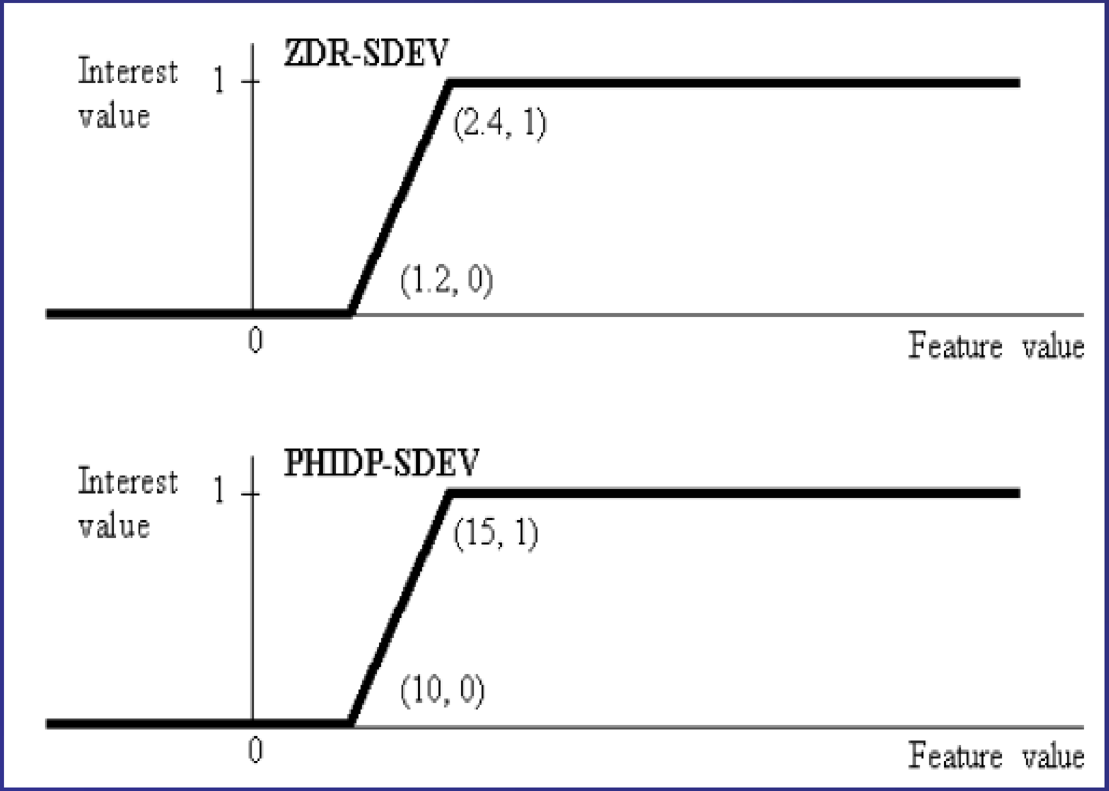


# Mean ZDR bias (dB) in mixed weather and clutter: -8 > CSR > -10 (dB)

| Mean ZDR bias | 0.06 | 0.19 | 1.0 | 1.32 | 1.69 |
|---|---|---|---|---|---|

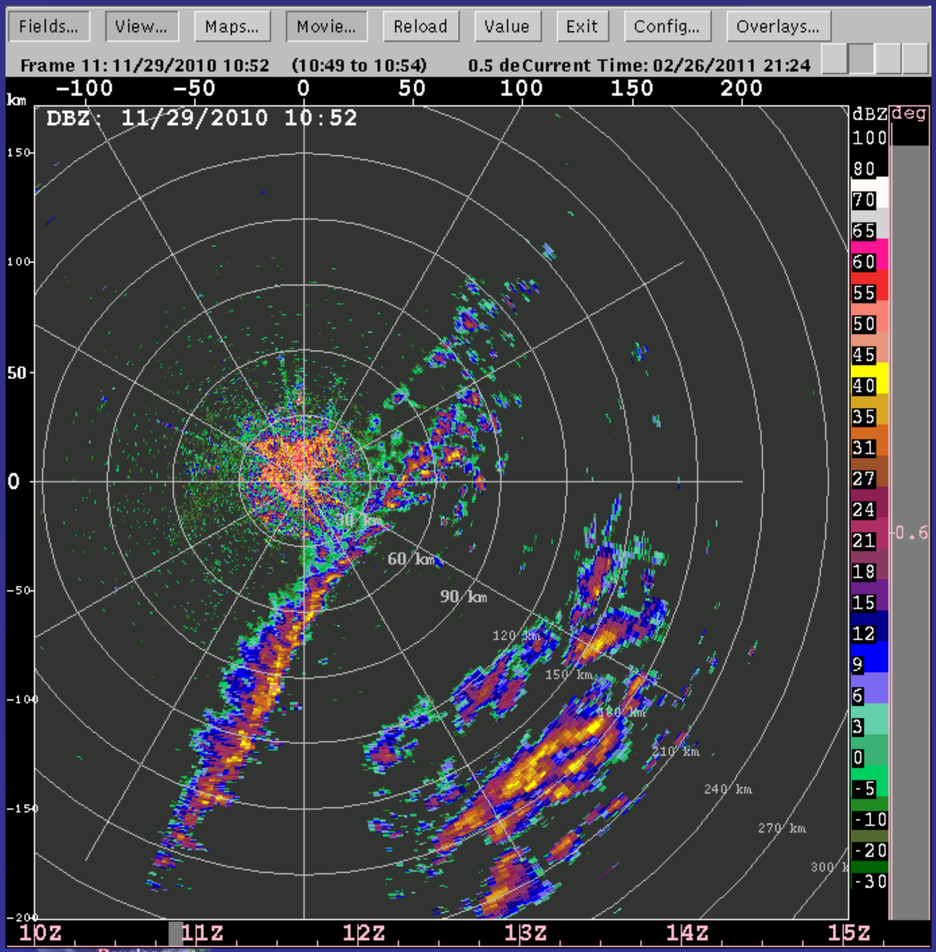


# Std Dev $Z_{DR}$ and $\Phi_{DP}$ Membership Functions

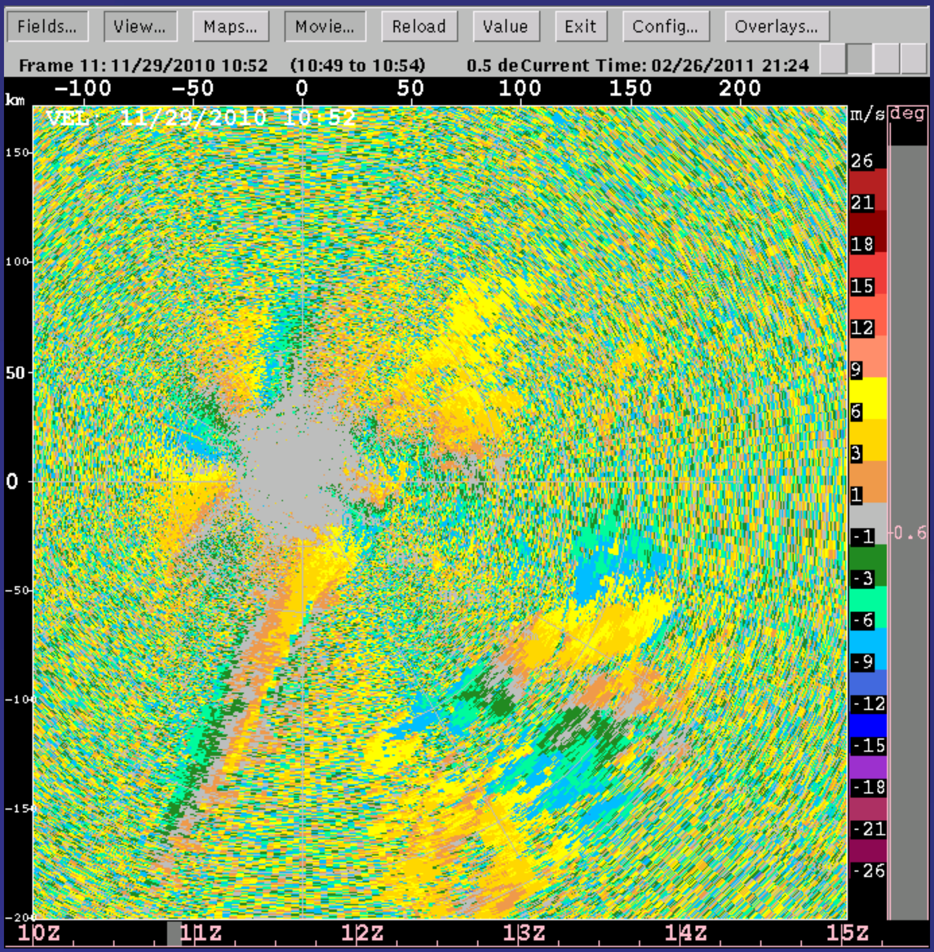


# KOUN Example 10:52, 29 Nov 2010

**Reflectivity (dBZ)**

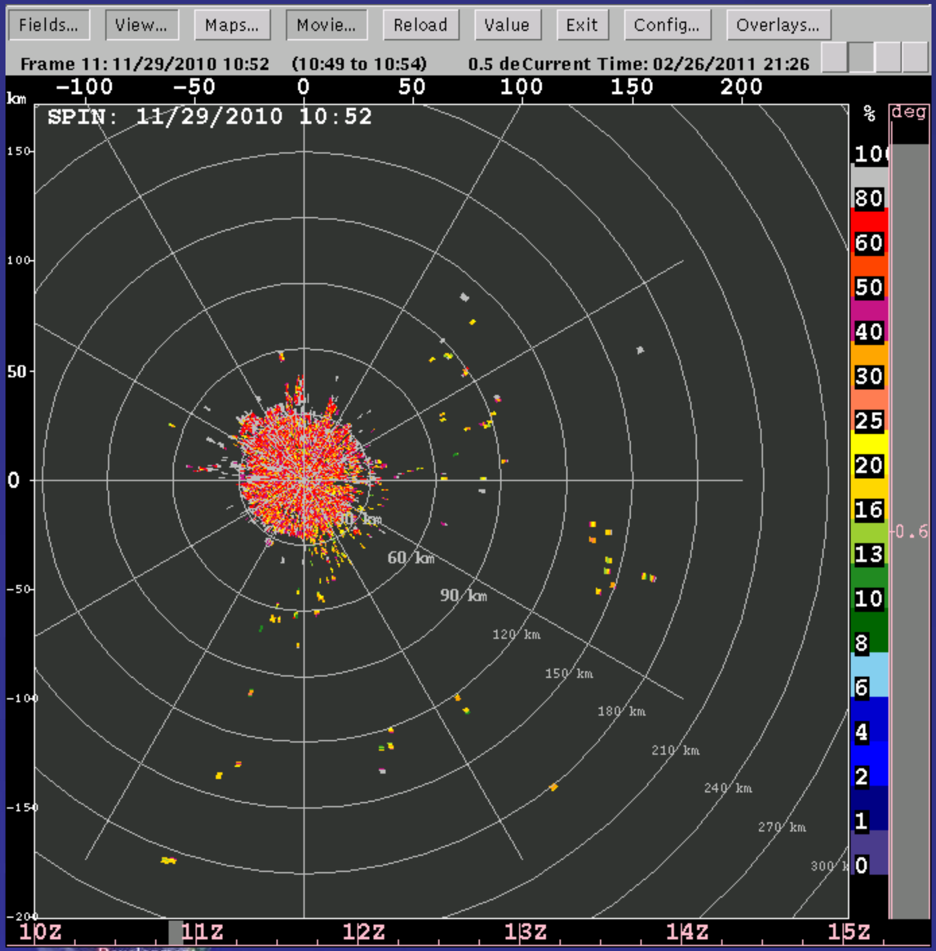



