Scan-to-Scan Correlation of Weather Radar Signals to Identify Ground Clutter

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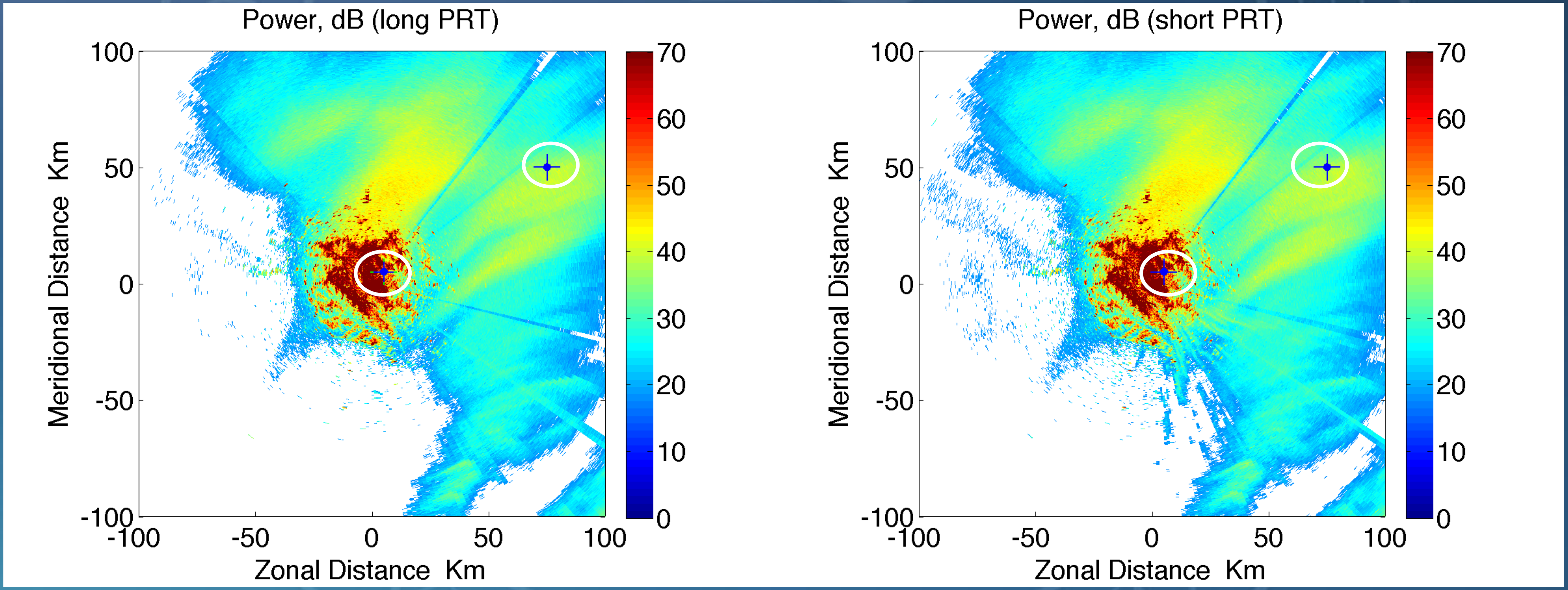
Examples

Two scans. Data were collected by KOUN on 14:02 UTC Feb 9th 2011 at 0.5°.

