Hybrid-Scan Estimators:
Using **split cut** data to **improve** the quality of polarimetric variables

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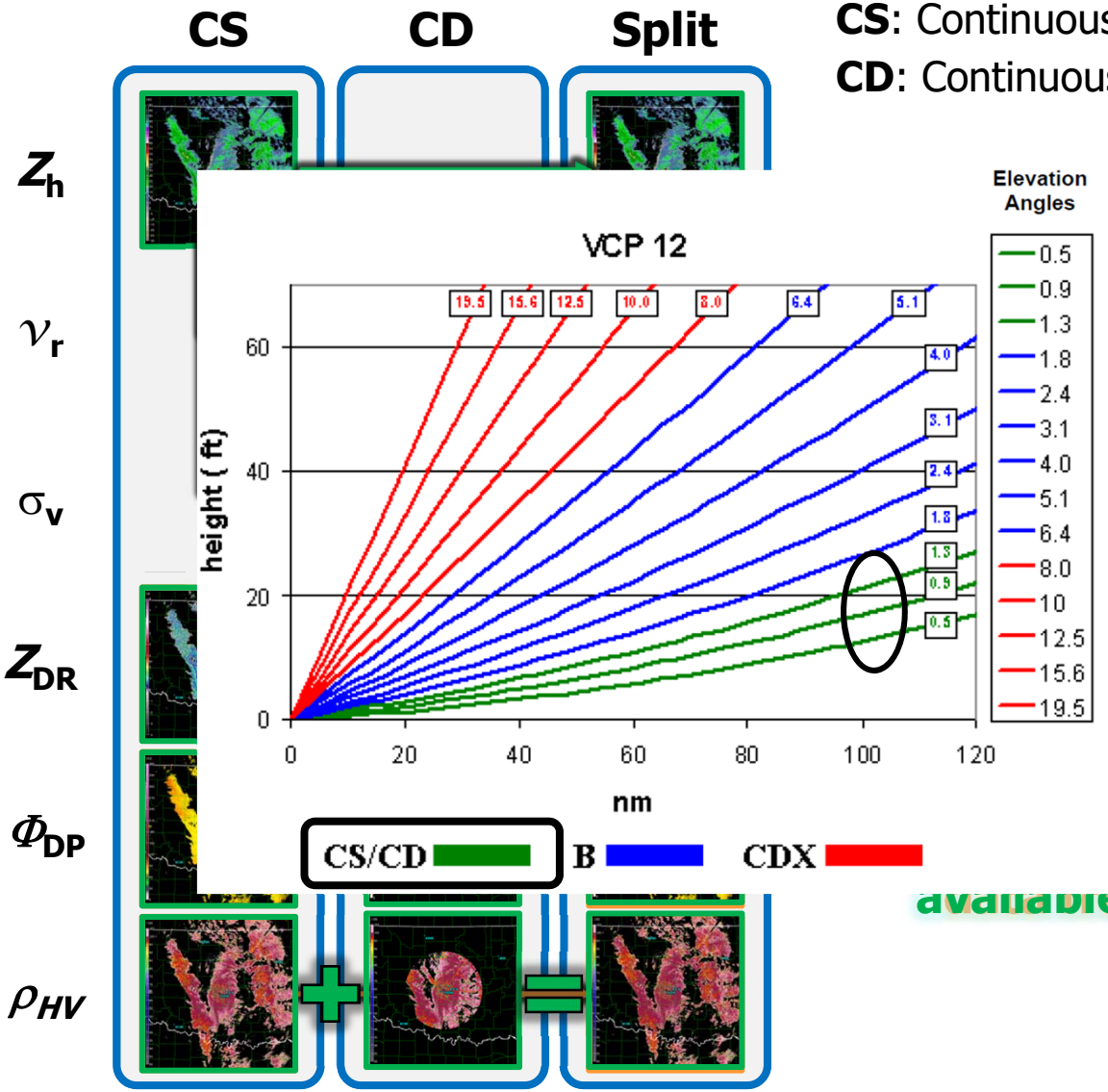
CIMMS/The University of Oklahoma
and National Severe Storms Laboratory/NOAA

04/29/19

Exploiting split-cuts to improve DQ

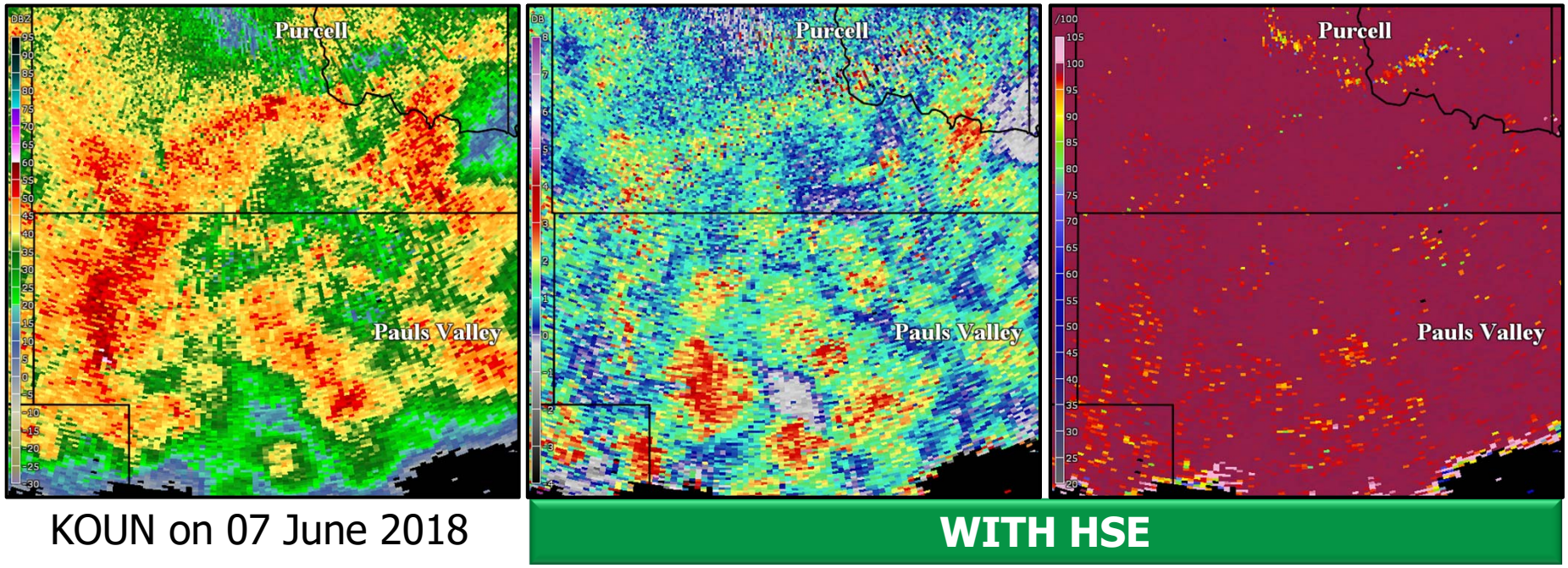
WSR-88D

CS: Continuous Surveillance
CD: Continuous Doppler



DQ from
available data!

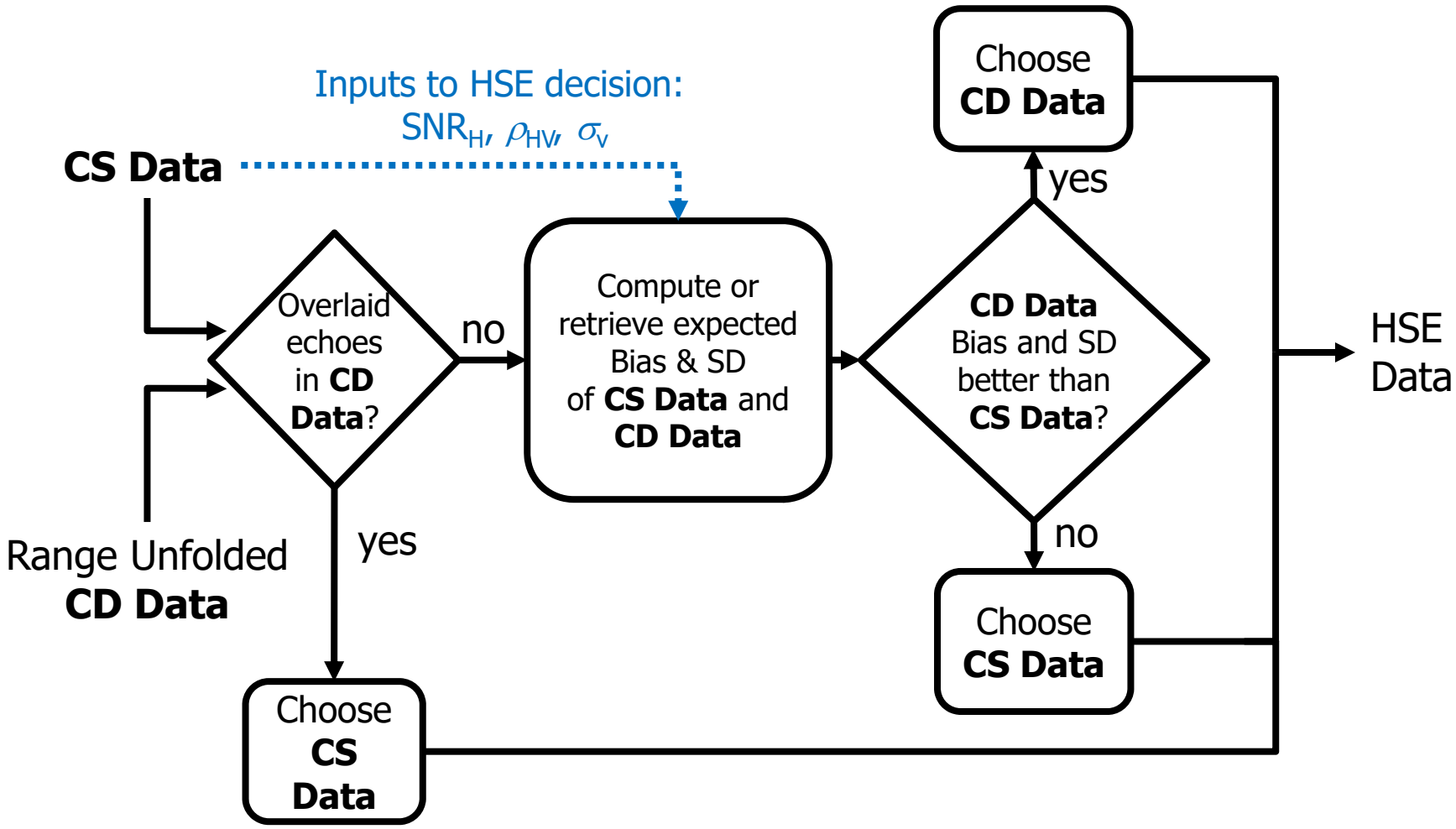
Hybrid Scan Estimators (HSE)



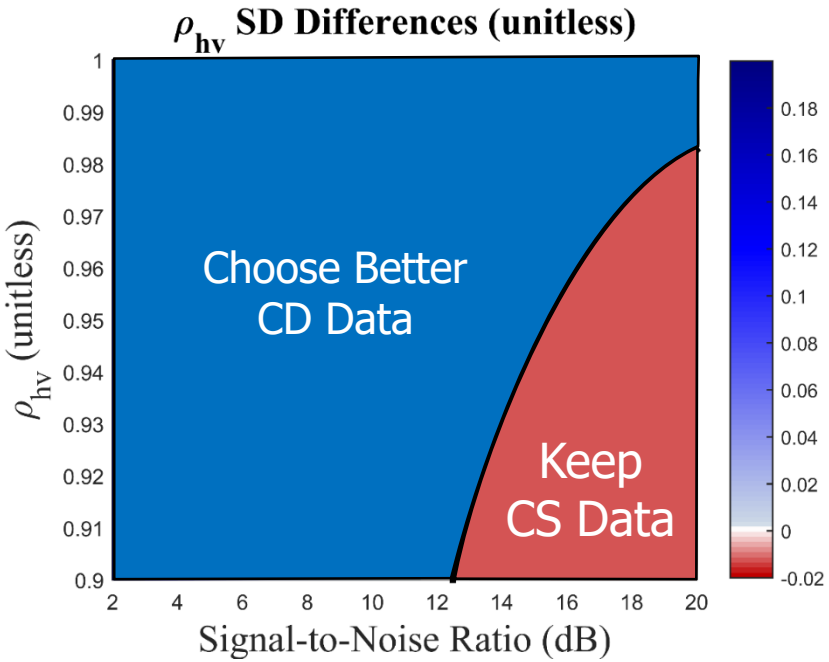
Percentage of gates improved: Z_{DR} → **40%**, Φ_{DP} → **45%**, ρ_{HV} → **26%**