**Radial Velocity (m s$^{-1}$)**

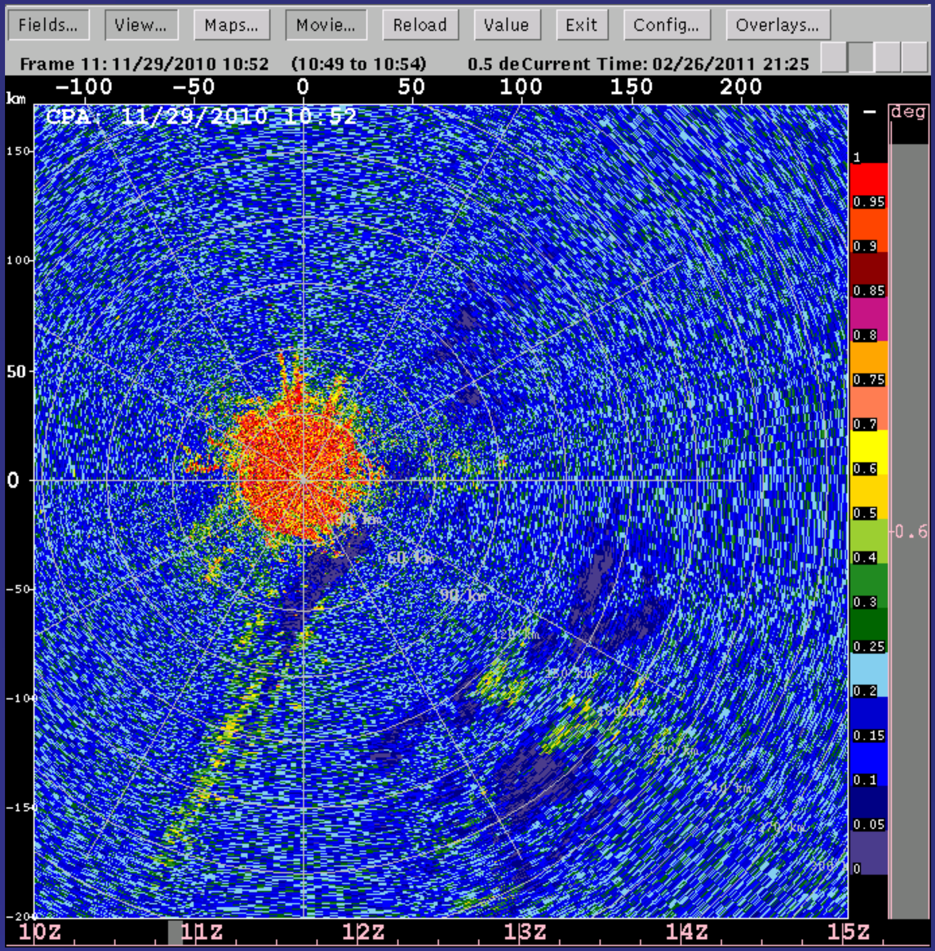


# KOUN Example 10:52, 29 Nov 2010

**SPIN**

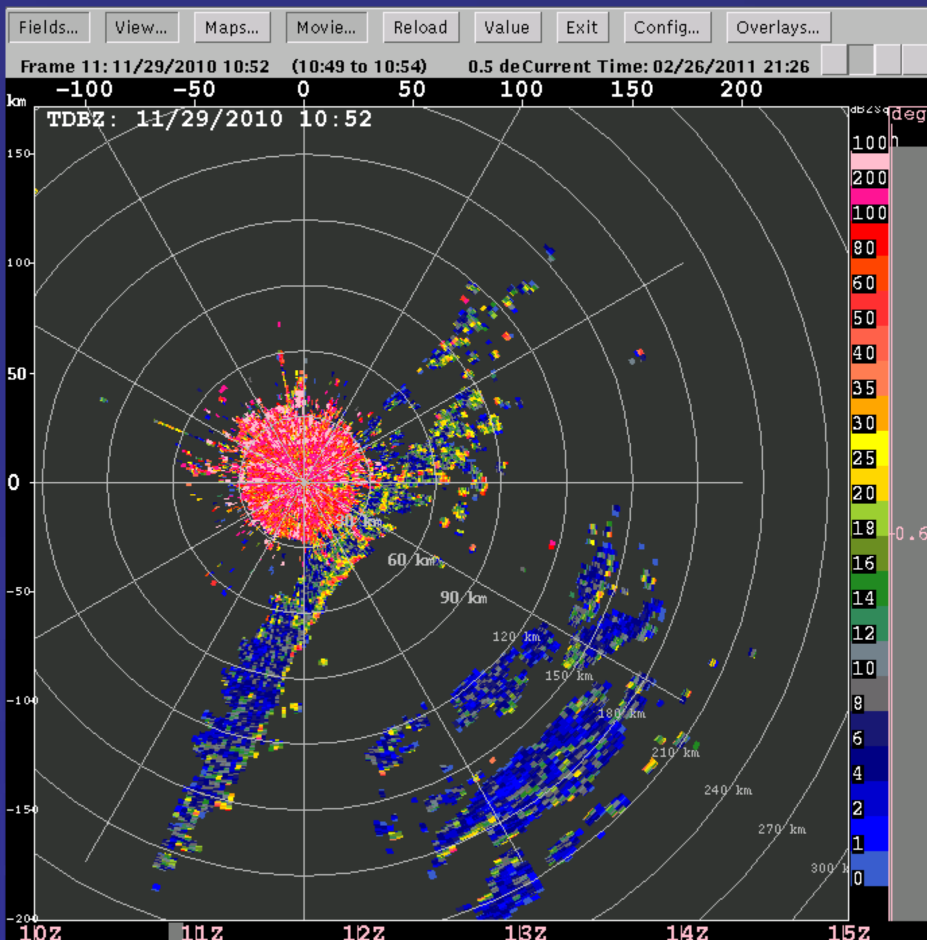



**CPA**

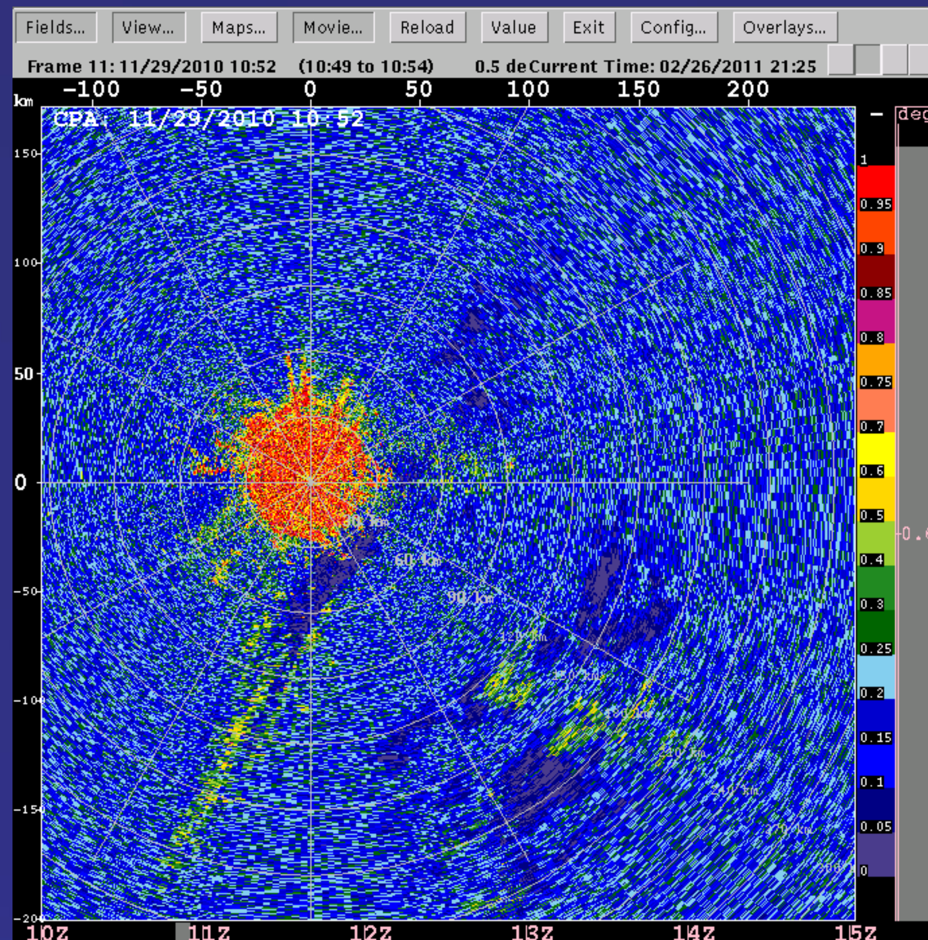


# KOUN Example 10:52, 29 Nov 2010

## Texture of Reflectivity

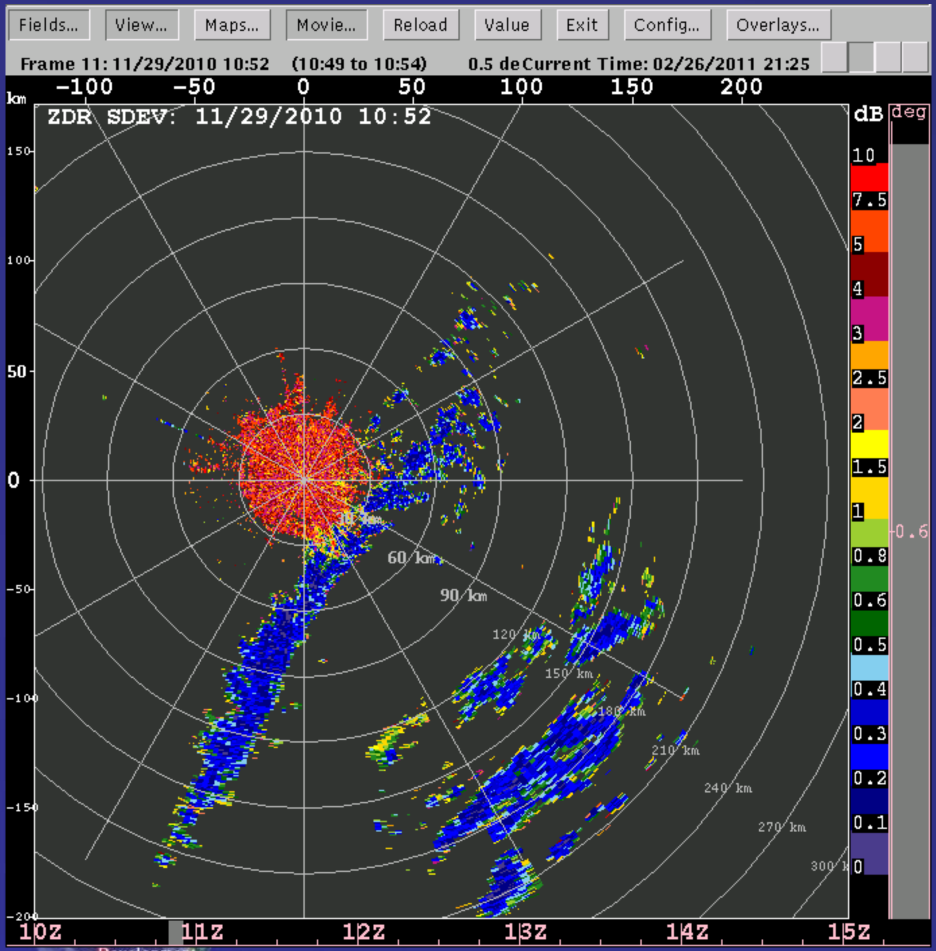



## CPA

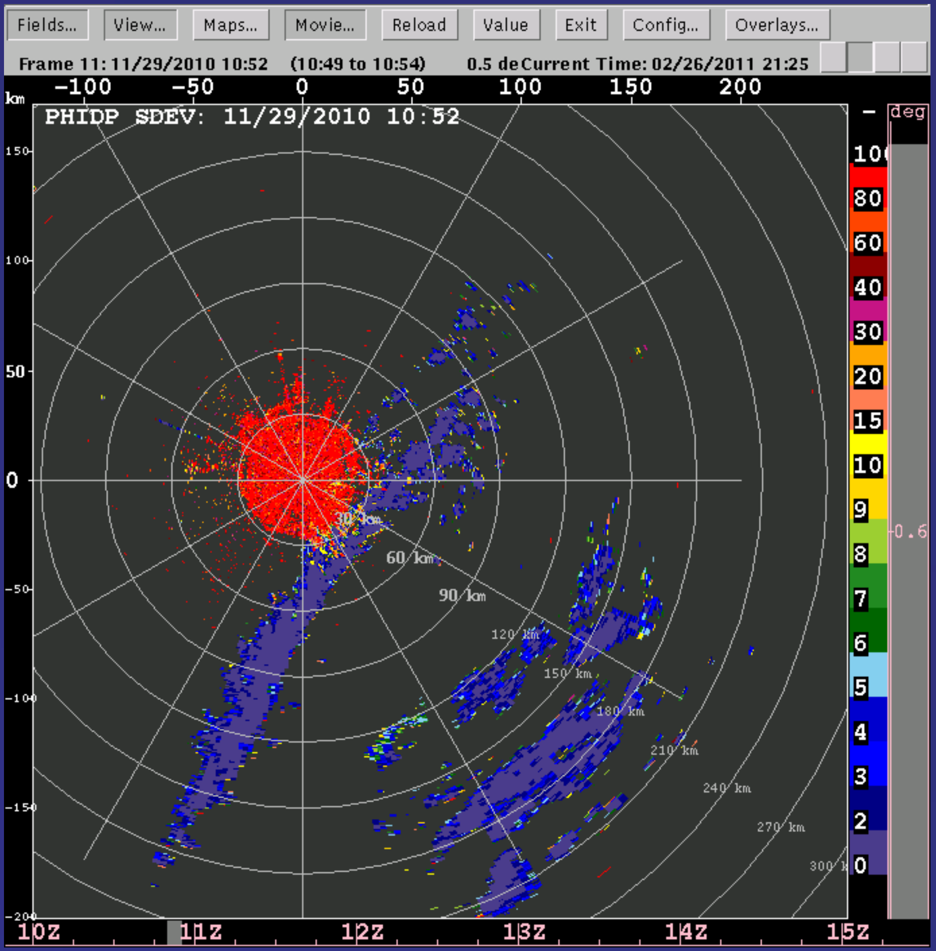