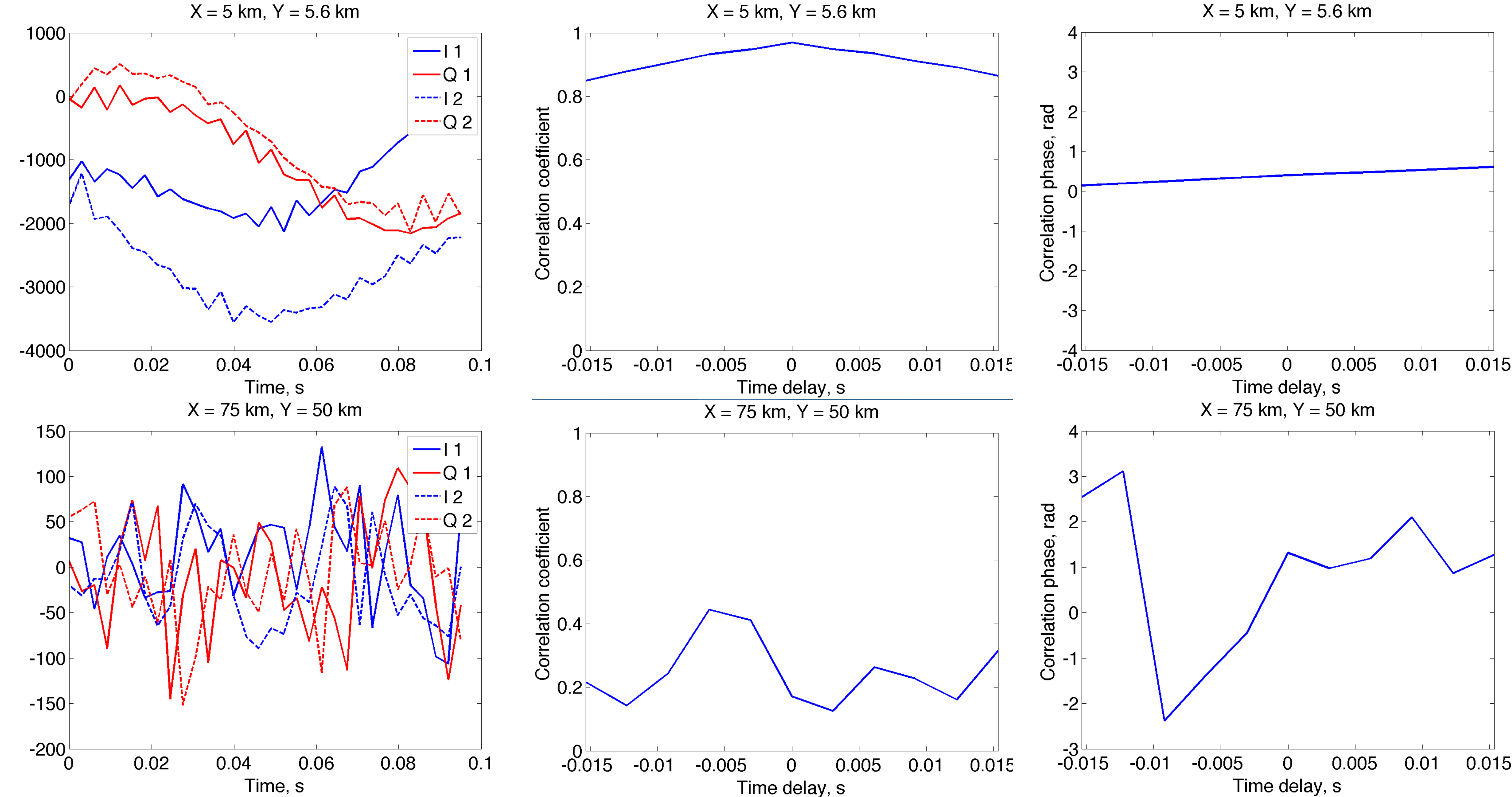


Left panel: PRT1=3.1 ms, 32 pulses

Right panel: PRT2 = 0.97 ms, 90 pulses

Examples (cont'd)

- Clutter vs. Weather



Overview

- Existing Ground Clutter Detection Algorithms
- Statistical Properties of the Discriminants
- *Bayes* Classifier and Implementation Procedures
- Performance Evaluation
- Summary and Future Work

Existing Algorithms

- Current Ground Clutter Detection Methods (Single-pol)
  1. Static Clutter Map (Clear-Air Condition)
  2. Three-Dimensional Reflectivity Structure (SPIN, Steiner and Smith 2002)
  3. CMD Algorithm (CPA, TDBZ, SPIN, J. Hubbert et al. 2009)
  4. CLEAN-AP (Combined with a filter, Warde and Torres 2010)
  5. Multipattern Technique (PAR, Moving Targets, Zhang et al. 2011)
  6. SCI Algorithm (SPD, SPF, PT, SWT, low CSR, Li et al. 2012)

Definition of Scan-to-Scan Correlation

- The complex correlation coefficient between two adjacent scans:

$$\tilde{\rho}_{12}(\tau) = \frac{\langle x_1(t+\tau)x_2^*(t)\rangle}{\langle |x_1(t)|^2\rangle^{\frac{1}{2}}\langle |x_2(t)|^2\rangle^{\frac{1}{2}}} = \rho_{12}(\tau)\exp[j\varphi_{12}(\tau)]$$

$\rho_{12}(\tau)$: Correlation Coefficient

$\varphi_{12}(\tau)$: Correlation Phase

Definition of Discriminants

- Two Discriminants:
  1. Correlation Coefficient Mean (CCM)

$$\mathrm{CCM}=\langle\rho_{12}(-\Delta\tau:\Delta\tau)\rangle$$
$$\Delta\tau = 3Ts1$$