The quality of polarimetric data **can be improved** by carefully **choosing** the **better estimate** between the Surveillance and Doppler scans

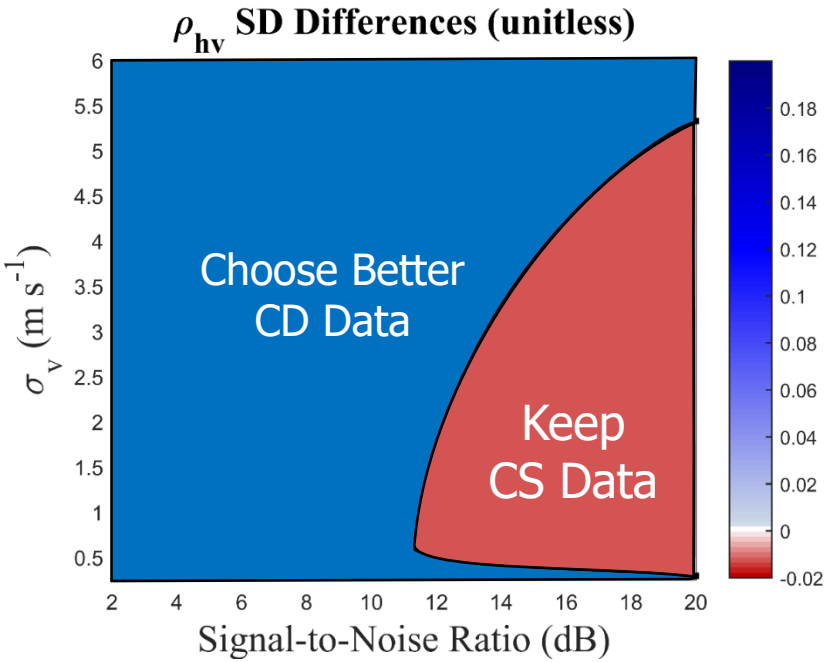
How does HSE choose better data?



HSE Decision (CS or CD?)



σ_v = 2 m/s, Z_{DR} = 0 dB (0.5° VCP 12)

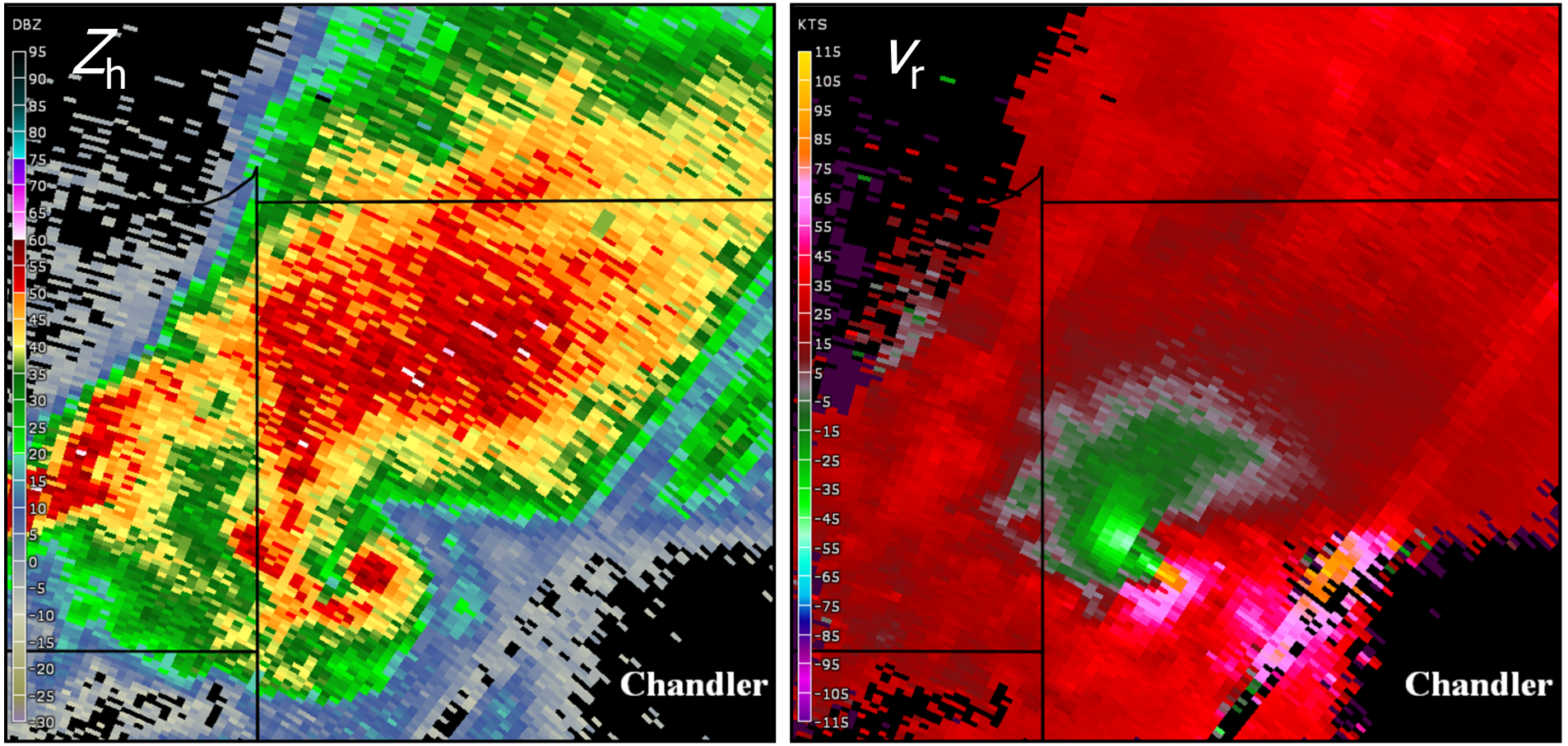


ρ_{HV} = 0.90, Z_{DR} = 0 dB (0.5° VCP 12)

The **HSE** processing **improves** over conventional processing in regions of **low-to-medium SNR** (~0-10 dB) **or relatively high** ρ_{HV} **or wide** σ_v

Case 1: Convective Storms (Supercell)

KCRI - VCP212 @ 0.9° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)

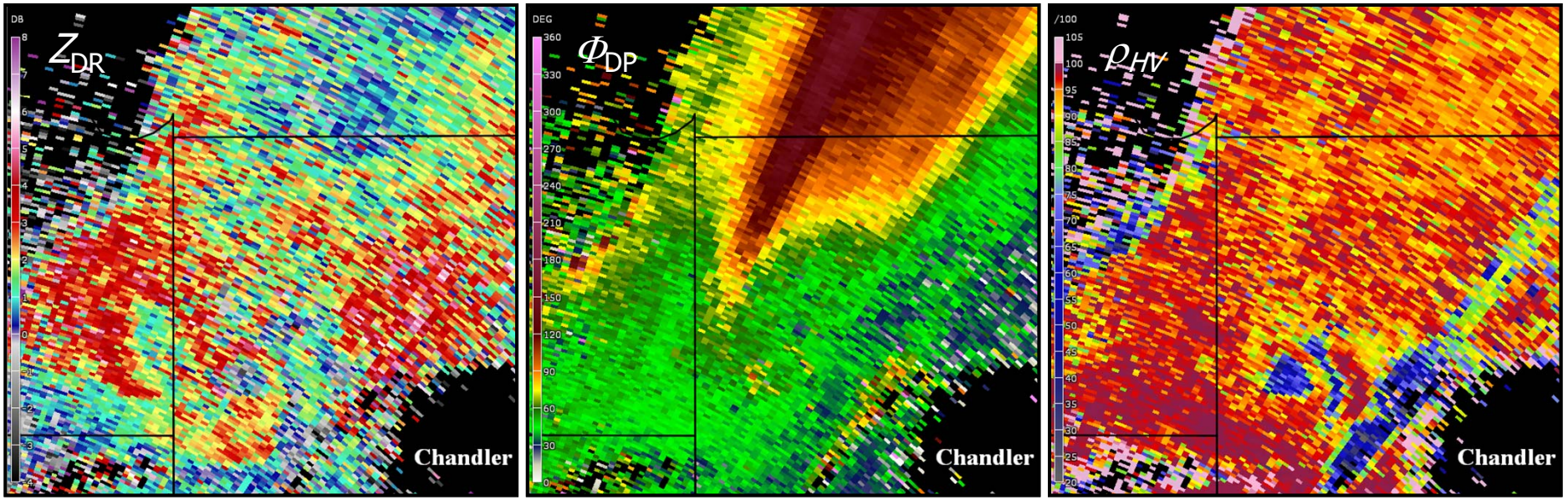


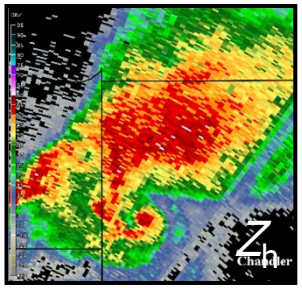
NWS Reported: "Seven tornadoes occurred in central Oklahoma on May 19th, 2013. These tornadoes were spawned from two supercell thunderstorms. The Norman-Shawnee tornado was rated **EF-4**."

Case 1: Convective Storms (Supercell)

KCRI - VCP212 @ 0.9° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)