# KOUN Example 10:52, 29 Nov 2010

**Std Dev ZDR (dB)**

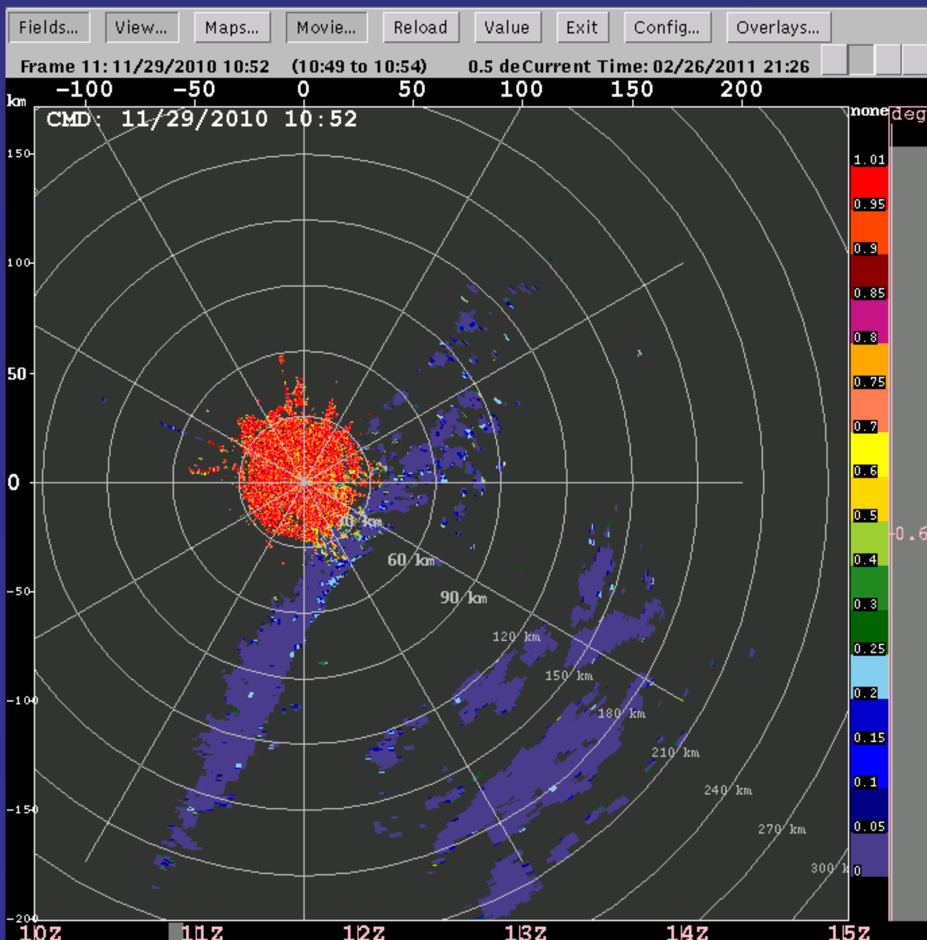



**Std Dev PHIDP (deg)**

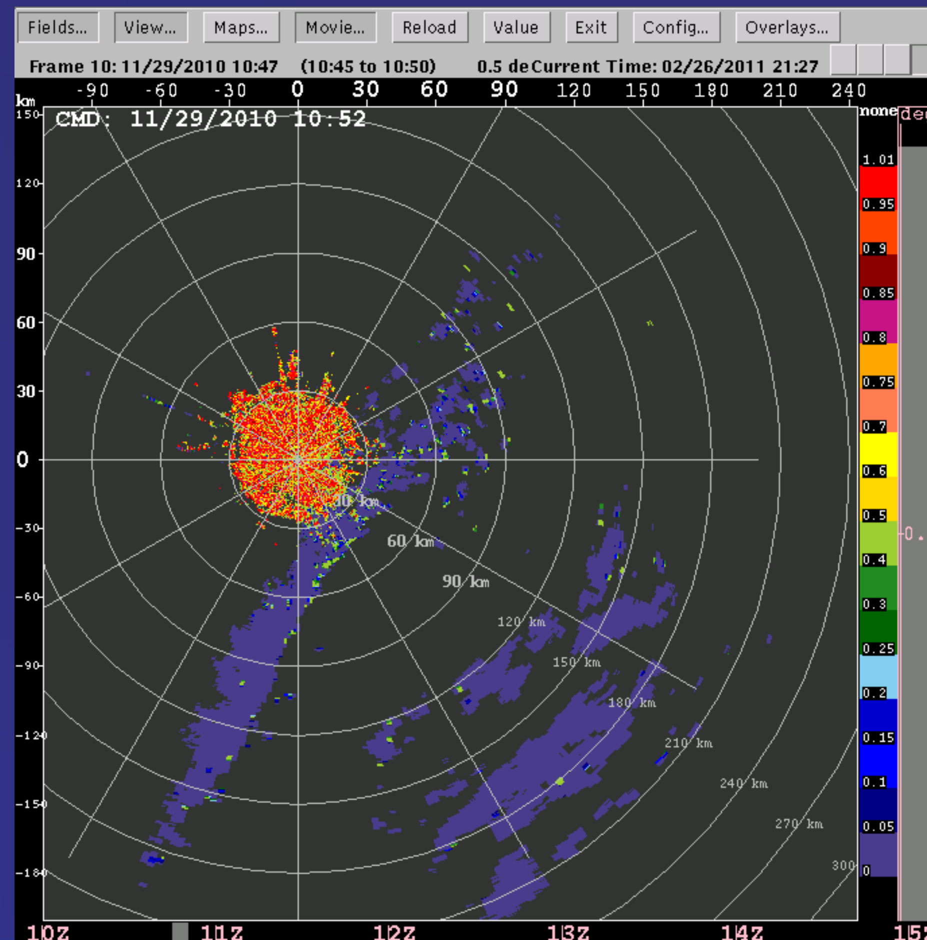


# KOUN Example 10:52, 29 Nov 2010

**Dual-Pol CMD (0 to 1)**

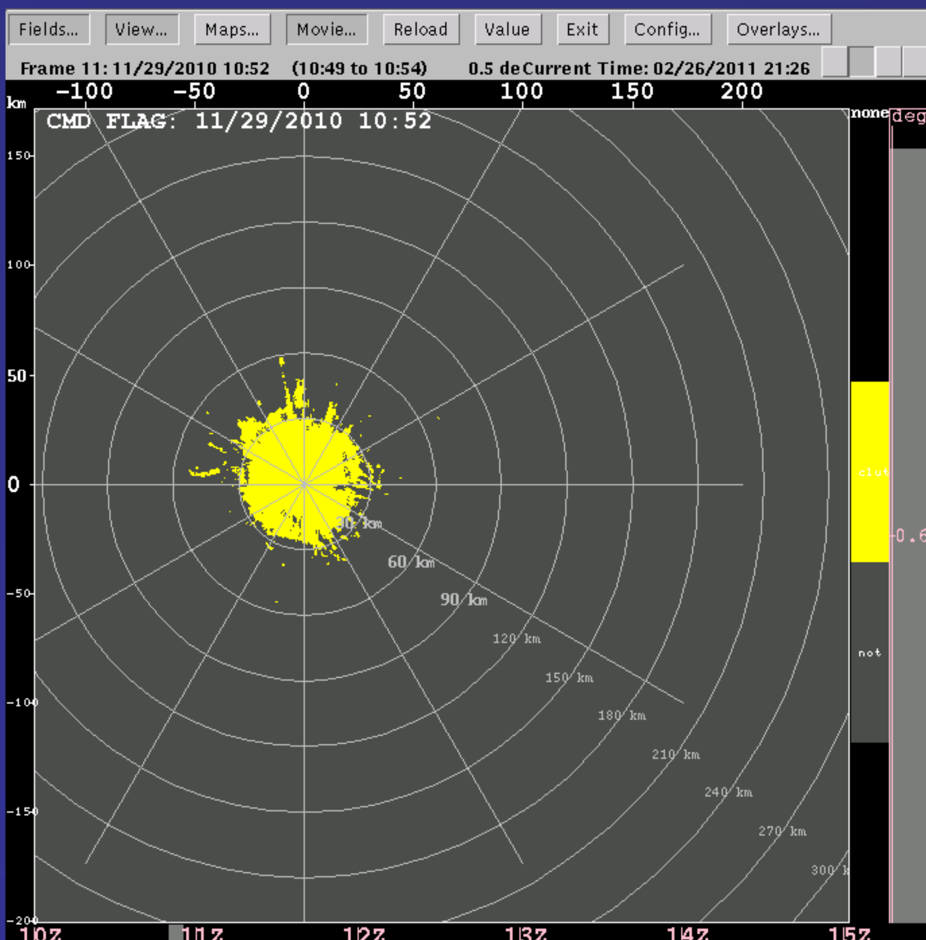



**Single-Pol CMD (0 to 1)**

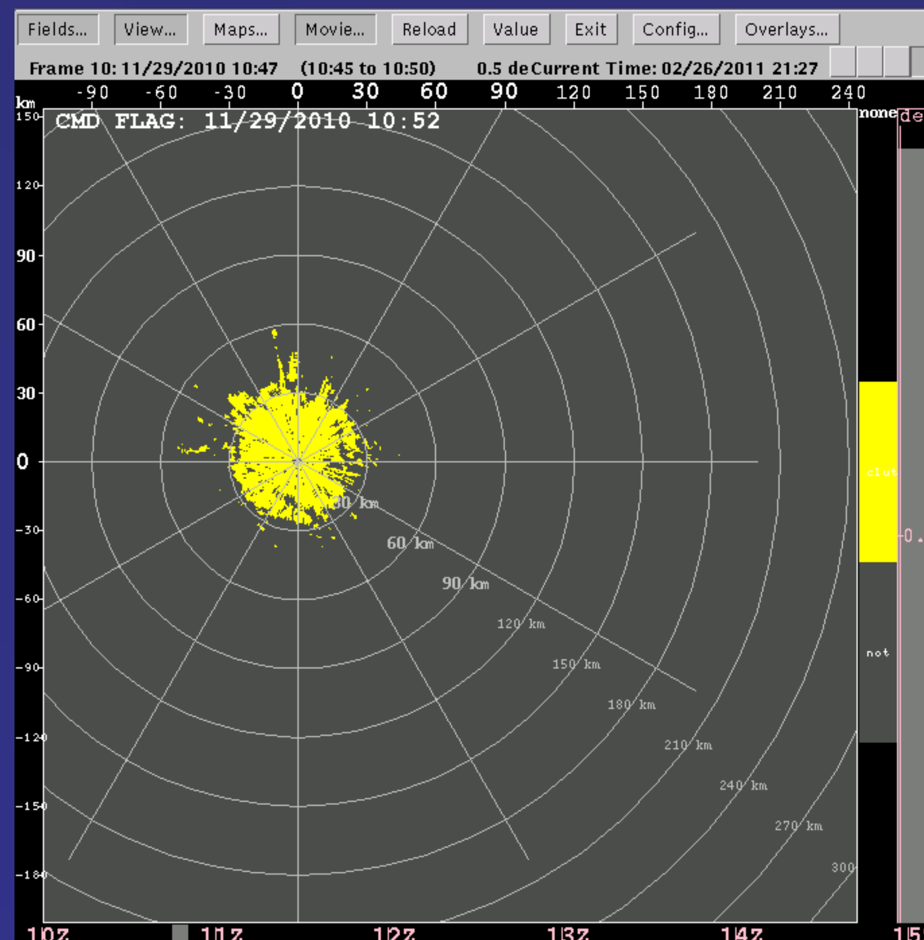


# KOUN Example 10:52, 29 Nov 2010

## Dual-Pol CMD Flag

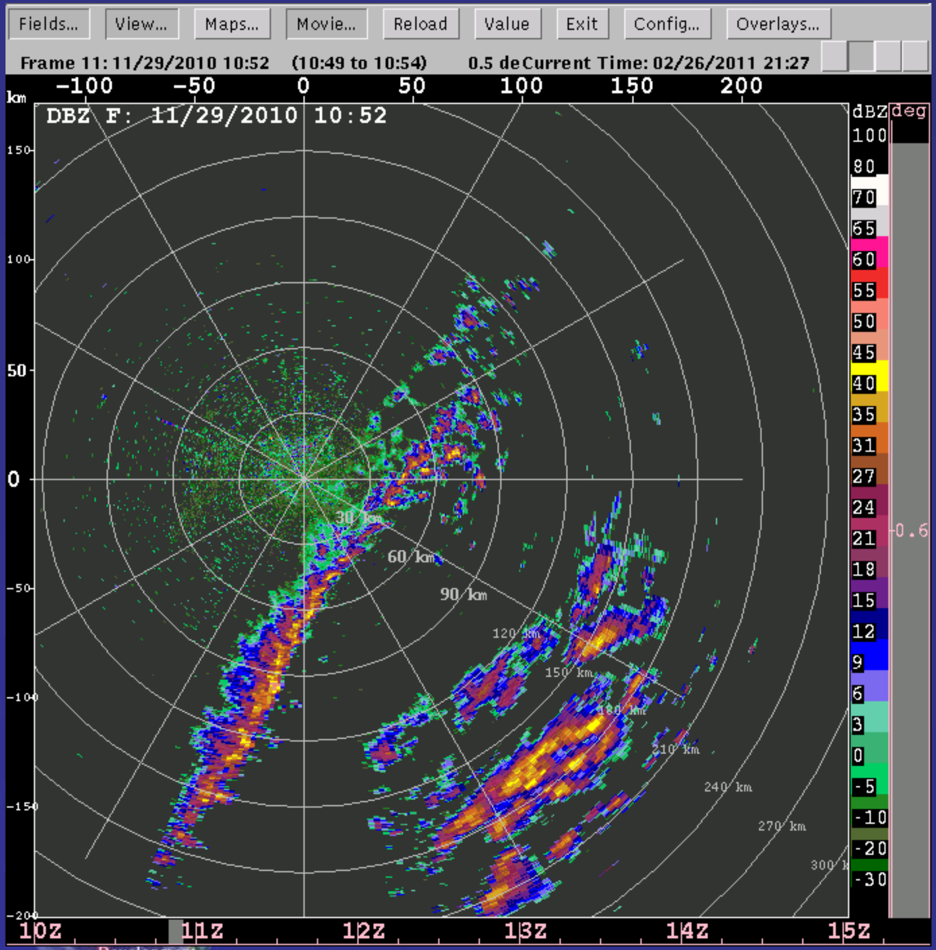