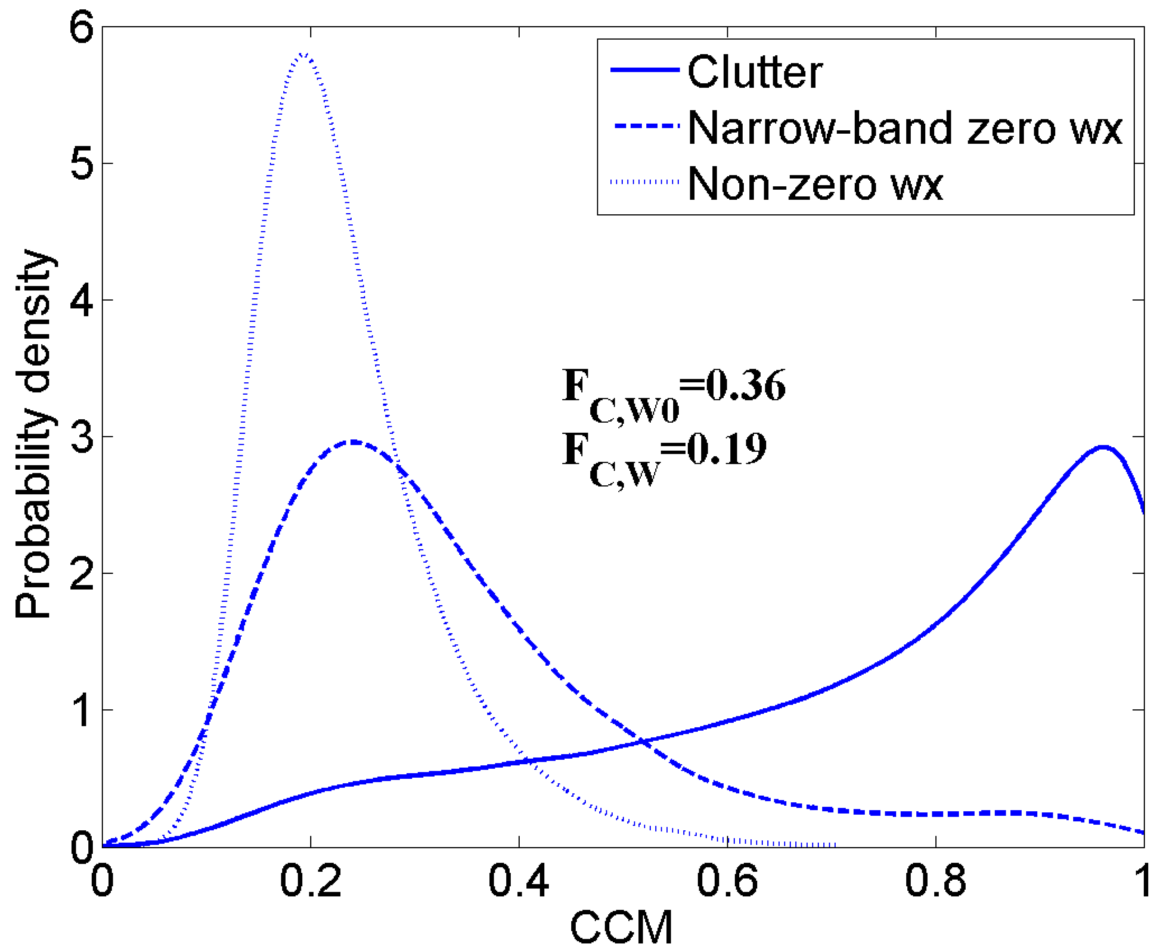
  2. Correlation Phase Fluctuations (CPF)