WITH HSE



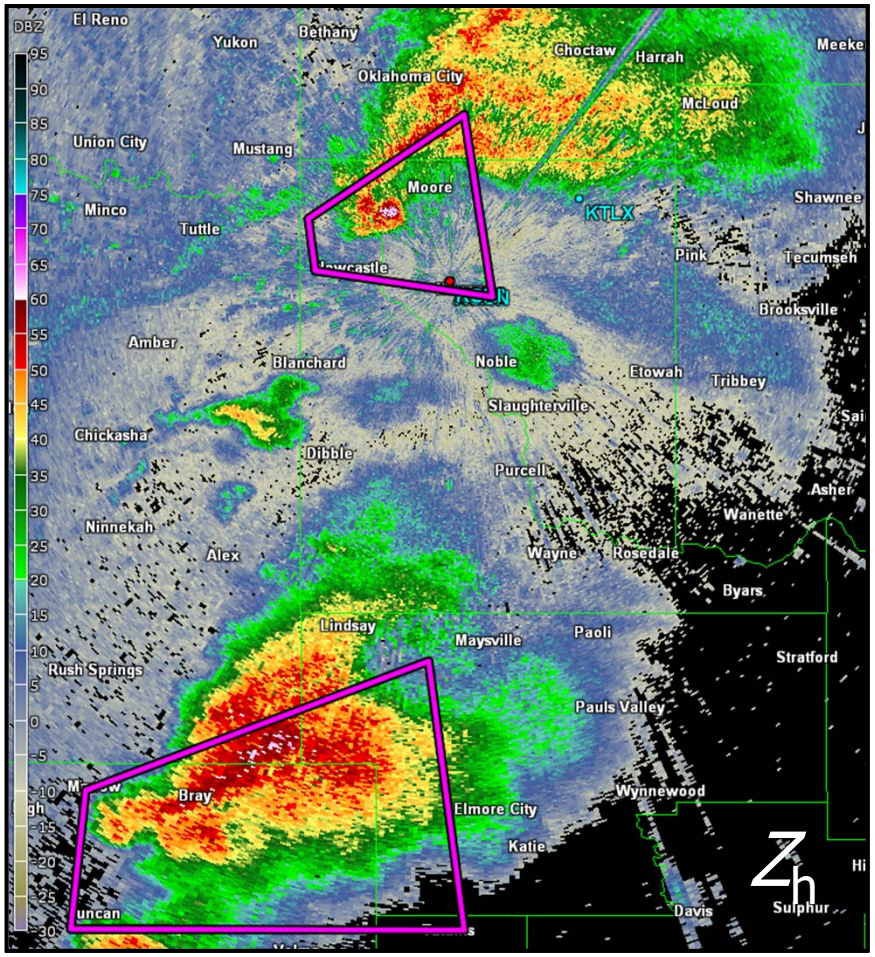


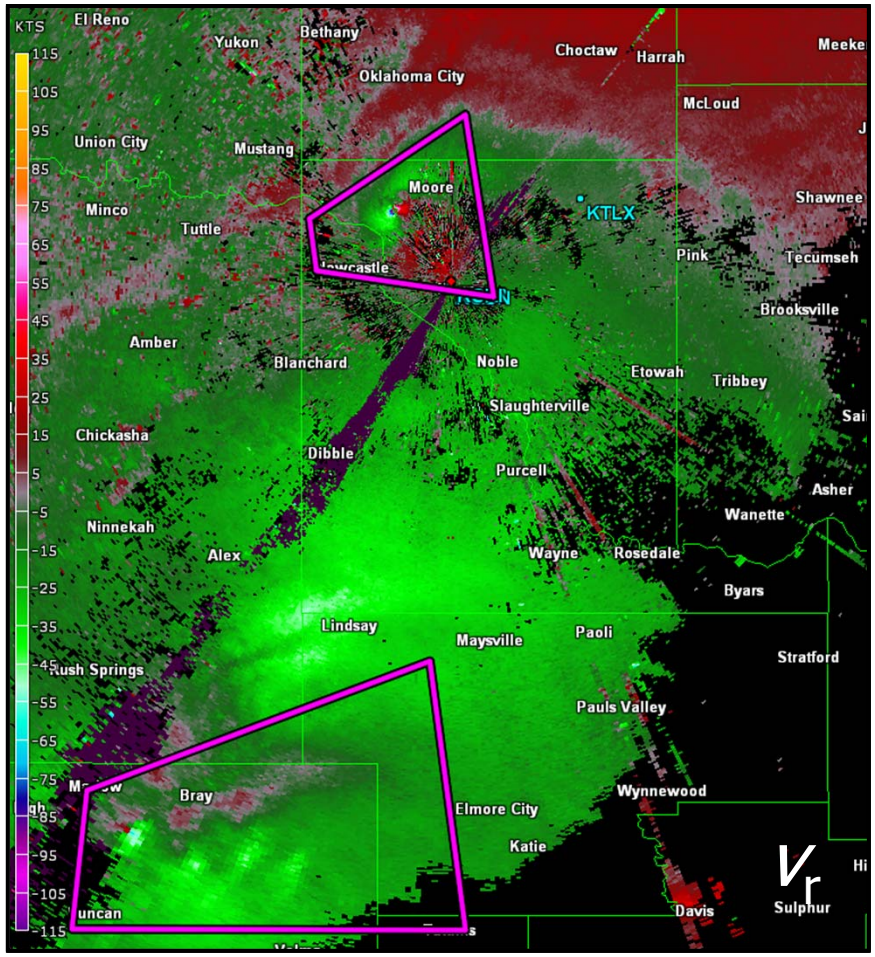
Improvement: Z_{DR} → **65%**, Φ_{DP} → **65%**, ρ_{HV} → **43%**

Percentage of ρ_{HV} **invalid** to **valid** → **20%**

Case 2: Convective Storms (Supercell)

KCRI - VCP212 @ 0.5° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)



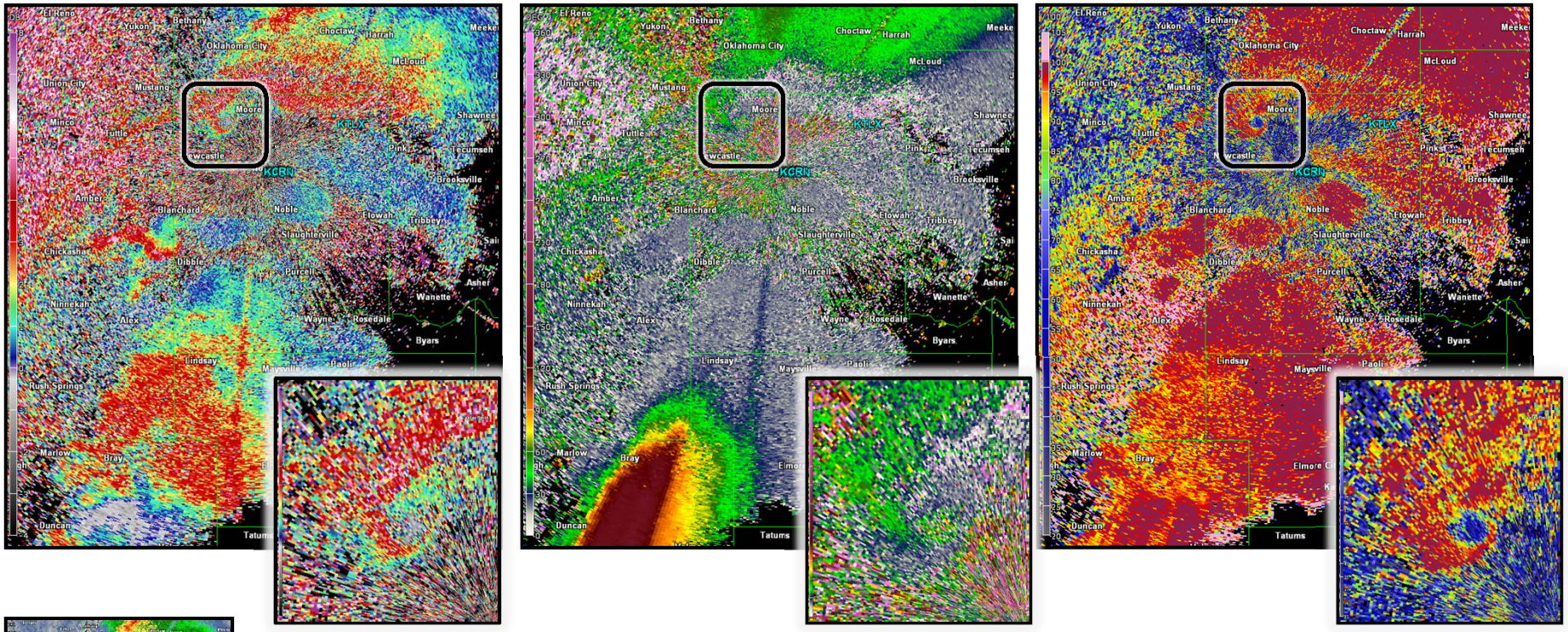


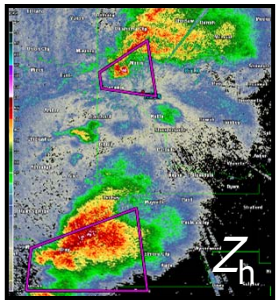
NWS Reported: A tornado outbreak occurred during May 20, 2013. This event produced the ***most deadly and devastating*** tornado of the year for Oklahoma and the U.S.

Case 2: Convective Storms (Supercell)

KCRI - VCP212 @ 0.5° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)

WITH HSE



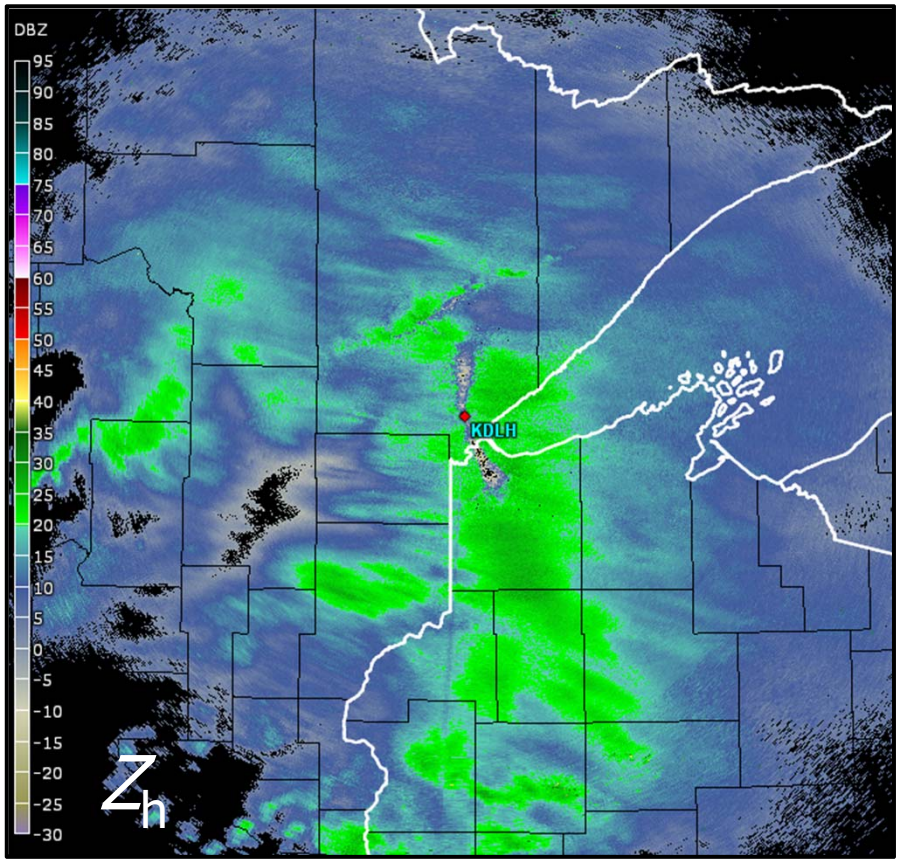


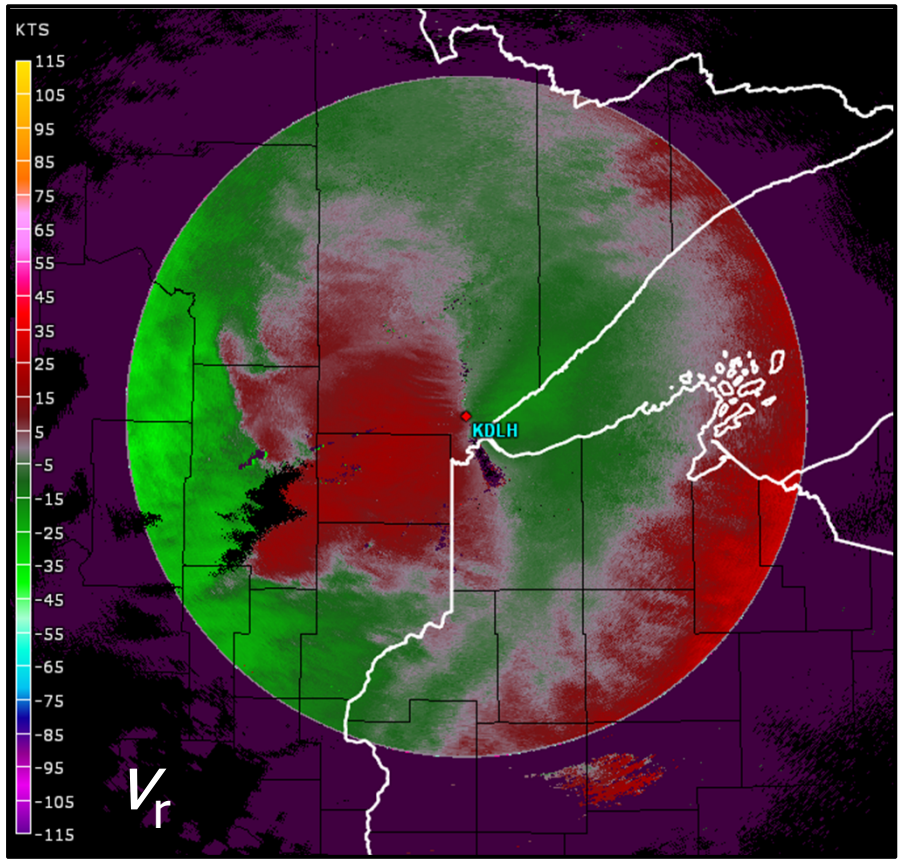
Improvement: Z_{DR} → **29%**, Φ_{DP} → **24%**, ρ_{hv} → **25%**

Percentage of ρ_{hv} **invalid** to **valid** → **21%**

Case 3: Widespread Snow Storm

KDLH – VCP32 @ 0.5° – CS 64 Pulses (3.1 ms) & CD 222 Pulses (0.98 ms)