## Single-Pol CMD Flag

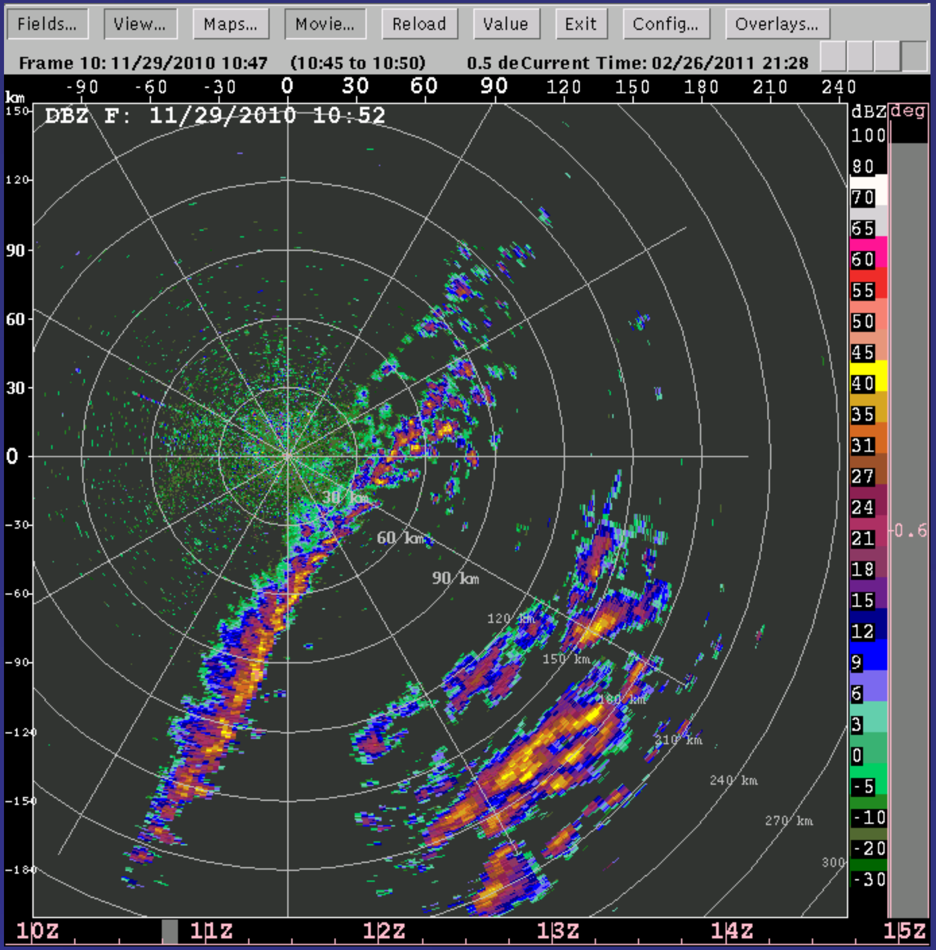


# KOUN Example 10:52, 29 Nov 2010

**Dual-Pol Filtered dBZ**



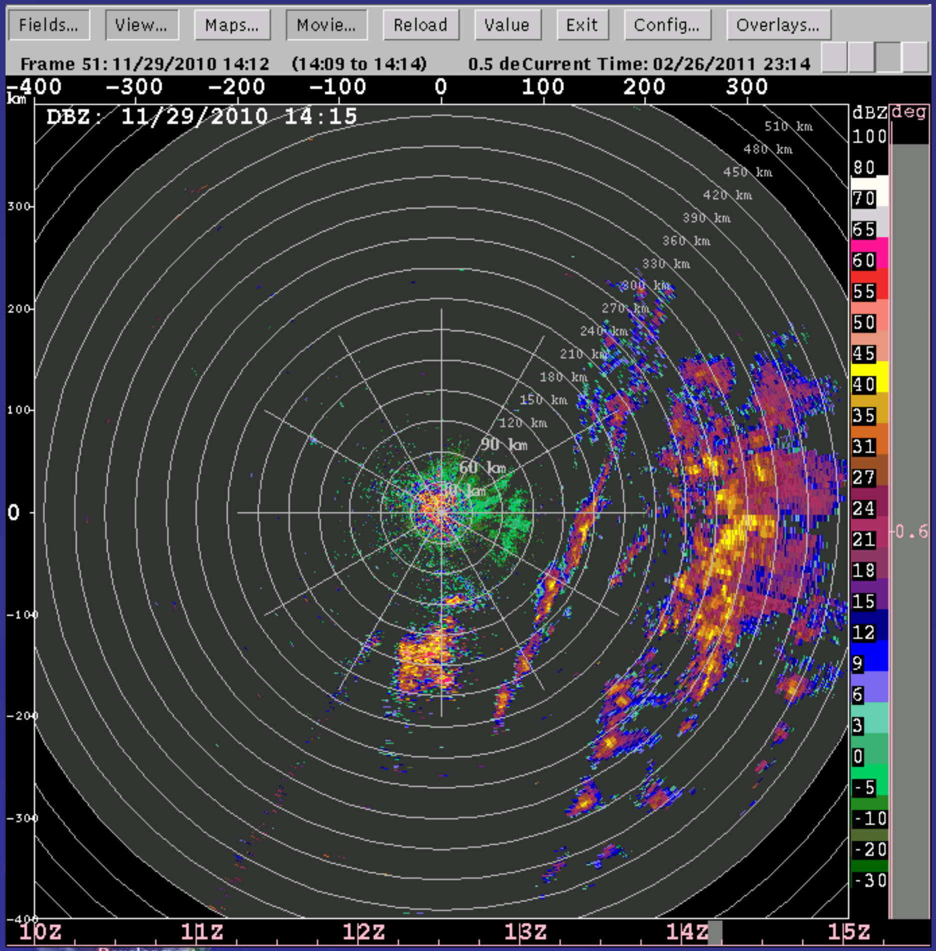

**Single-Pol Filtered dBZ**



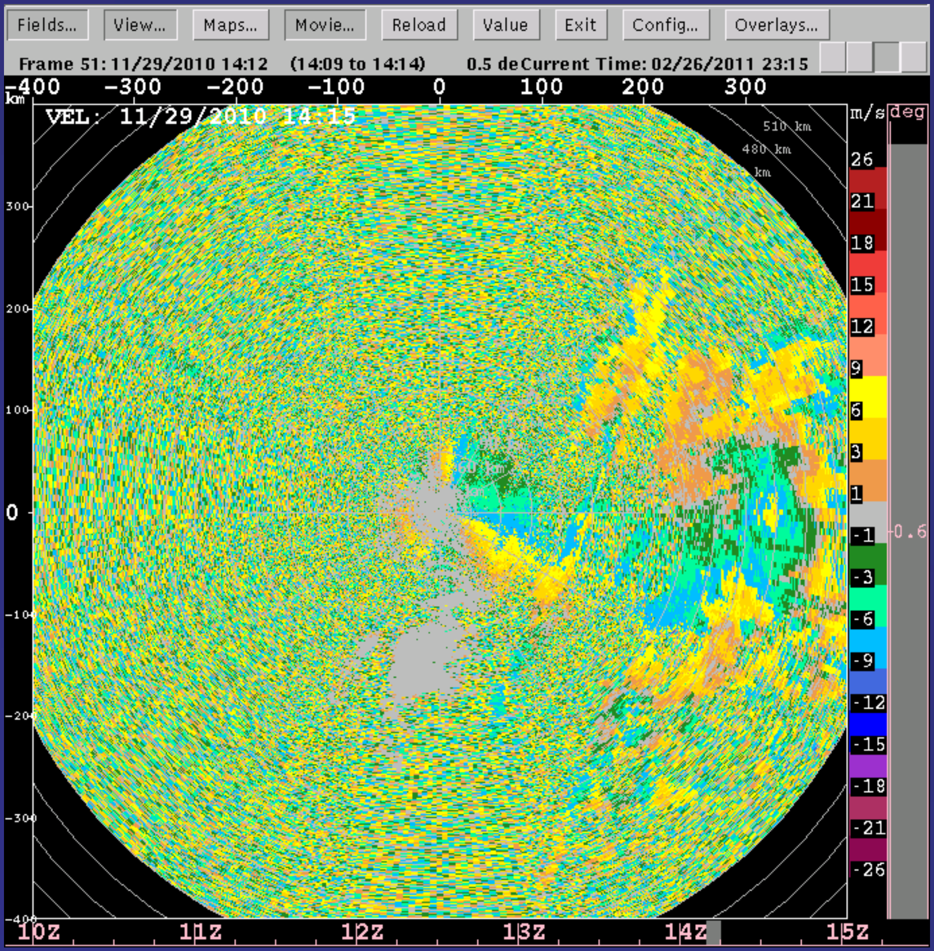

Development Data Services

# KOUN Example 14:15, 29 Nov 2010

**Reflectivity (dBZ)**



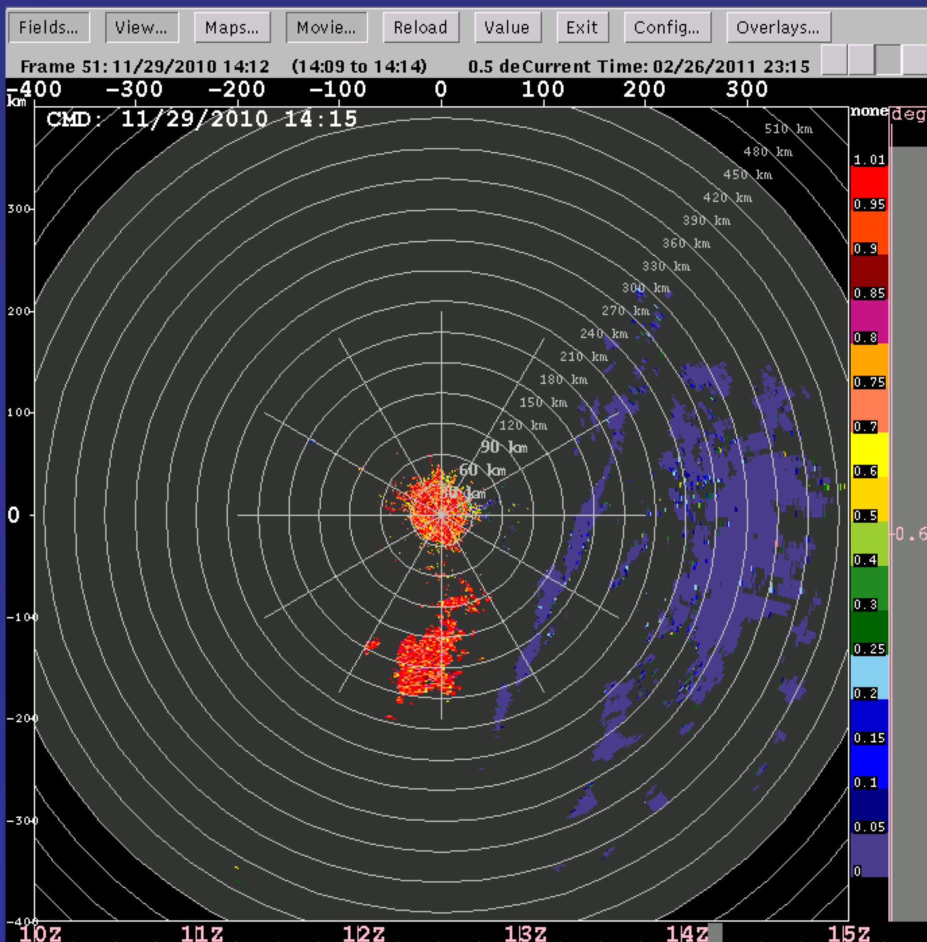

**Radial Velocity (m s$^{-1}$)**



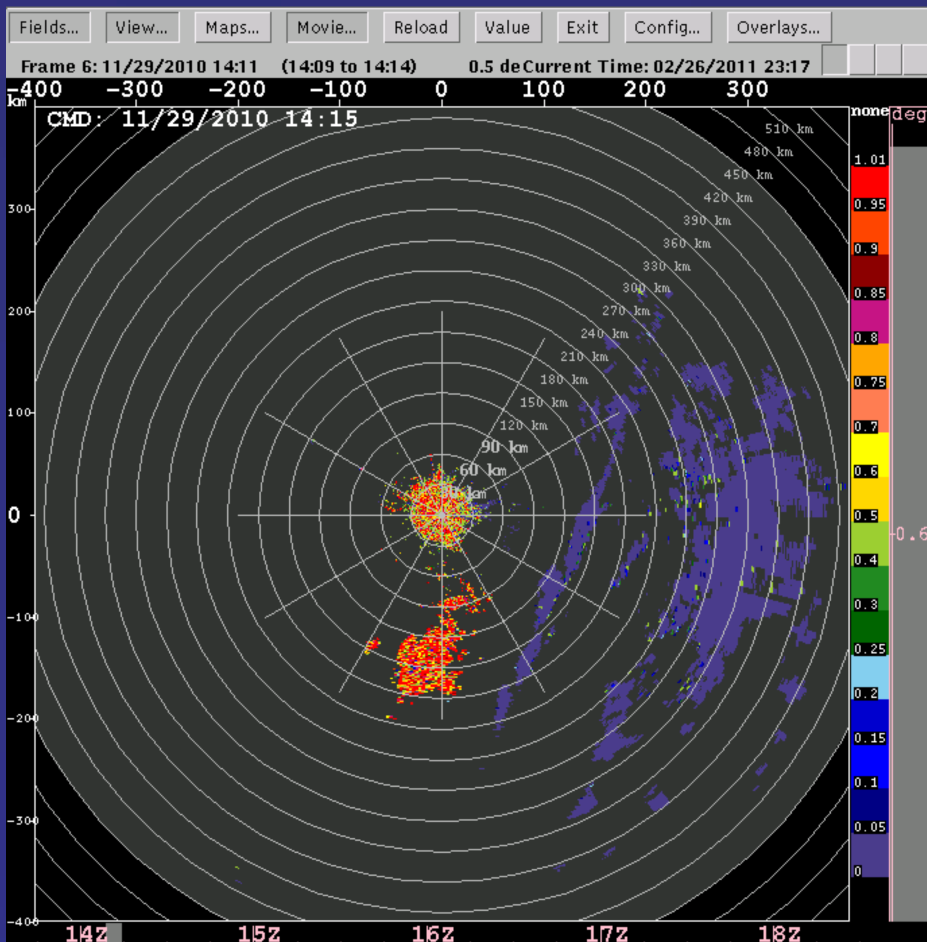