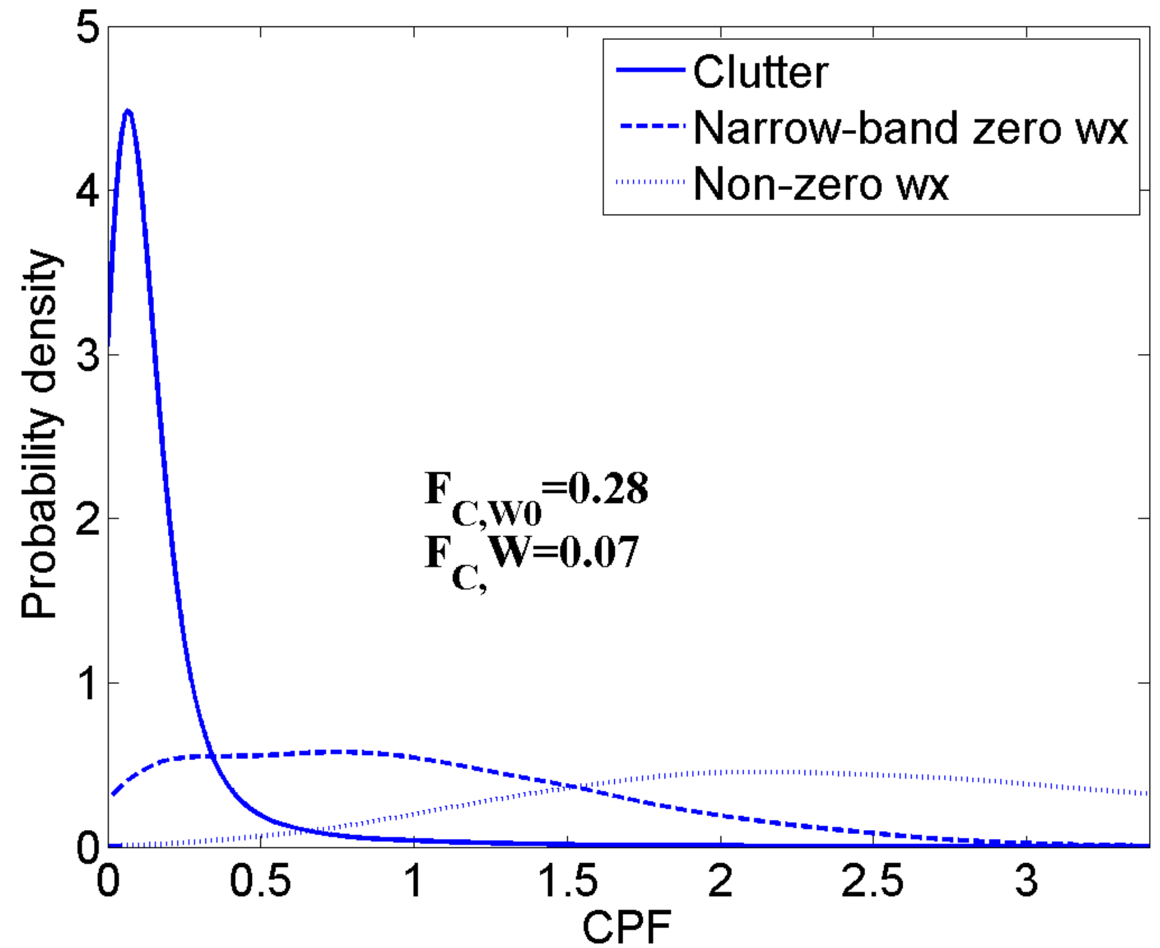
$$CPF = SD[\varphi_{12}(-\Delta\tau:\Delta\tau)]$$

Statistical Properties of the Discriminants (cont'd)

- The conditional probability density functions (pdfs) of CCM and CPF given ground clutter and weather signals are needed and they are essential to the *Bayes* classifier.
- But how to obtain the true class labels?
  - Using the CMD algorithm. A CMD code, CMD AEL V4.1, received from the ROC is used to create the algorithm.

Statistical Properties of the Discriminants (cont'd)