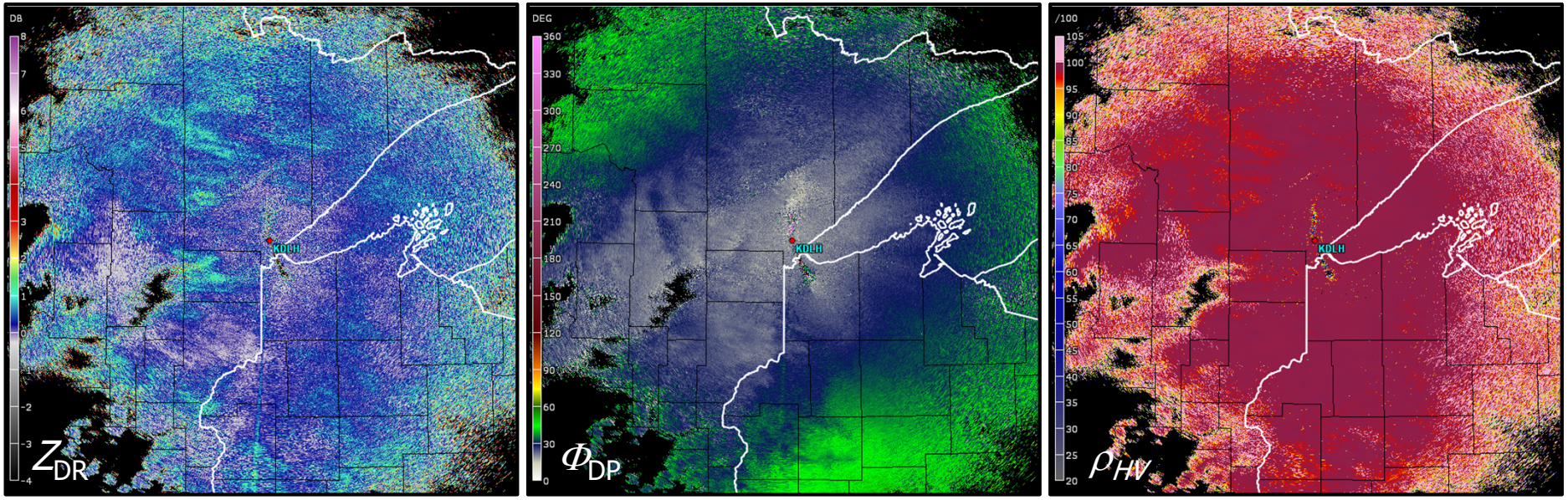


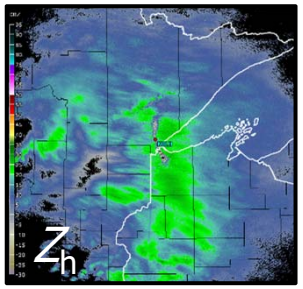
A widespread precipitation system that developed on March 16th of 2013 covered most of Minnesota and Wisconsin, producing a field of relatively low reflectivity (low SNR).

Case 3: Widespread Snow Storm

KDLH – VCP32 @ 0.5° – CS 64 Pulses (3.1 ms) & CD 222 Pulses (0.98 ms)

WITH HSE



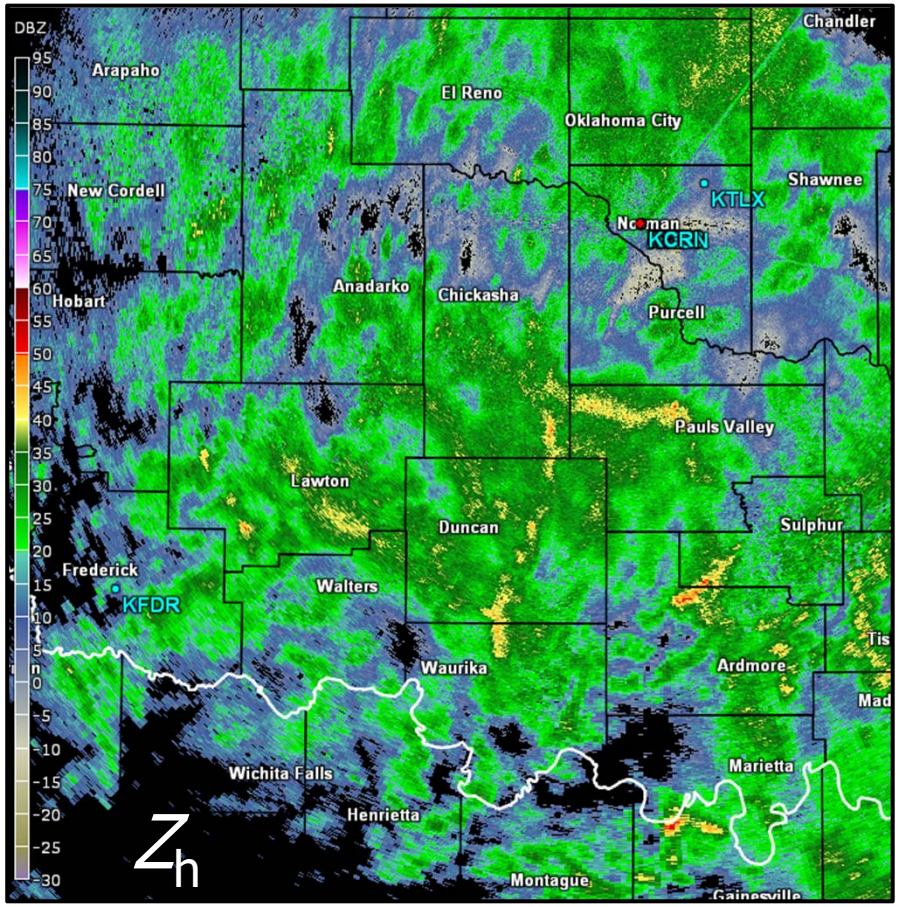


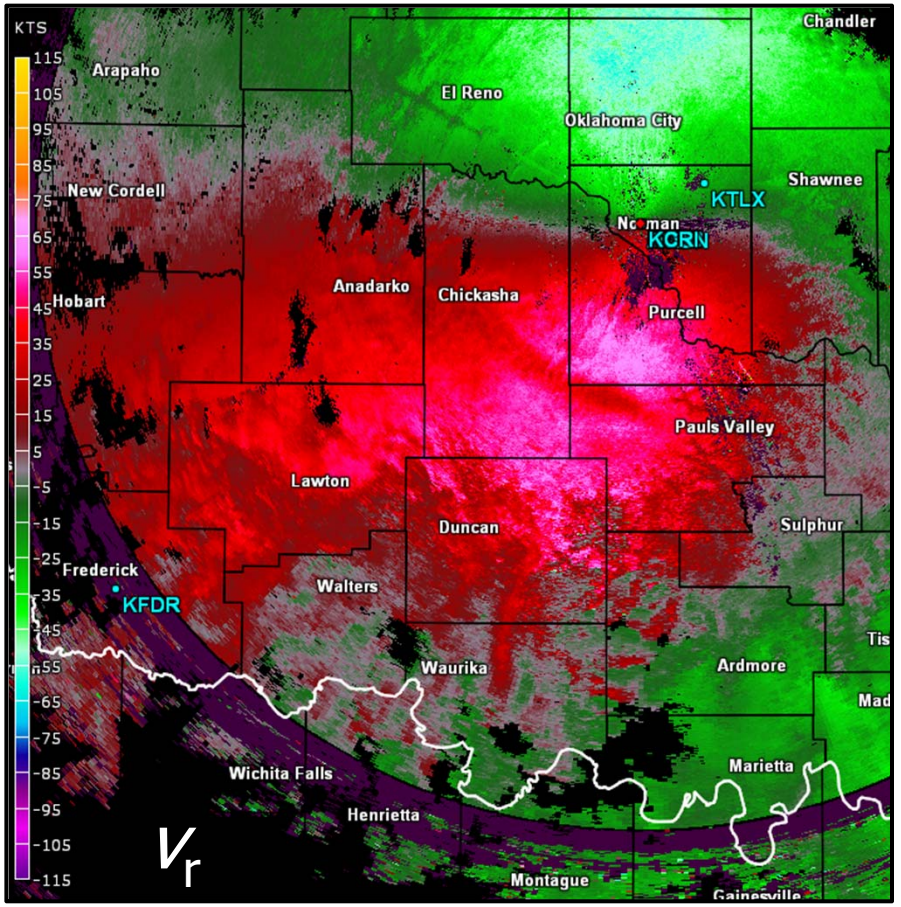
Improvement: Z_{DR} → 37%, Φ_{DP} → 32%, ρ_{hv} → 33%

Percentage of ρ_{hv} invalid to valid → 24%

Case 4: Widespread Light Rain

KOUN - VCP212 @ 0.5° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)



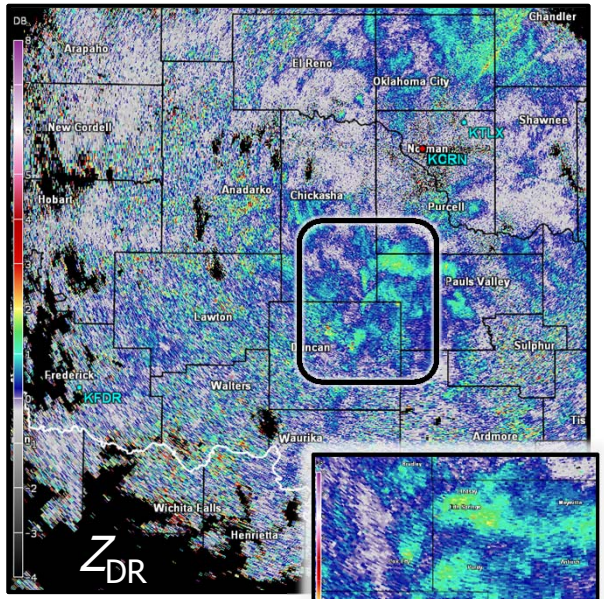


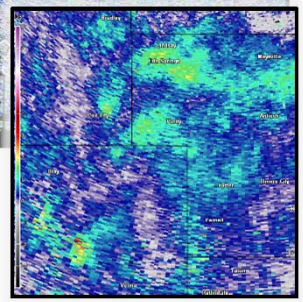
Widespread light precipitation covered most of the state on **December 13th, 2018**. The HSE are most effective on this type of weather (low-to-medium SNR).

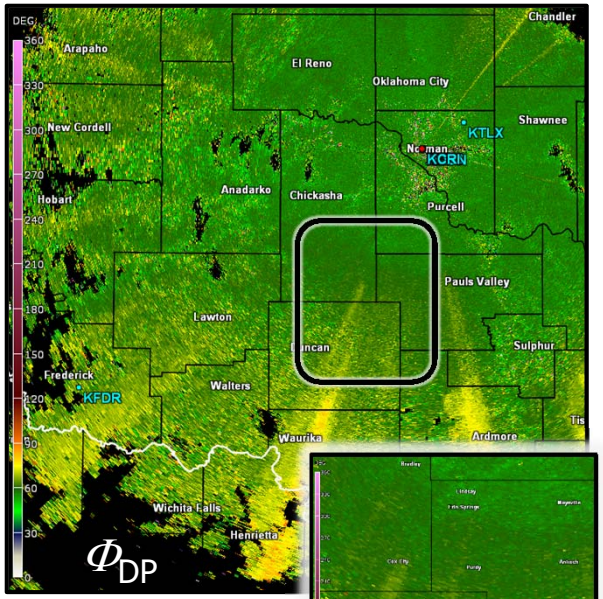
Case 4: Widespread Light Rain

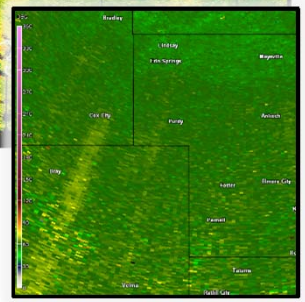
KOUN - VCP212 @ 0.5° – CS 15 Pulses (3.1 ms) & CD 64 Pulses (0.98 ms)