Development Data Services

# KOUN Example 14:15, 29 Nov 2010

**Dual-pol CMD (0 to 1)**



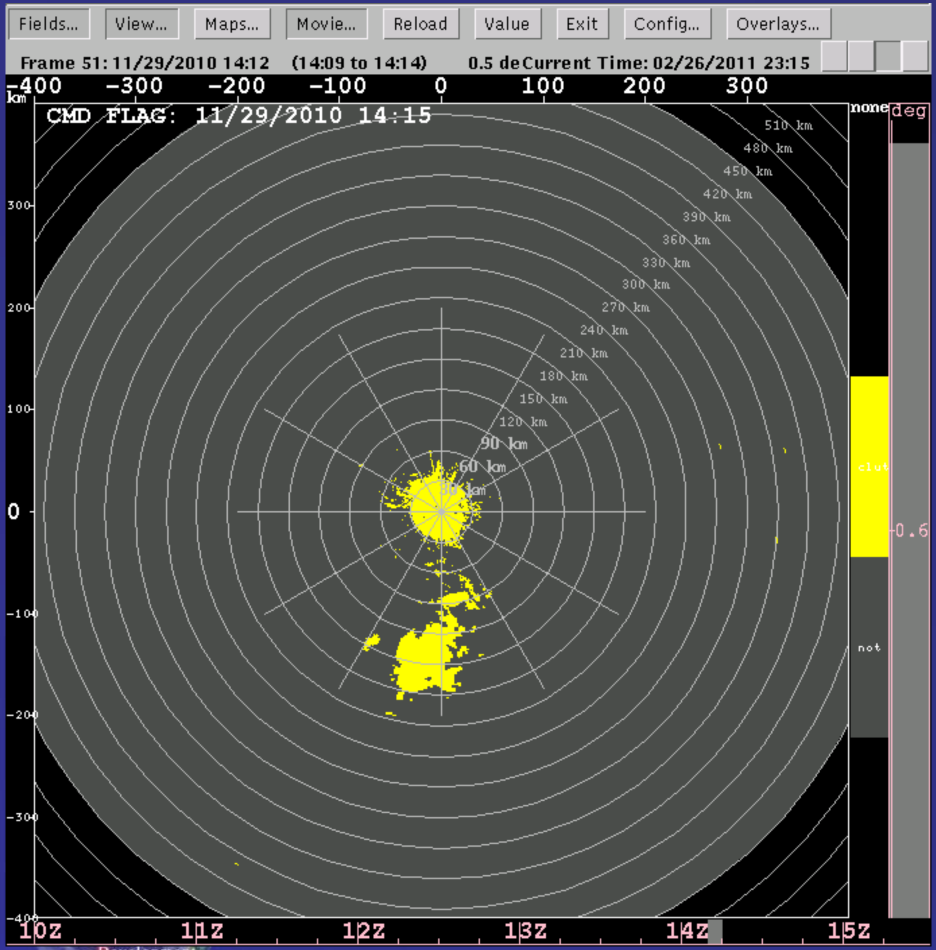

**Single-pol CMD (0 to 1)**



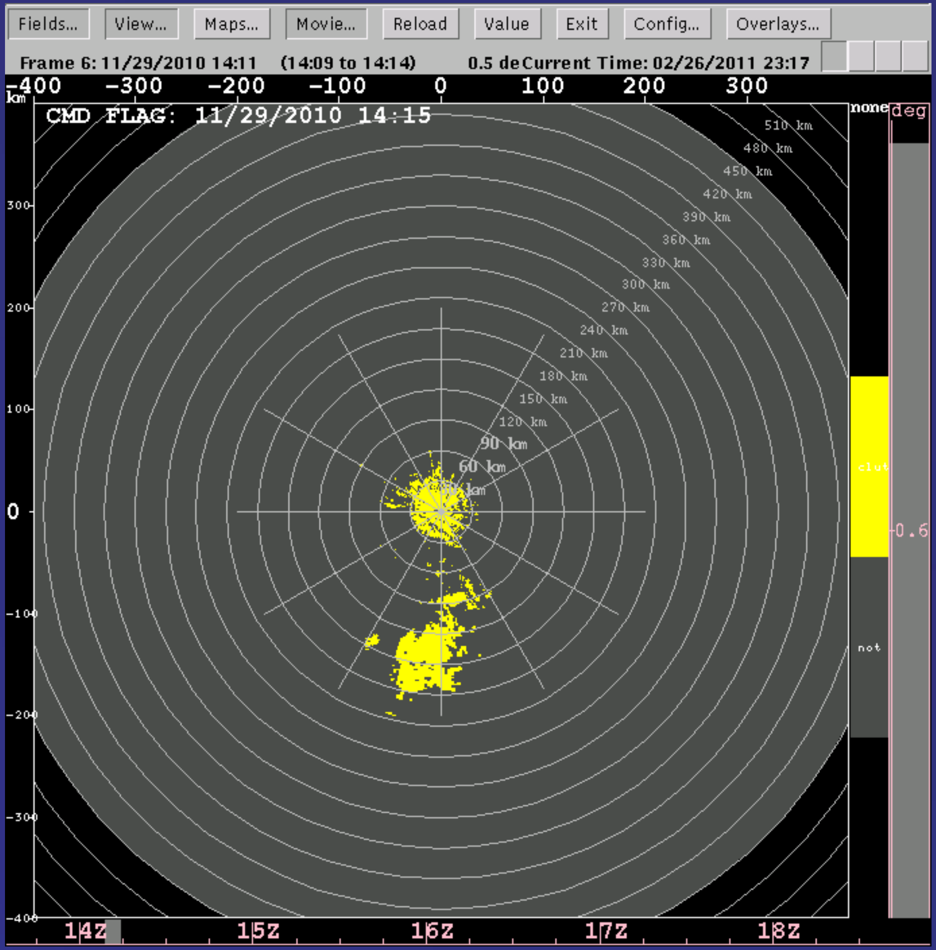

Development Data Services

# KOUN Example 14:15, 29 Nov 2010

**Dual-pol CMD Flag**

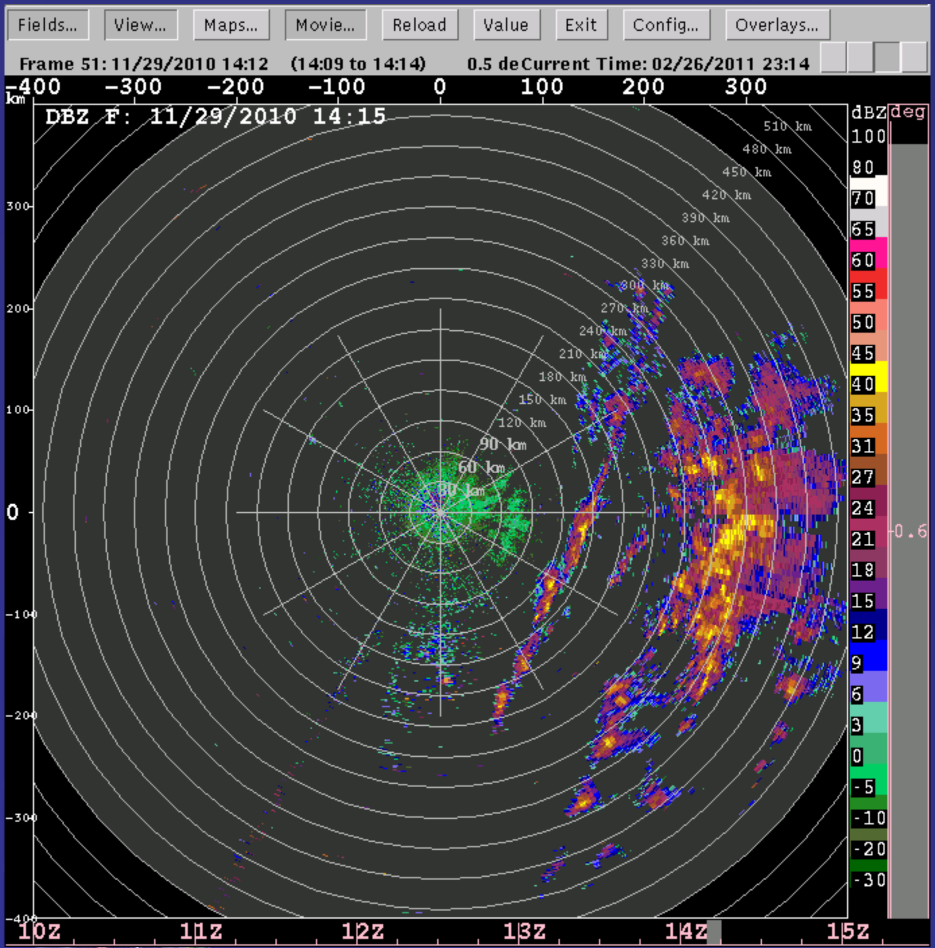



**Single-pol CMD Flag**

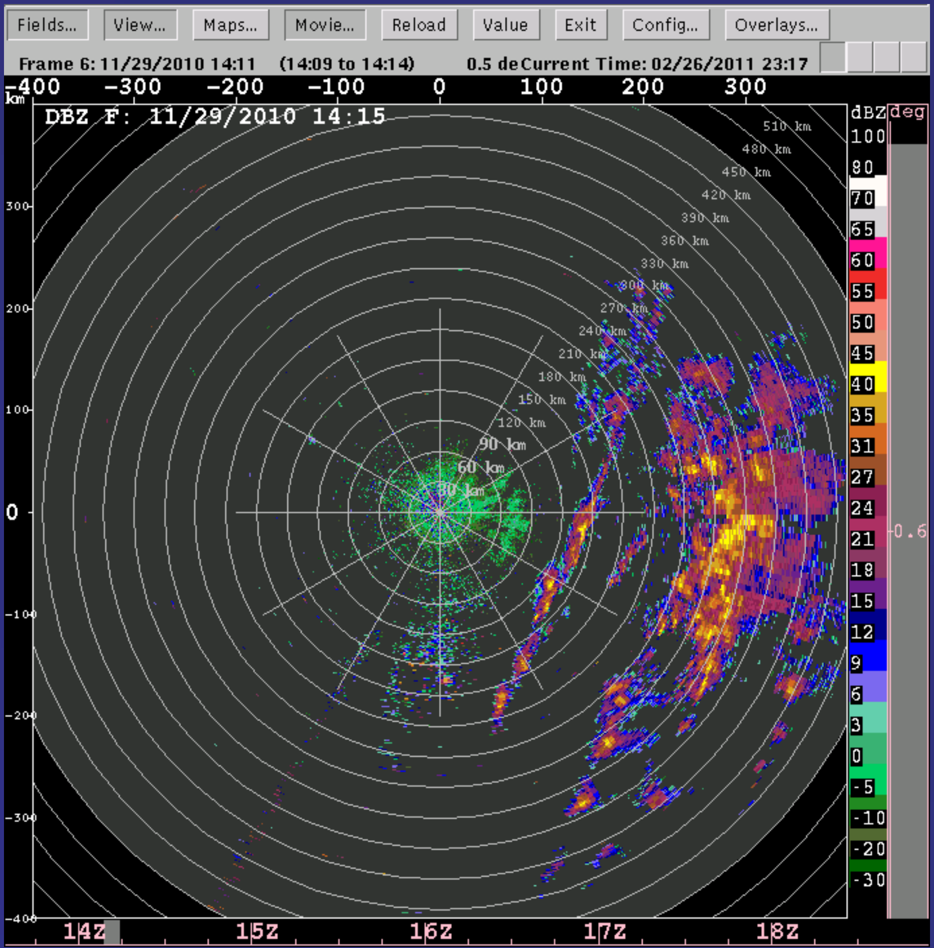