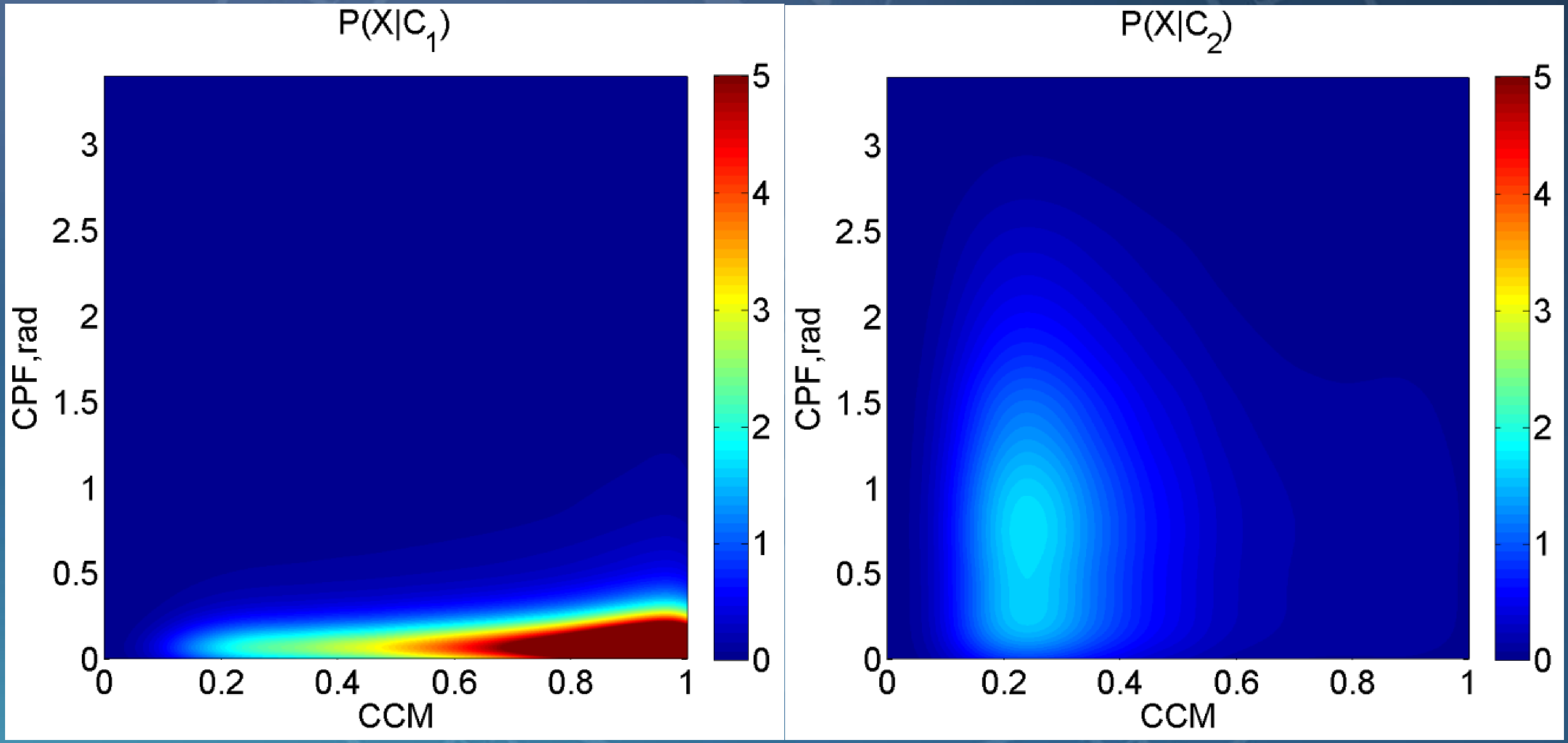


Narrow-band Zero wx: $|v_r|<2$ m s^{-1} and $\sigma_v<2$ m s^{-1}

Non-zero wx: $|v_r|>2$ m s^{-1}

Statistical Properties of the Discriminants (cont'd)

- Conditional Joint PDF



P($\mathbf{X}$|C_1): Conditional joint PDF given clutter (C_1)

P($\mathbf{X}$|C_2): Conditional joint PDF given narrow-band zero wx (C_2)