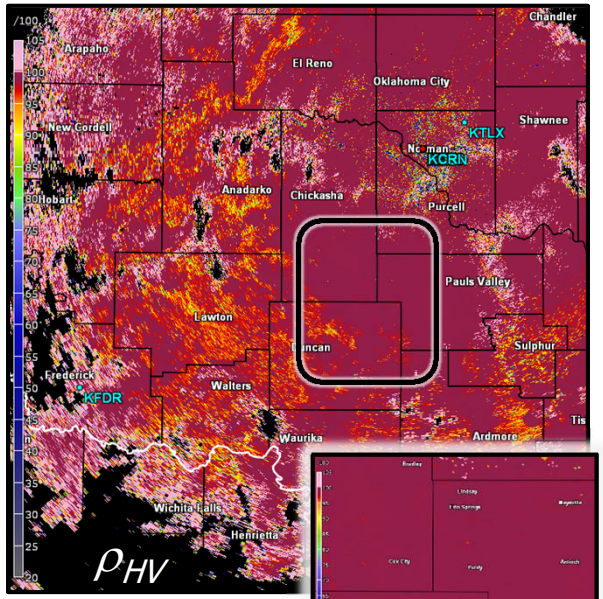
WITH HSE

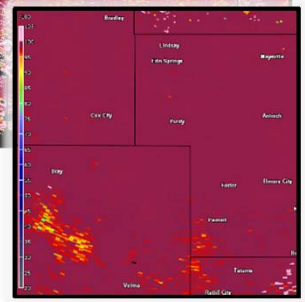


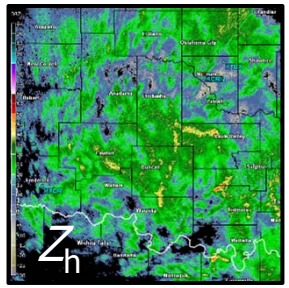












Improvement: Z_{DR} → 36%, Φ_{DP} → 31%, ρ_{hv} → 32%

Percentage of ρ_{hv} invalid to valid → 26%

Summary

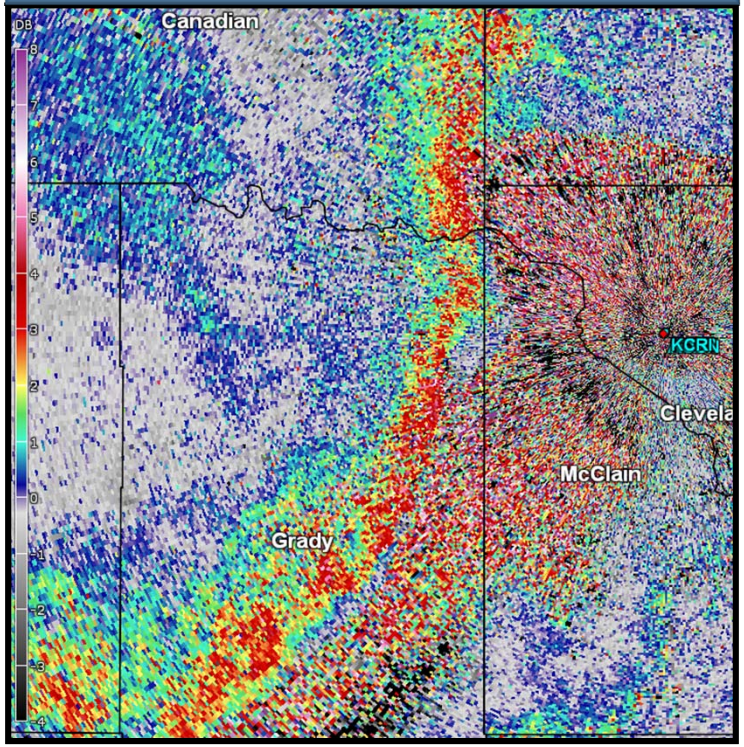
- The proposed technique is **simple** and uses **untapped data** in split cuts.
- The **"do no harm" decision** ensures that the HSE preserve or improve the quality of the polarimetric variables.
- Presented the HSE to the ROC DQ Team twice, resulting in improvements to technique.
- Processed a total of 84 cases to date; some were processed through the ORPG.
- The HSE **algorithm description** was provided to the ROC in our FY18 RPI MOU annual report.

Takeaway

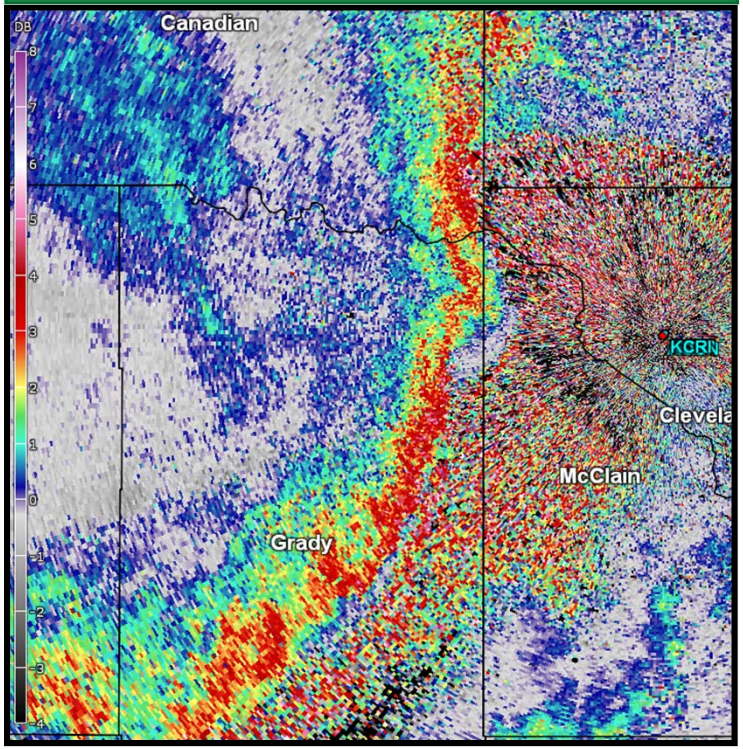
The quality of polarimetric data **can be improved** by carefully **choosing** the **better estimate** between the Surveillance and Doppler scans

KOUN Z_{DR} on 04 April 2019 05:35Z (VCP 212)

NO HSE



WITH HSE

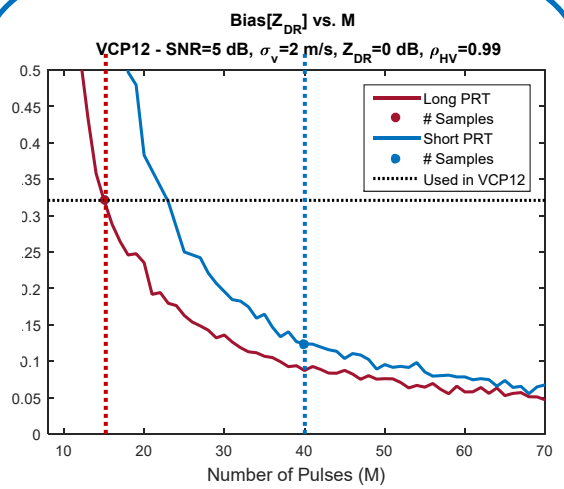


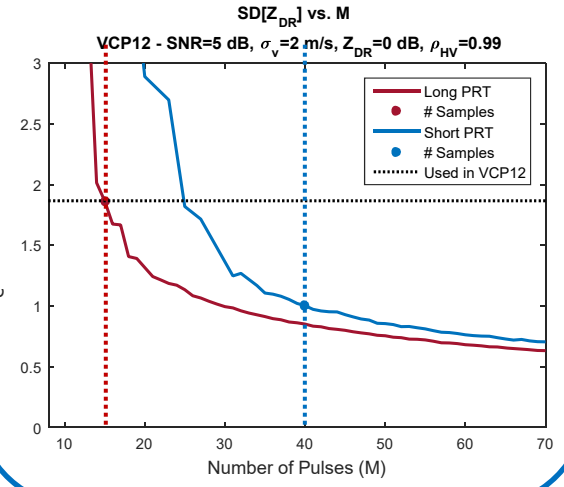
Statistics vs. Samples for VCP12

Simulation Parameters: SNR=5 dB, σ_v=2 m/s, ρ_{HV}=0.99, Z_{DR}=0 dB

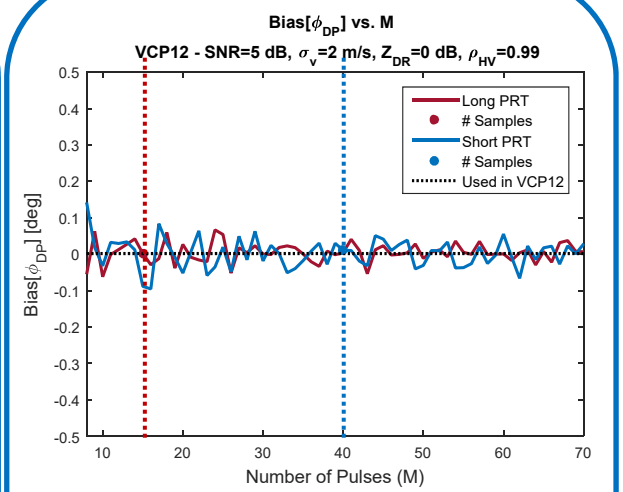
There may be something we can do for these (weather-like) conditions…