# KOUN Example 14:15, 29 Nov 2010

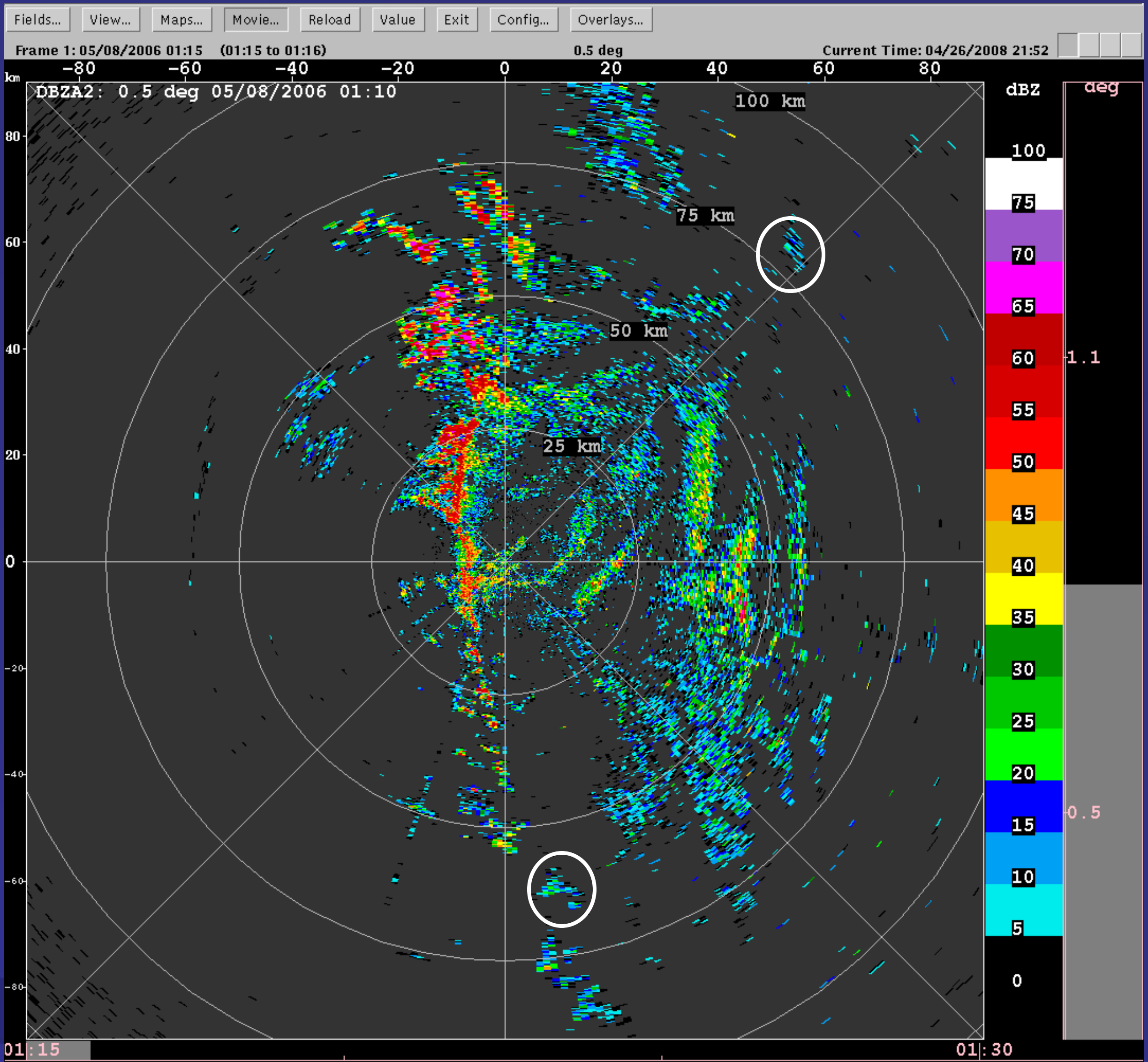
## Dual-pol Filtered dBZ



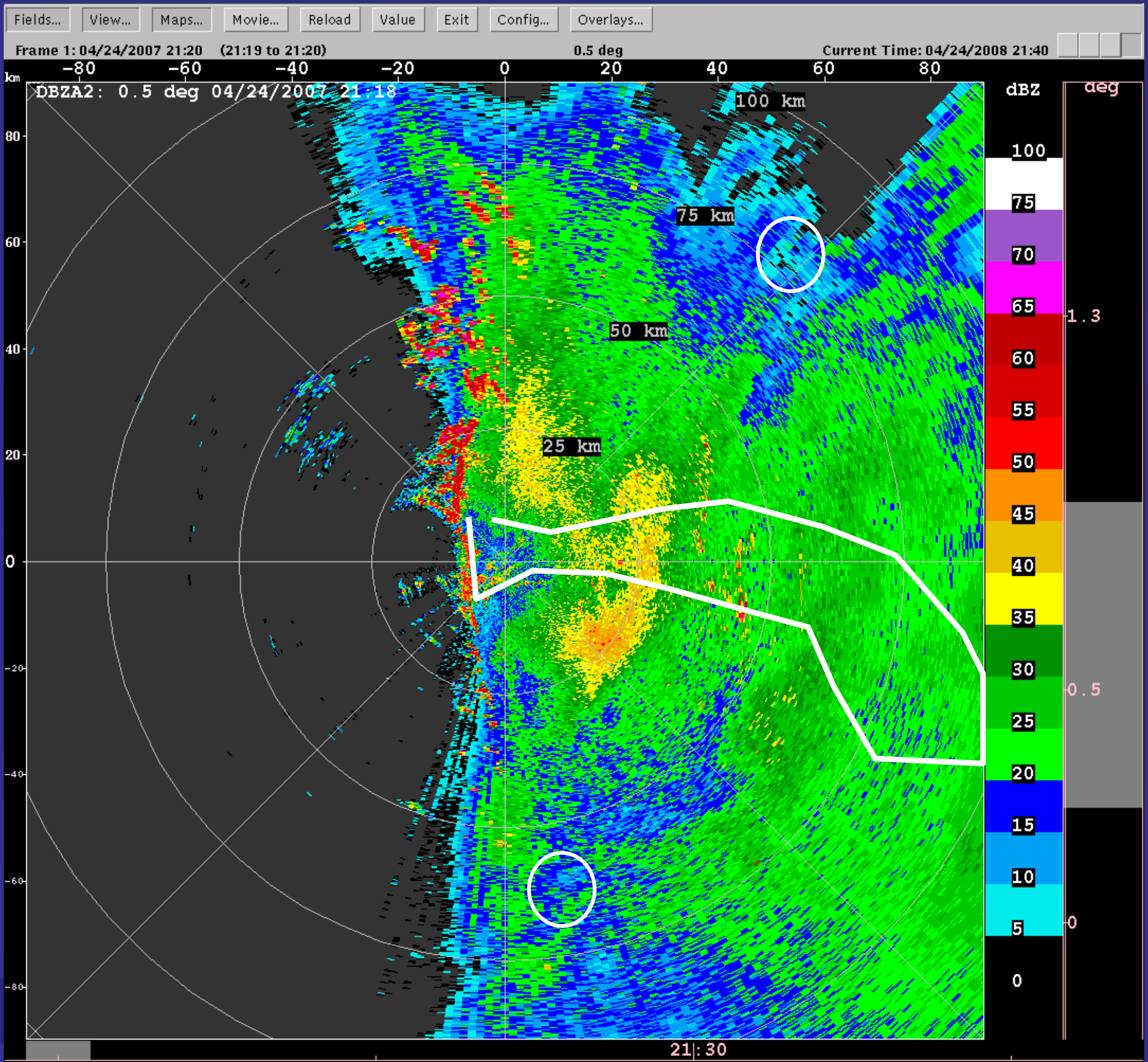

## Single-pol Filtered dBZ



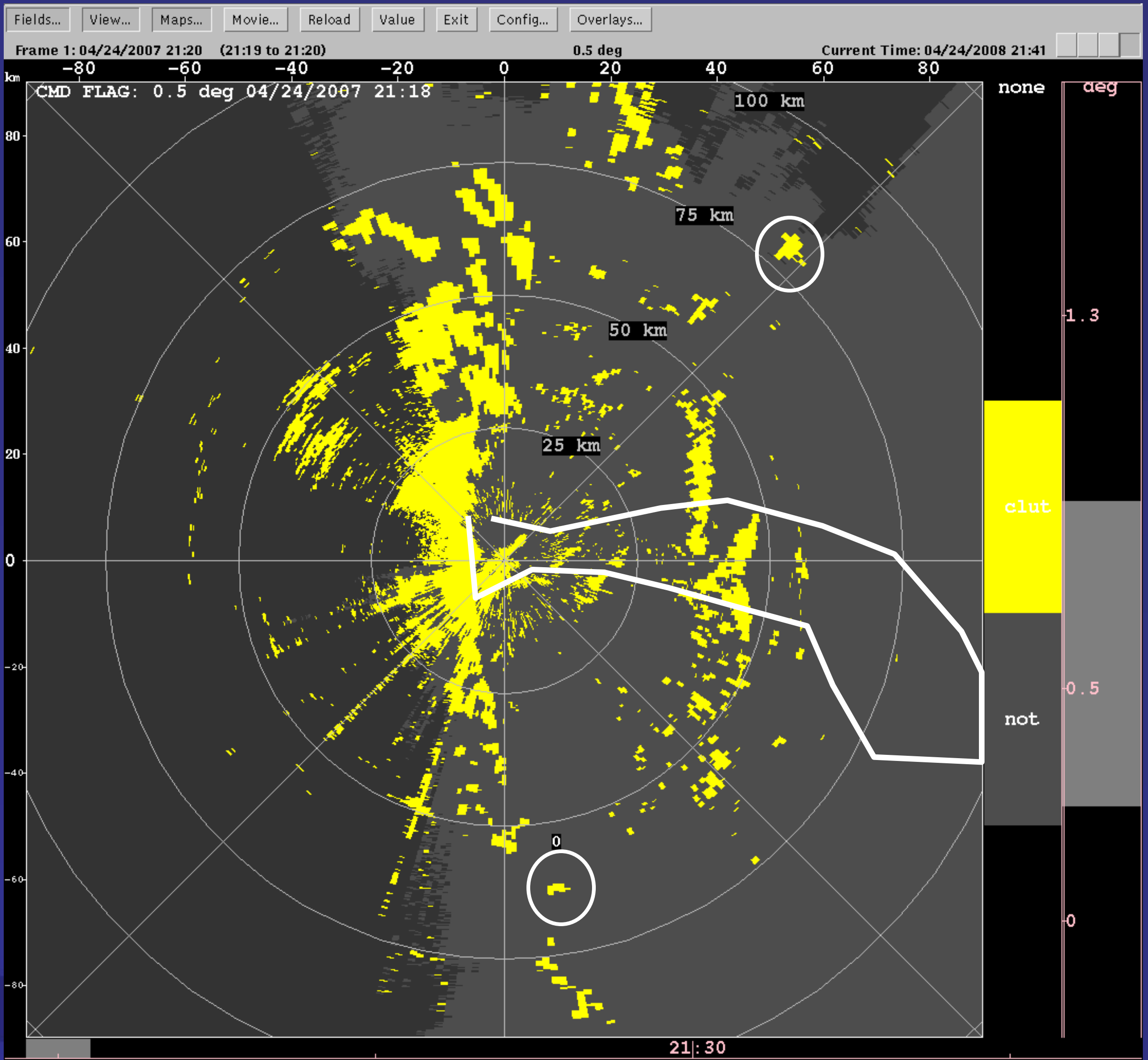
# S-Pol Example: Clear Scan dBZ



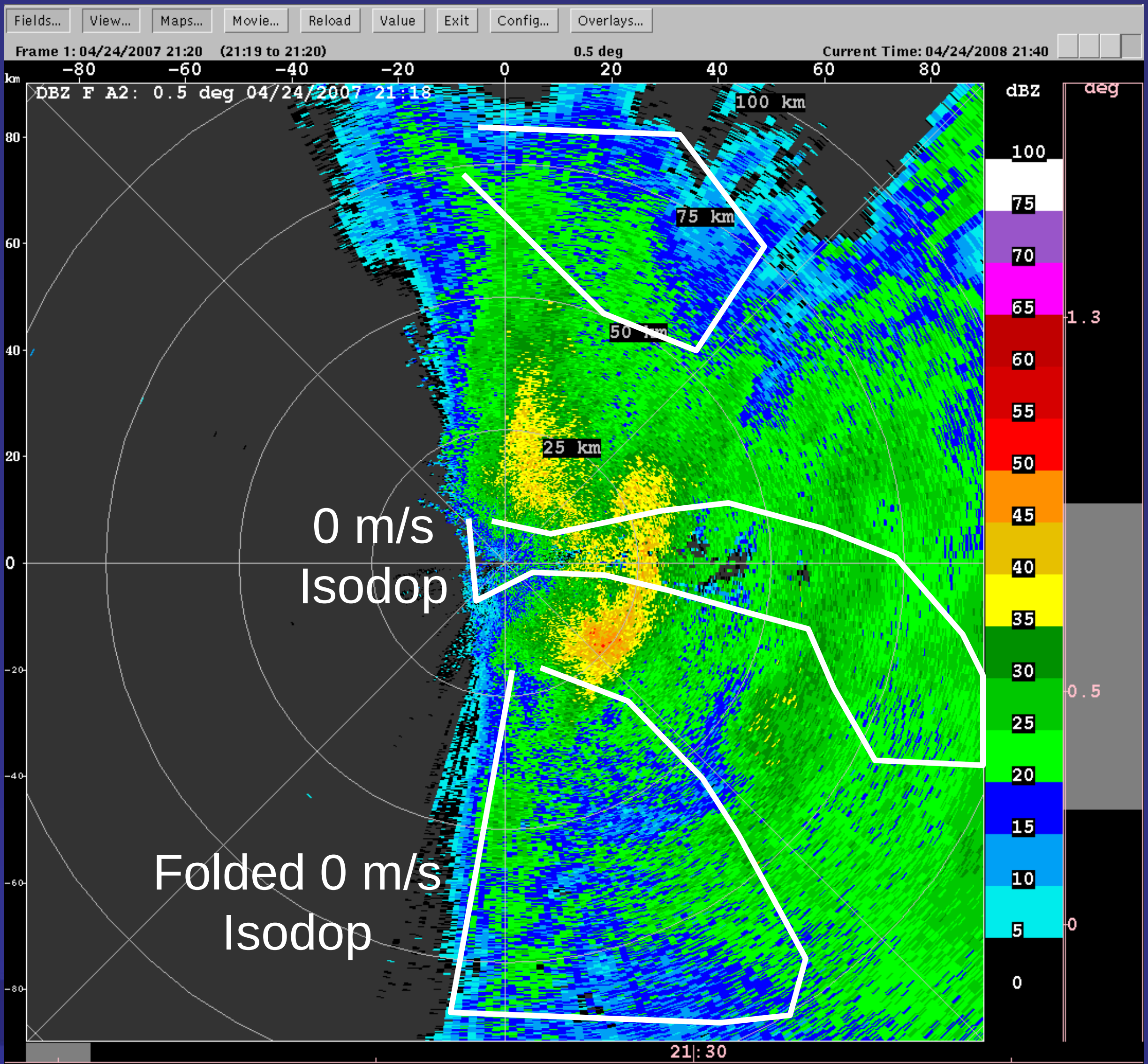
# S-Pol Example: Unfiltered dBZ



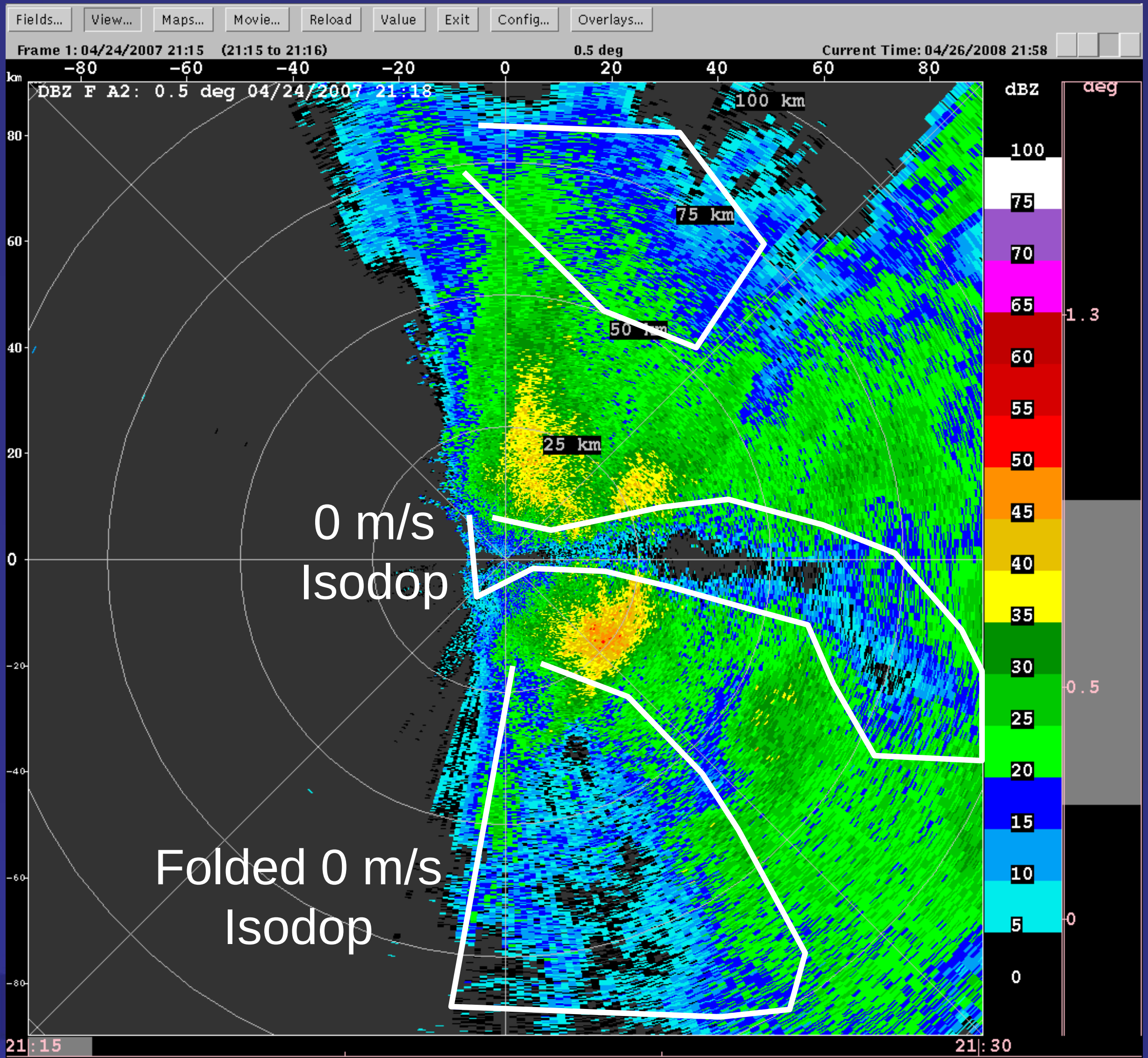

# S-Pol Example: Dual-Pol CMD Flag



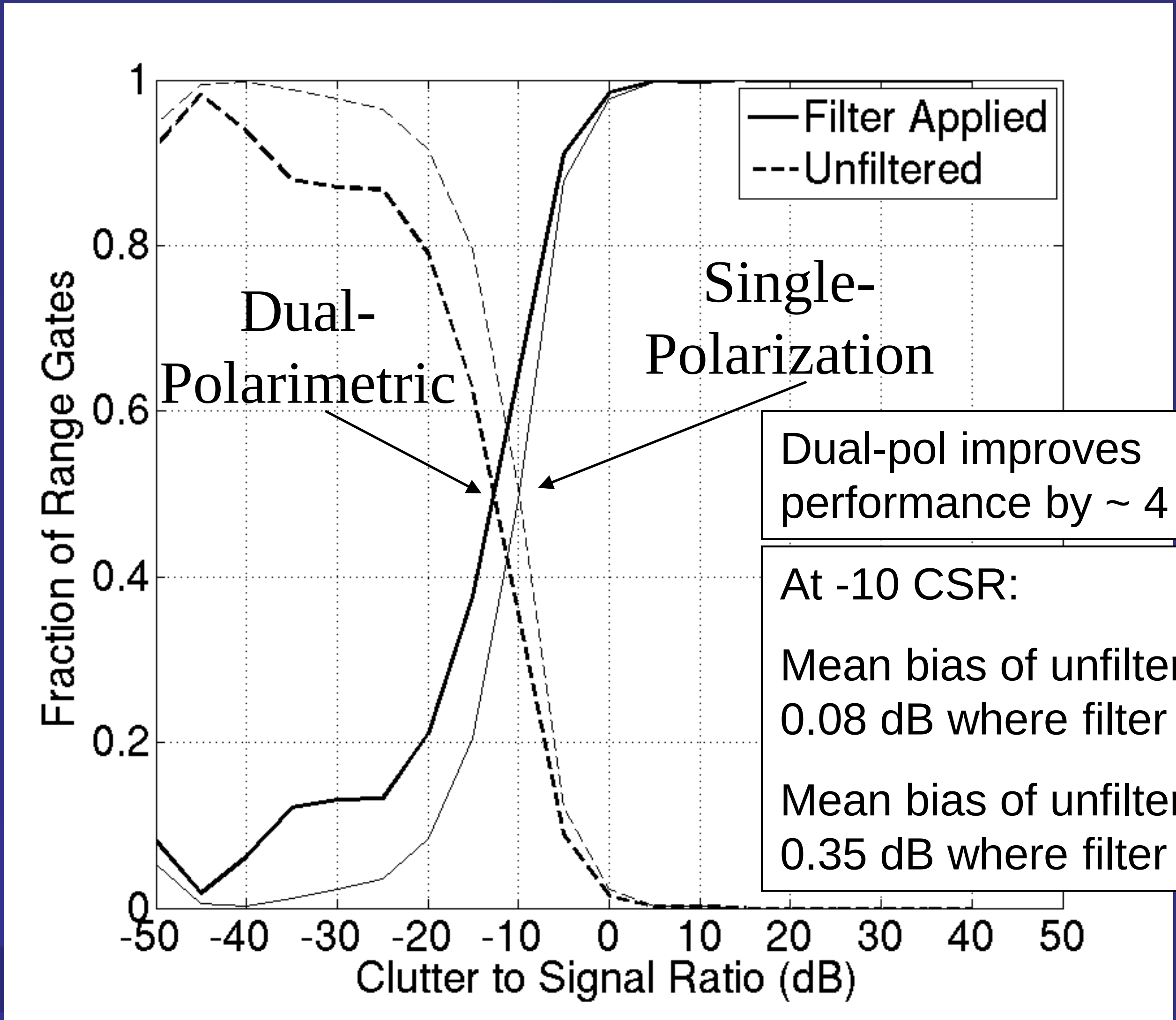