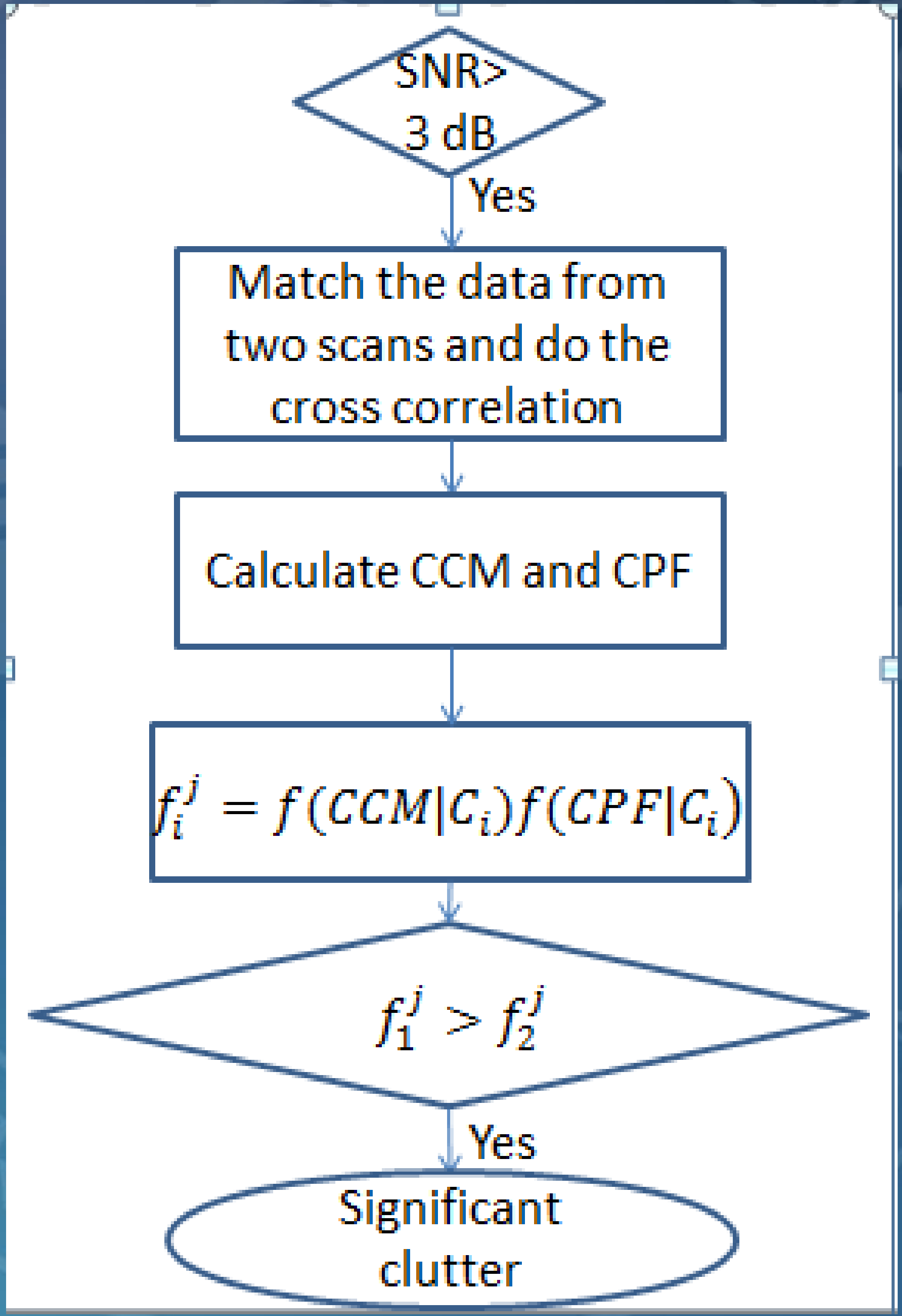
Bayes Classifier

- Two classes:
  - $C1$: clutter
  - $C2$: narrow-band zero-velocity weather signals
- Two attributes:
  - $X1$: CCM
  - $X2$: CPF
  - $\boldsymbol{X} = (X1, X2)$
- How to determine if a gate is contaminated by GC?
  - $P(C_1|\boldsymbol{X}) > P(C_2|\boldsymbol{X})$
- How to obtain $P(C_\mathrm{i}|\boldsymbol{X})$?