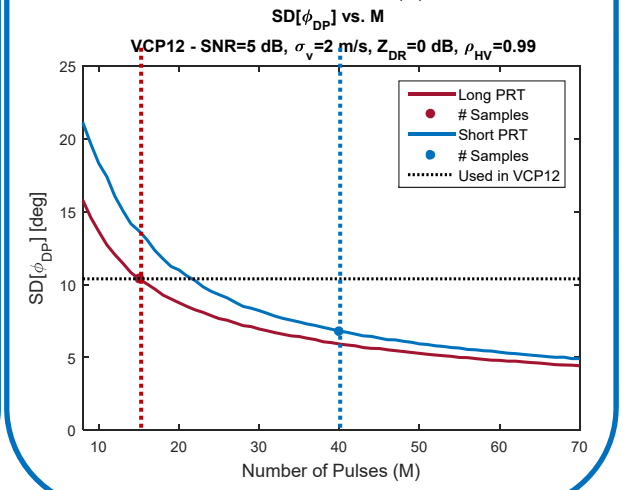
Z_{DR}



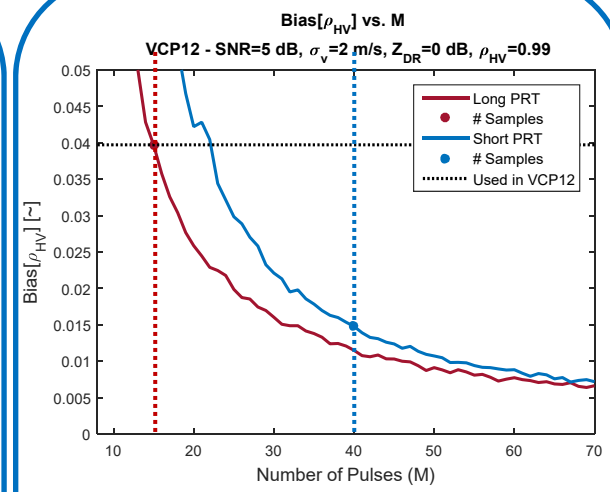


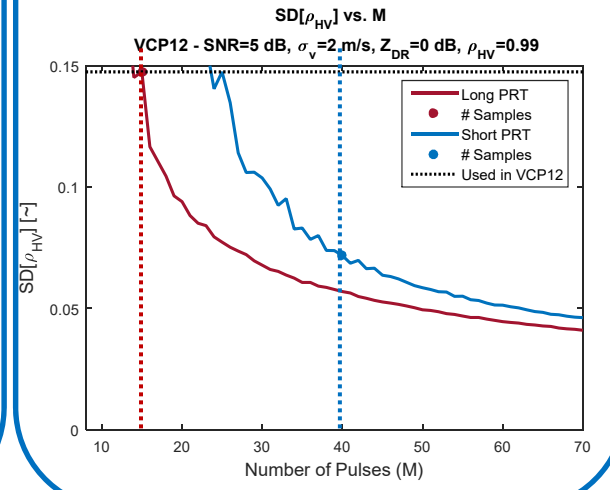
φ_{DP}





ρ_{HV}



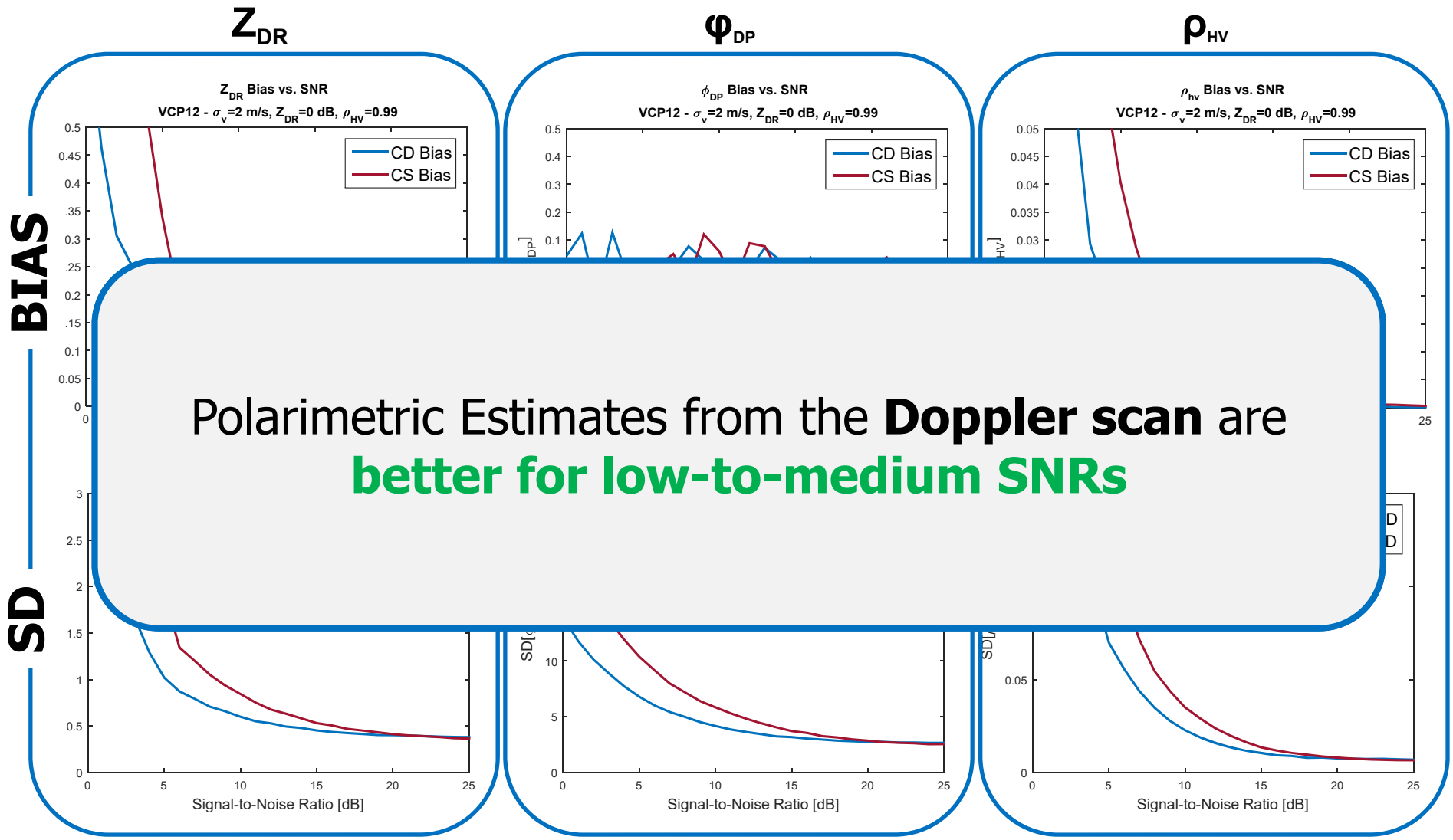


BIAS

SD

Statistics vs. SNR for VCP12

Simulation Parameters: M_{CS}=15, M_{CD}=40 (VCP12), σ_v=2 m/s, ρ_{HV}=0.99, Z_{DR}=0 dB

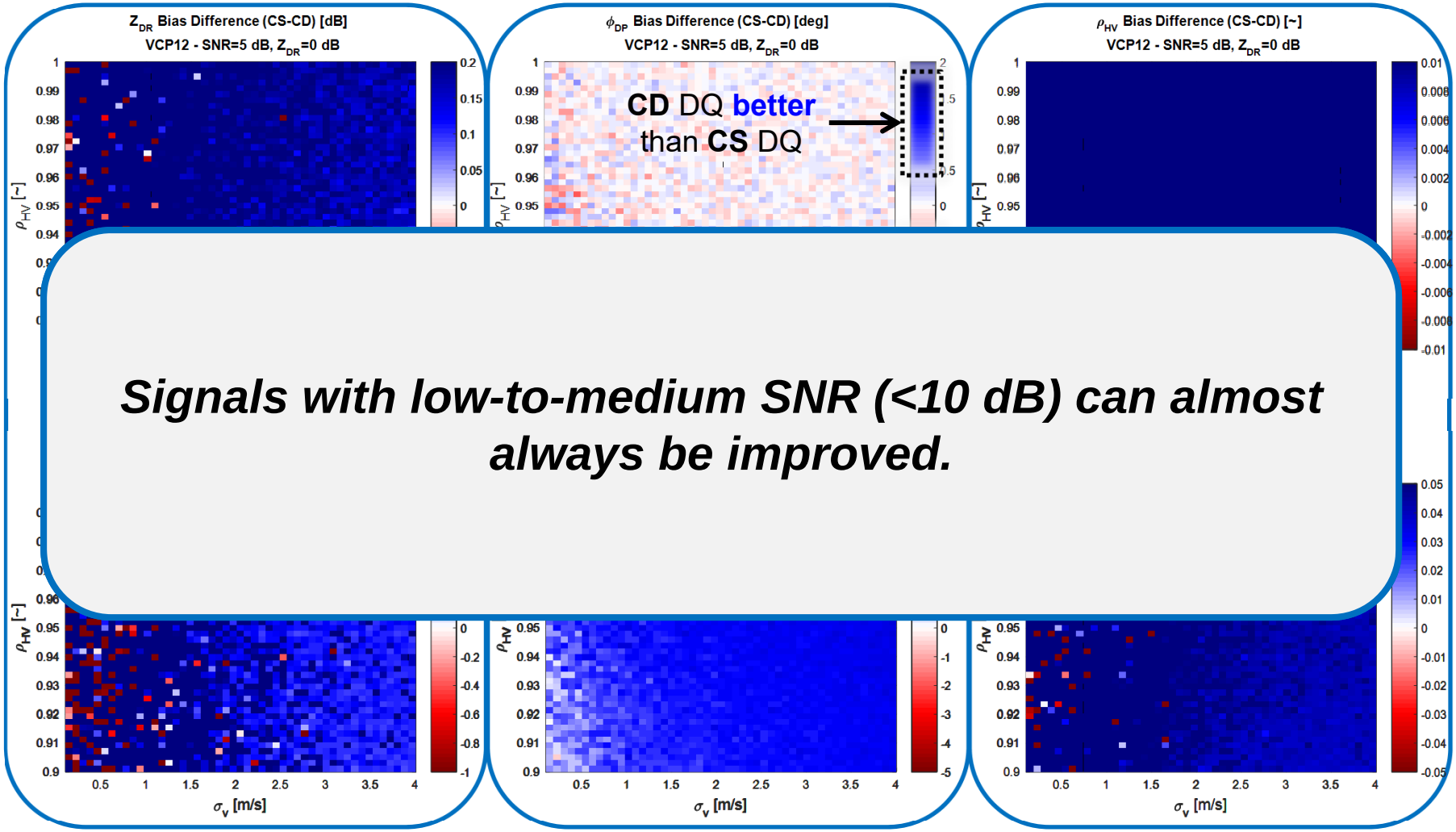


Statistics vs. σ_v and SNR for VCP12

Difference in Bias and SD for fixed M_{CS}=15, fixed M_{CD}=40 vs. SNR and σ_v

BIAS **SD**

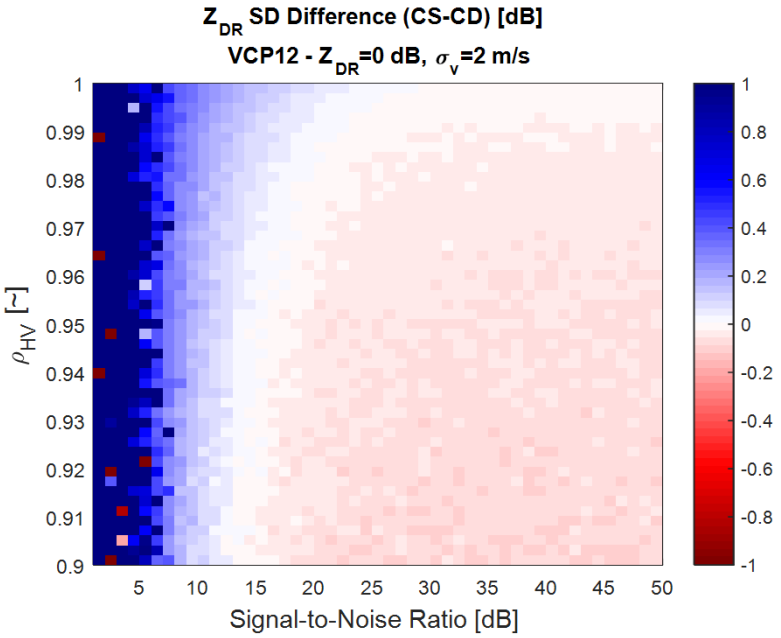
Z_{DR} **φ_{DP}** **ρ_{HV}**

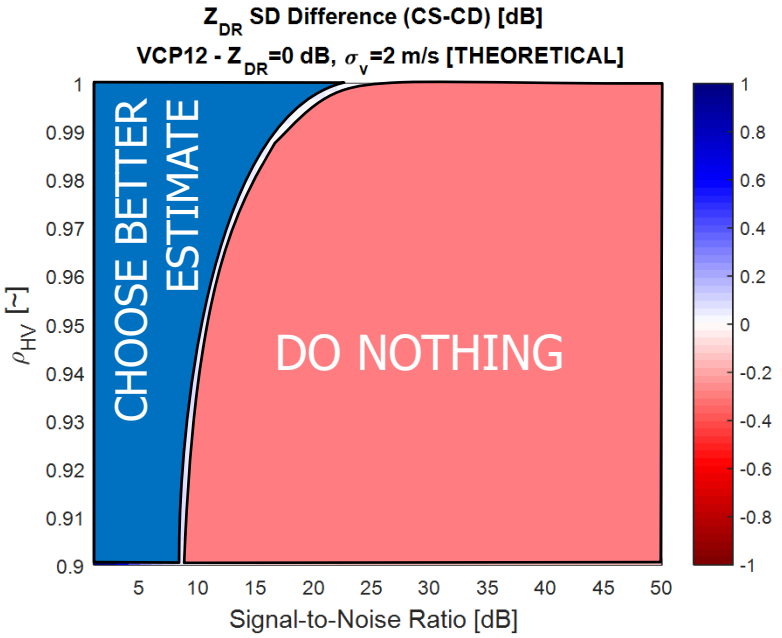


Signals with low-to-medium SNR (<10 dB) can almost always be improved.