# S-Pol Example: dBZ Filtered on CMD



# S-Pol Example: dBZ Filtered All Bins



# CMD Performance




Dual-pol improves performance by ~ 4 to 5 dB

At -10 CSR:

Mean bias of unfiltered ZDR = 0.08 dB where filter not applied

Mean bias of unfiltered ZDR = 0.35 dB where filter applied

# Dual-pol CMD Conclusions

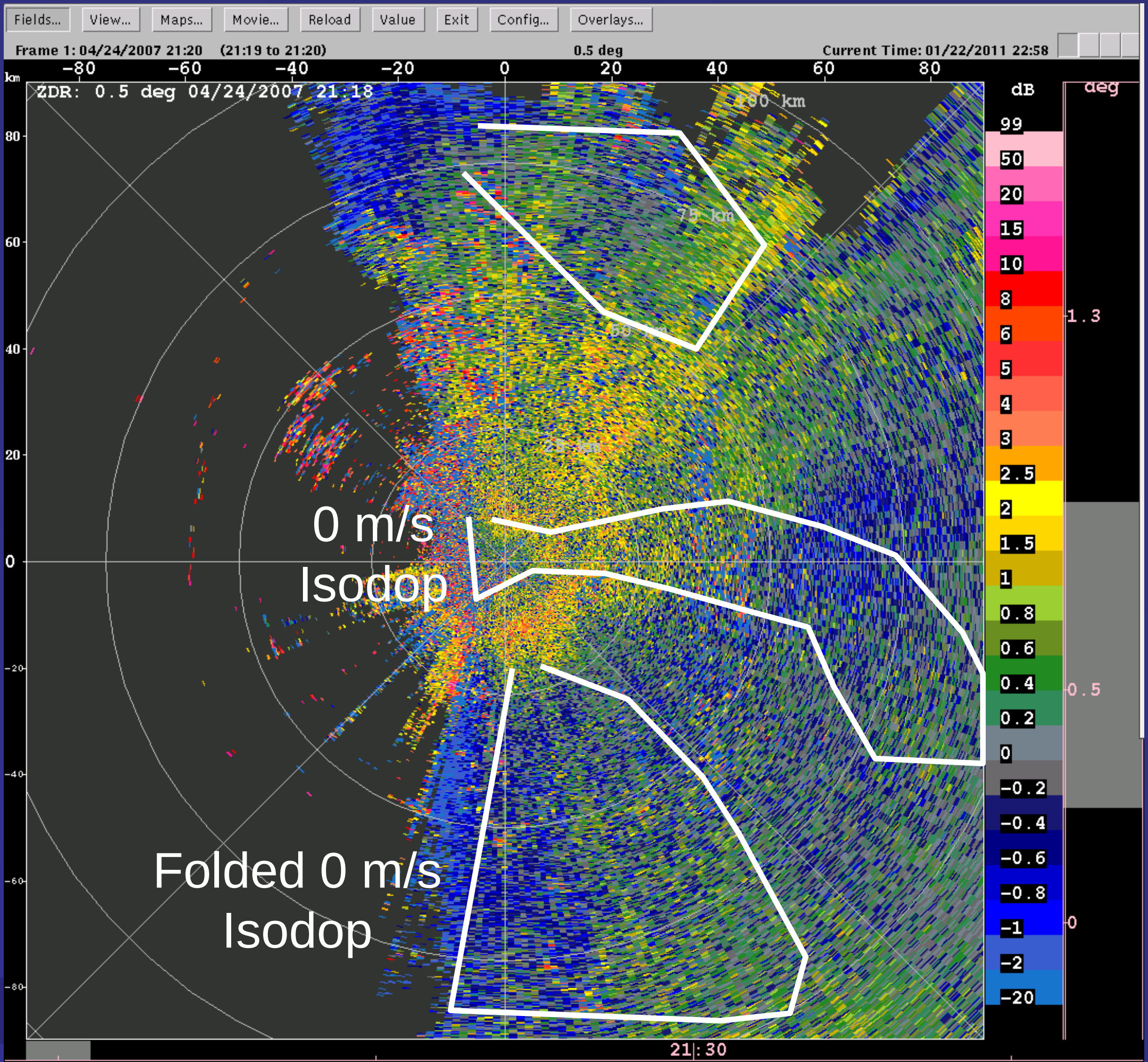
- Dual-pol CMD is similar architecture to the single pol version
- Two additional inputs
  - Standard deviation of $Z_{DR}$
  - Standard deviation of $\Phi_{DP}$
- New dual-pol variables improve CMD performance
  - Detect clutter contamination at lower CSR values
  - Fewer false alarms
  - Fewer missed detections
- Ready for implementation and testing on WSR-88D
- AEL delivered to ROC

# Thanks for your attention

Questions?

hubbert@ucar.edu

# S-Pol Unfiltered ZDR



# S-Pol ZDR Filtered on CMD