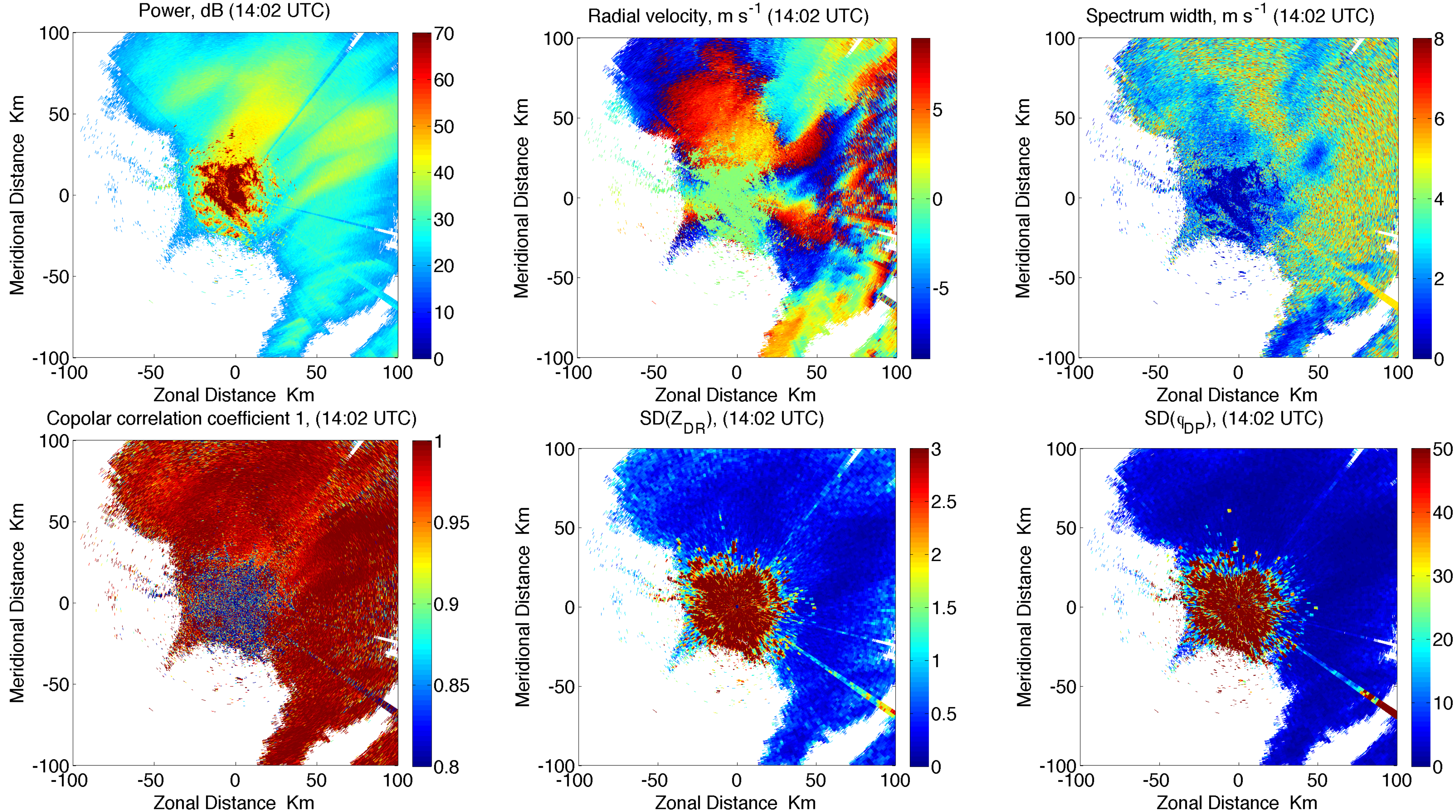
***Bayes* Classifier (cont'd)**

- *Baye's* Theorem:
  - $P(C_i|\boldsymbol{X}) = \frac{P(\boldsymbol{X}|C_i)P(C_i)}{P(\boldsymbol{X})}$
- $P(C_i|\boldsymbol{X}) \propto P(\boldsymbol{X}|C_i)$ if every class is equal likely to happen.
- $P(\boldsymbol{X}|C_i) = P(x_1|C_i)P(x_2|C_i)$ because CCM and CPF are conditionally independent given class label C_i.
- $P(x_1|C_i)$ and $P(x_2|C_i)$ can be obtained from training data (ground truth).