Theoretical Expressions for HSE Decision

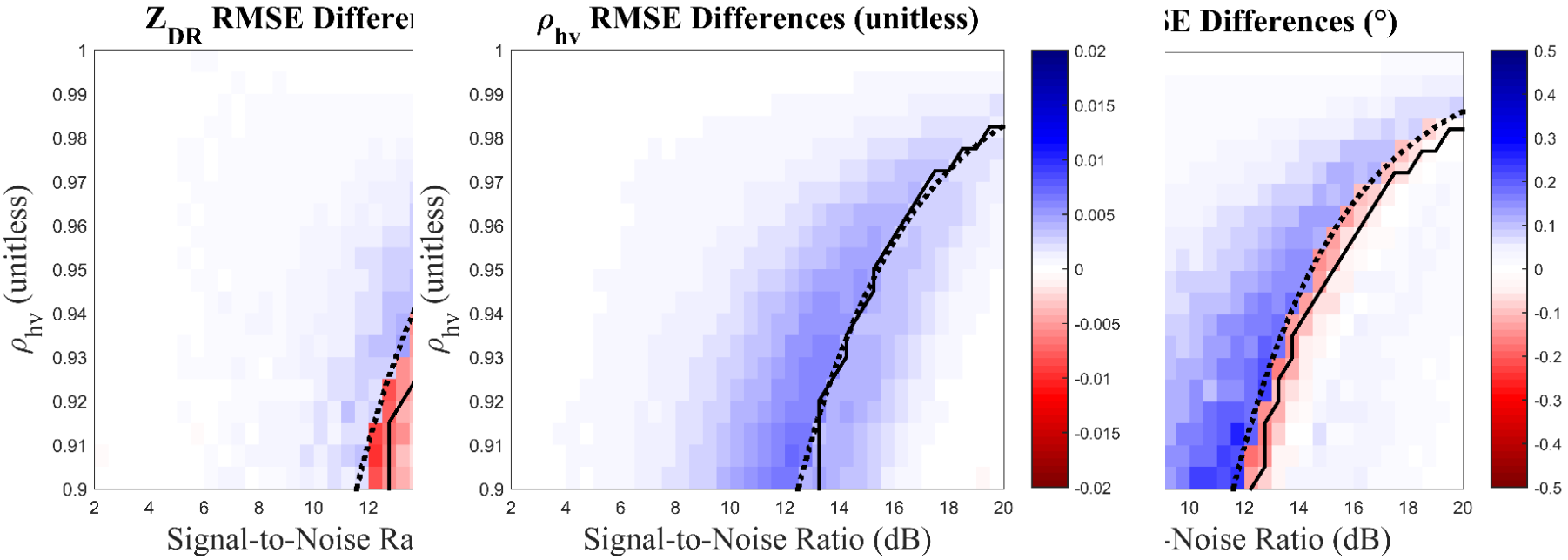
- In 2004, V. Melnikov and D. Zrnić reported **specific analytical expressions** of bias and standard deviation of spectral moments and polarimetric variables for the simultaneous transmission mode.
- We implemented those equations and compared the results obtained with the simulations.
- For example,



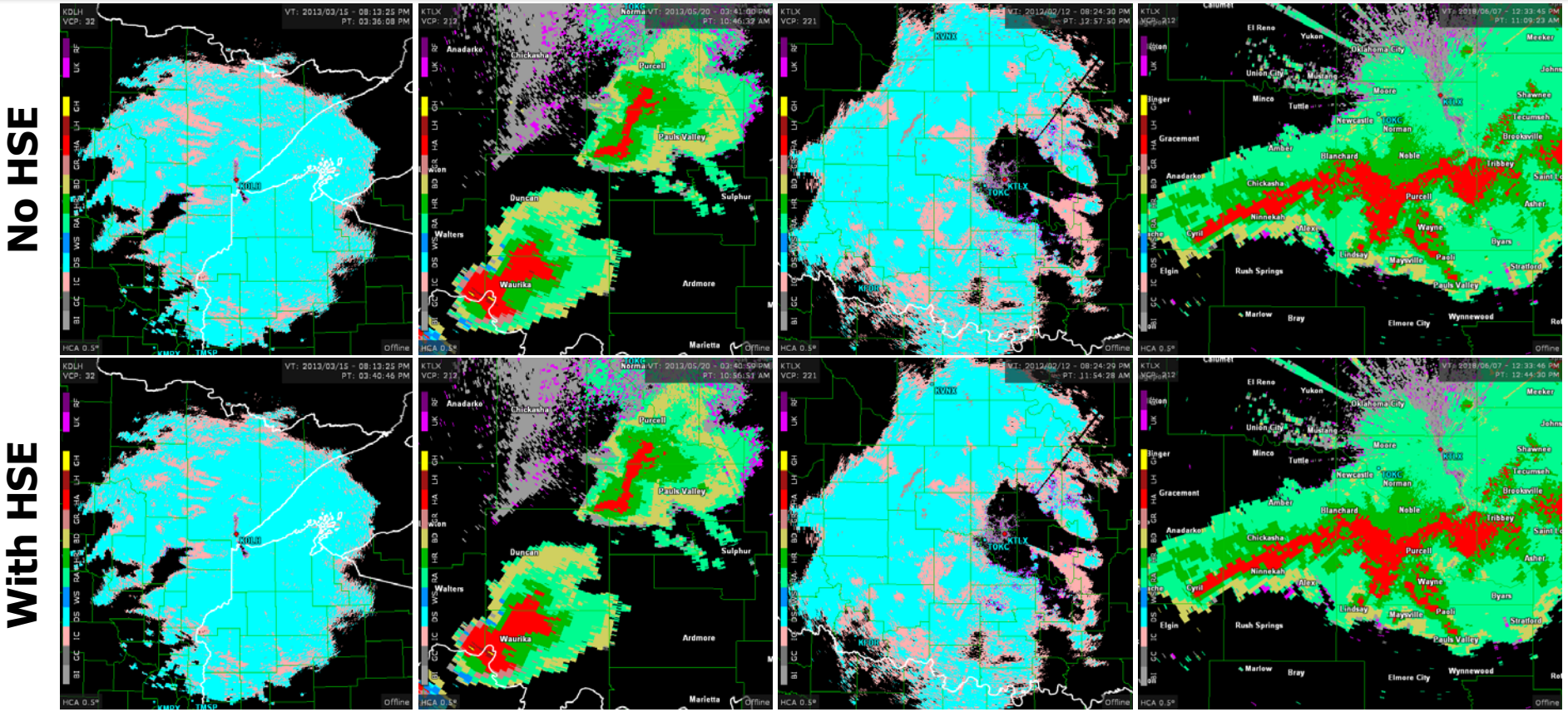


The HSE Robustness

- The HSE use estimates of SNR_H, ρ_{HV}, σ_v as inputs.
- We studied the impact of the statistical fluctuations of real estimates on the HSE decision. Here are the results:



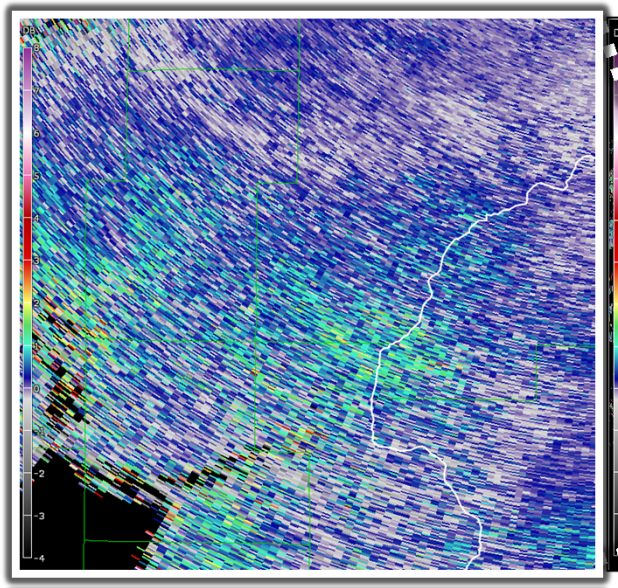
Impact of HSE on HCA

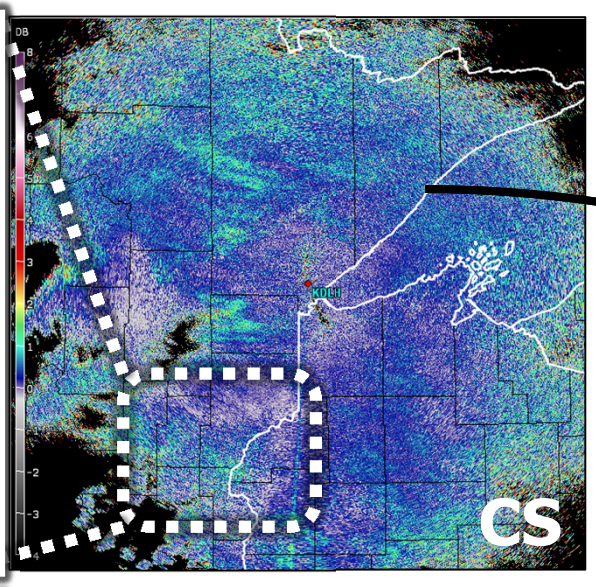


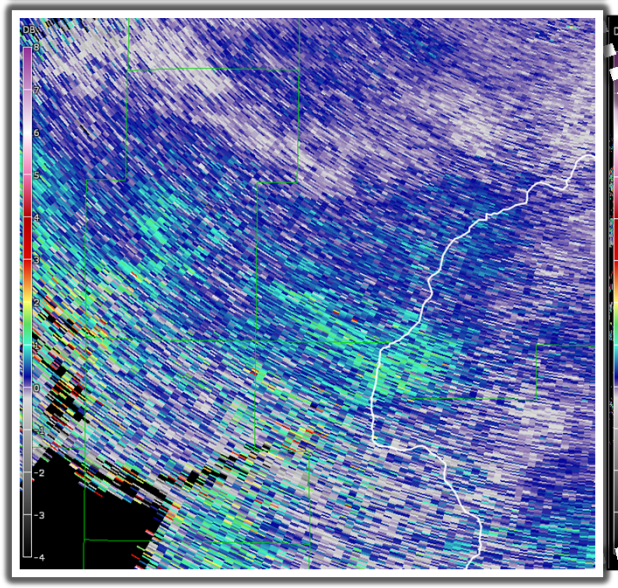
HSE can improve the quality of polarimetric-variable estimates with no harm on the Hydrometeor Classification

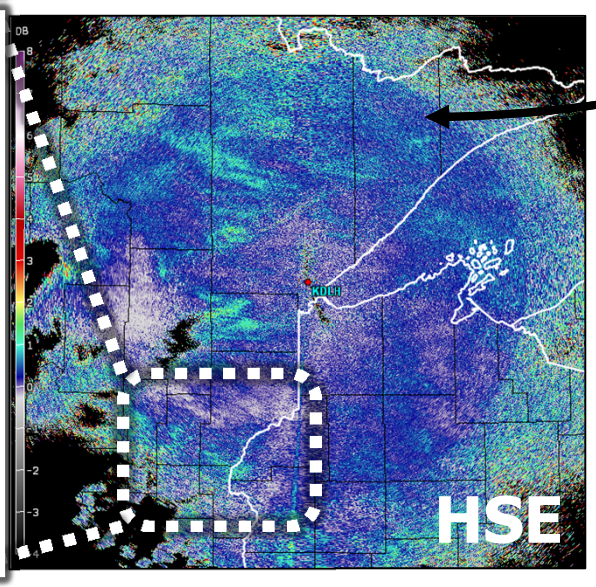
CS/CD DQ Blending (Range Weights)

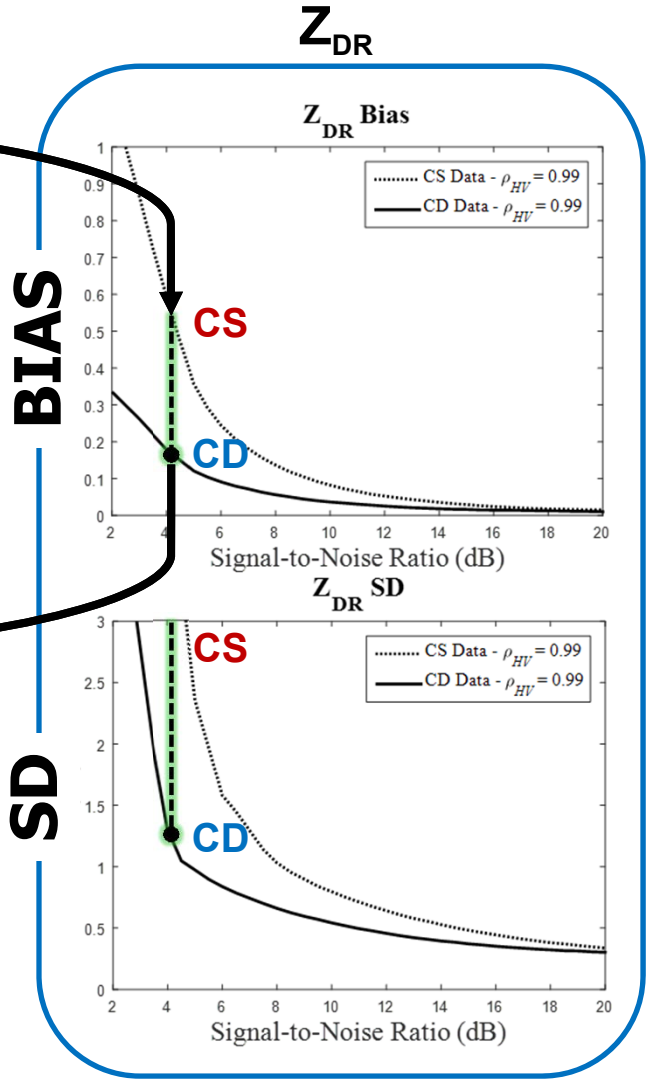
KDLH - VCP32 @ 0.5° – CS 64 Pulses (3.1 ms) & CD 220 Pulses (0.98 ms)









