CMD: Improvements and Transition to Dual Polarization

NEXRAD Technical Advisory Committee Meeting
Norman, OK

7-9 March 2011

Scott Ellis, Mike Dixon, John Hubbert, and Greg Meymaris

National Center for Atmospheric Research
Boulder, Colorado
(hubbert@ucar.edu)
Presentation Overview

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

(a) Power spectrum (dB)
(b) Time series power (dBm)
(c) Time series phase (deg.)
(d) Time series, imaginary part
(e) Time series, real part
Doubled Peaked Spectra

• What type of ground clutter target would cause a “null” at zero velocity?
Two Dominant Clutter Targets

Model

180° phase difference

256 \( a_i \) scattering centers

antenna beam

192 discrete points

3 degrees width
Simulated Double Peaked Spectrum

• Quite rare
• Two dominant targets
• 180 degree phase shift difference between the two targets
Time Series
Magnitude and Phase

Graphs showing magnitude and phase over a range of indices.
How to Identify Such Targets as Clutter?
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
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

Old Membership Function

<table>
<thead>
<tr>
<th>Interest Value</th>
<th>CPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Feature Value

- (0.6, 0)
- (0.75, 0)
- (0.9, 1)
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
CMD Flag: Old versus New

With legacy CPA calculation

New CPA calculation
KFTG – Filtered DBZ and VEL with latest CPA

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

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

IF not, set CMD_flag at center gate to FALSE

<table>
<thead>
<tr>
<th>Weight</th>
<th>Forward</th>
<th>Reverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/6</td>
<td>1/5</td>
<td>1/4</td>
</tr>
<tr>
<td>1/3</td>
<td>1/2</td>
<td>1/1</td>
</tr>
<tr>
<td>1/2</td>
<td>?</td>
<td>1/1</td>
</tr>
<tr>
<td>1/3</td>
<td>1/4</td>
<td>1/5</td>
</tr>
<tr>
<td>1/6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMD flag</th>
<th>CMD val</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.95</td>
</tr>
<tr>
<td>1</td>
<td>0.85</td>
</tr>
<tr>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>1</td>
<td>0.60</td>
</tr>
<tr>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>1</td>
<td>0.40</td>
</tr>
<tr>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>1</td>
<td>0.65</td>
</tr>
<tr>
<td>1</td>
<td>0.49</td>
</tr>
<tr>
<td>1</td>
<td>0.80</td>
</tr>
<tr>
<td>1</td>
<td>0.48</td>
</tr>
<tr>
<td>1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

(Threshold = 0.35)
Proposed CMD flag speckle filter

- 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

• Adapted for dual-pol following Chandrasekar et al. 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 $V_r$, wx $W$
• Specified high SNR
Simulated $Z_{DR}$ bias versus clutter $Z_{DR}$ for various CSR

Weather $Z_{DR} = 1$ dB
New Dual-Pol Inputs: S-Pol Clear Scan

Reflectivity (dBZ)  Radial Velocity (m/s)
S-Pol Clutter/Weather Mixed

Reflectivity (dBZ)

Differential Reflectivity (dB)
S-Pol Clutter/Weather Mixed

Reflectivity (dBZ)

SD(ZDR)
S-Pol Clutter/Weather Mixed

Reflectivity (dBZ)

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

Normalized Histograms

- Clutter
- Weather
- Membership Function
Normalized Histograms of SD(ZDR) in Clutter Mixed with weather at various CSR values

Membership Function
Mean ZDR bias (dB) in mixed weather and clutter: $-8 > \text{CSR} > -10$ (dB)
Histograms of $\text{SD}(\Phi_{DP})$ in pure weather and clutter.
Normalized Histograms of SD(PHIDP) in Clutter Mixed with weather at various CSR values

Membership Function
Mean ZDR bias (dB) in mixed weather and clutter: $-8 > \text{CSR} > -10$ (dB)

<table>
<thead>
<tr>
<th>Mean ZDR bias</th>
<th>0.06</th>
<th>0.19</th>
<th>1.0</th>
<th>1.32</th>
<th>1.69</th>
</tr>
</thead>
</table>

-4 to -6
-2 to -4
0 to -2

Normalized histogram of CSR values.
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
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

0 m/s Isodop
Folded 0 m/s Isodop
S-Pol Example: dBZ Filtered All Bins

0 m/s Isodop

Folded 0 m/s Isodop
CMD Performance

- Dual-polarimetric 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 $Z_{\text{DR}}$
  – Standard deviation of $\Phi_{\text{DP}}$

• 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

0 m/s Isodop

Folded 0 m/s Isodop
S-Pol ZDR Filtered on CMD

0 m/s Isodop

Folded 0 m/s Isodop