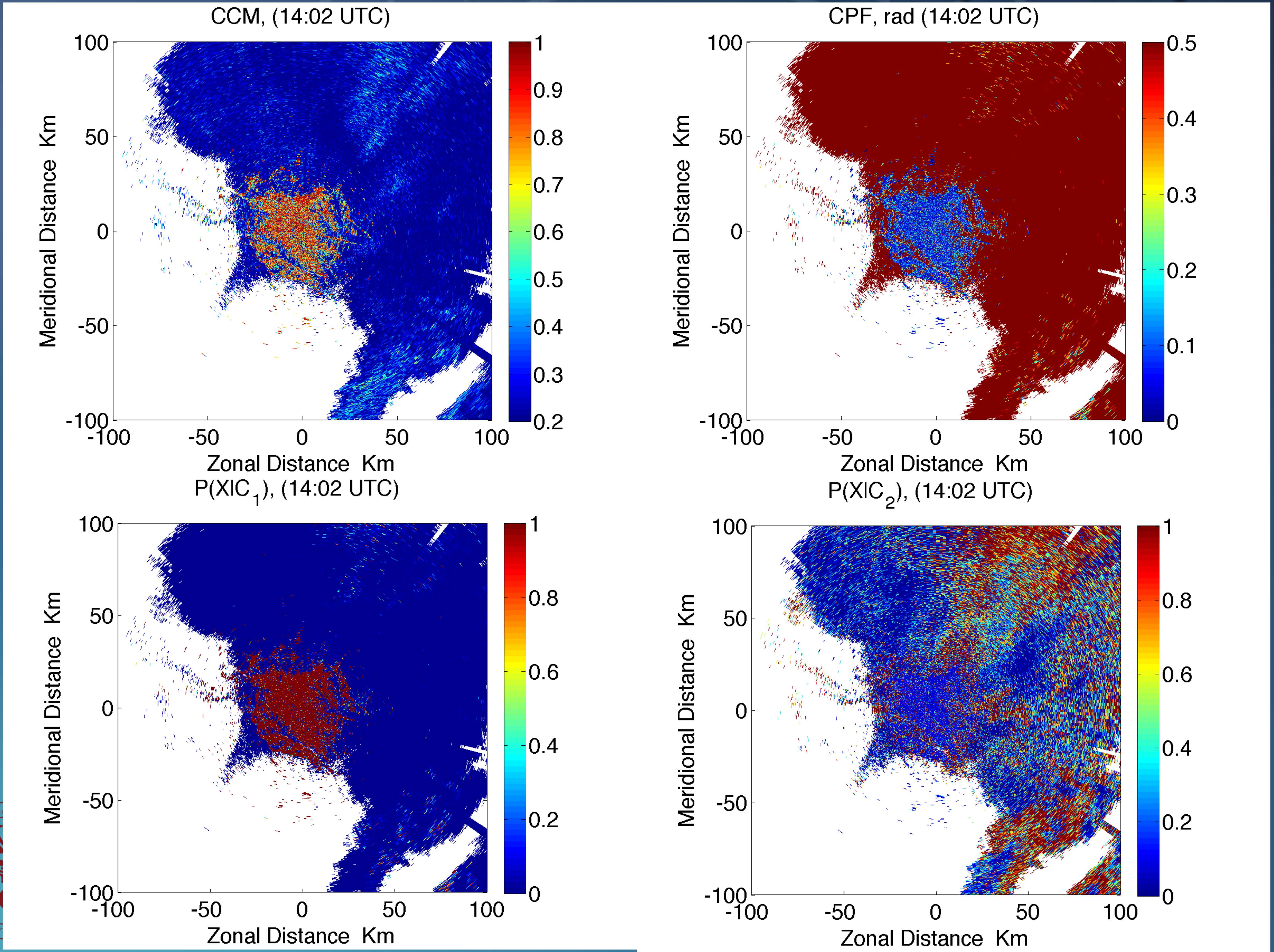
Implementation Procedures



Performance Evaluation

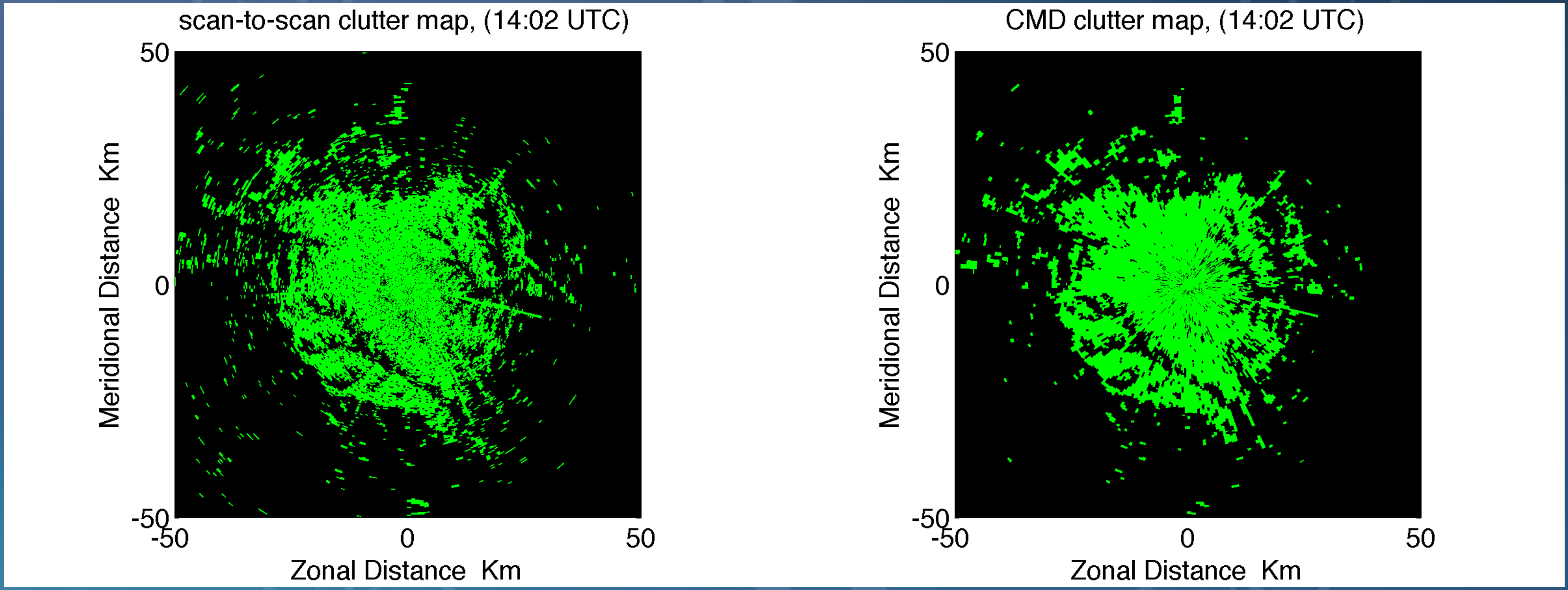


Performance Evaluation (cont'd)



Performance Evaluation (cont'd)

- Scan-to-Scan vs. CMD



Summary and Future Work

- A scan-to-scan correlation technique is introduced which combines two discriminants: CCM and CPF using *Bayes* classifier.
- The statistical properties of CCM and CPF are studied by exploring data collected by KOUN S-band dual-pol radar.
- No spatial texture information is needed.
- Quantitative evaluation of the scan-to-scan correlation technique (e.g., POD as a function of CSR) will be done in the future based on a well-controlled data set.

QUESTIONS?