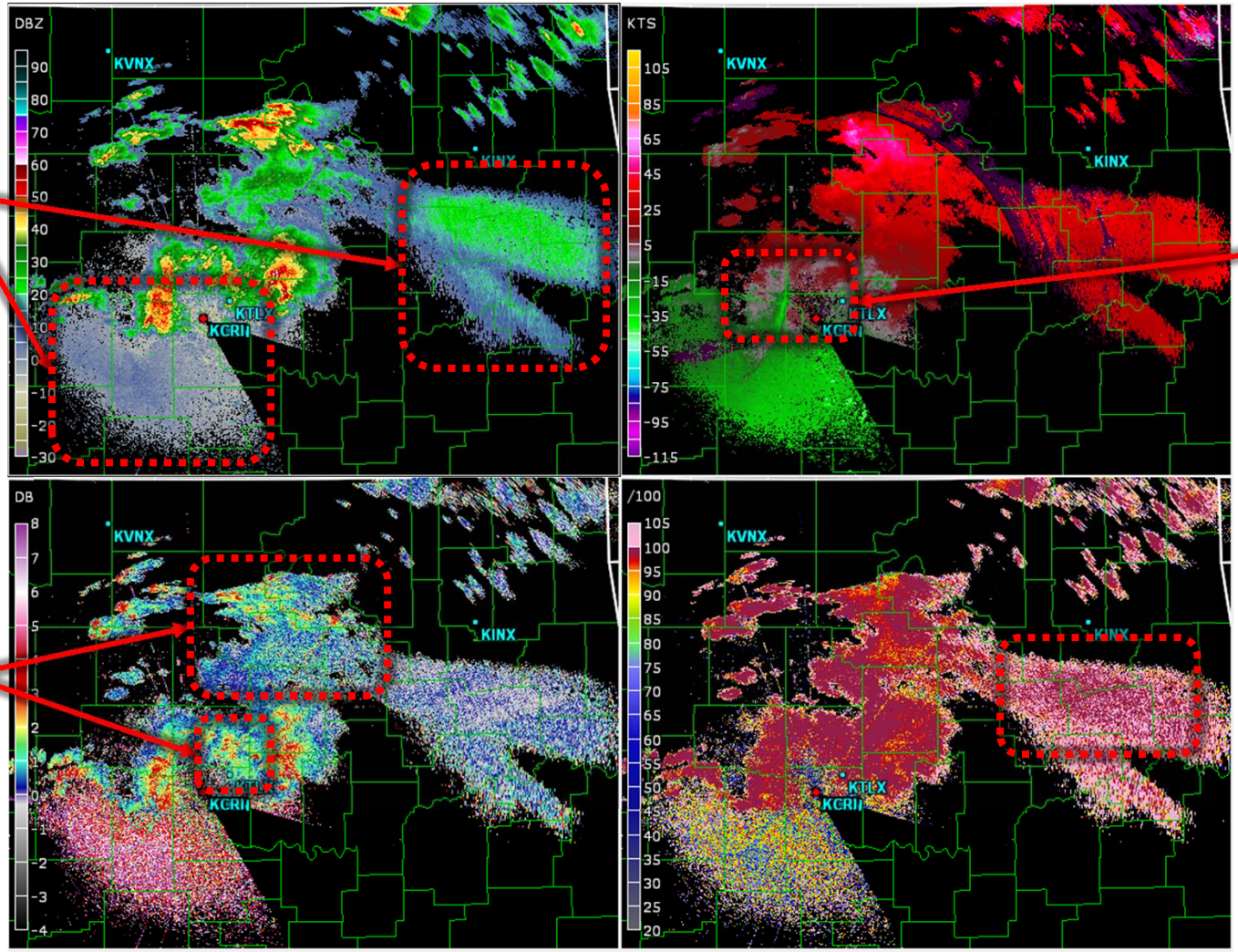


ART Team DQ Improvements

ART Data (with HSE)

Improved recovery (**CBT**)

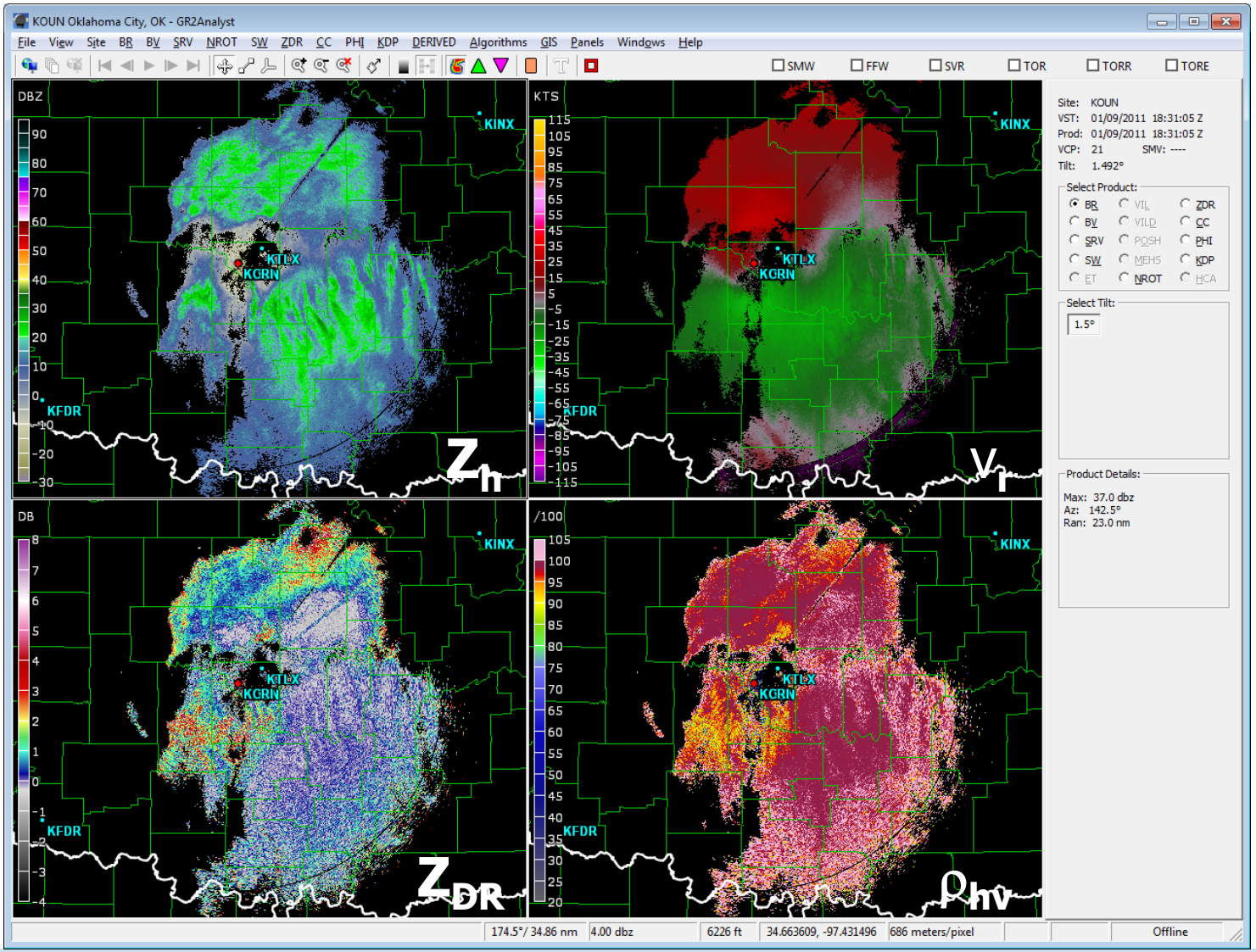
Improved DQ of dual-pol (**RbR noise**)



Improved GCF (**CLEAN-AP & WET**)

Widespread Precipitation KOUN

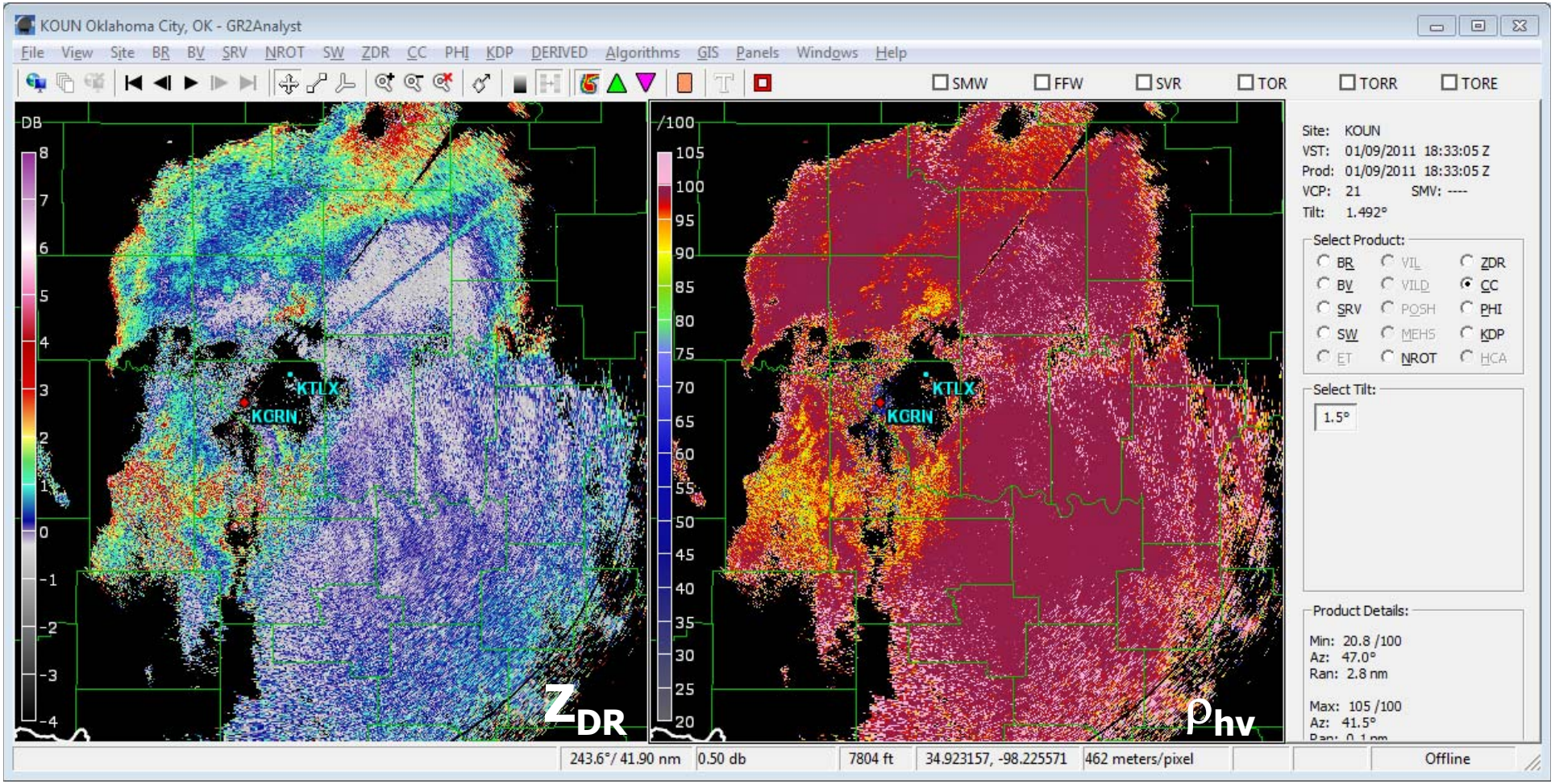
KOUN - VCP21 @ 0.5° – CS 28 Pulses (3.1 ms) & CD 88 Pulses (0.98 ms)



Widespread Precipitation KOUN

KOUN - VCP21 @ 0.5° – CS 28 Pulses (3.1 ms) & CD 88 Pulses (0.98 ms)

WITH HSE

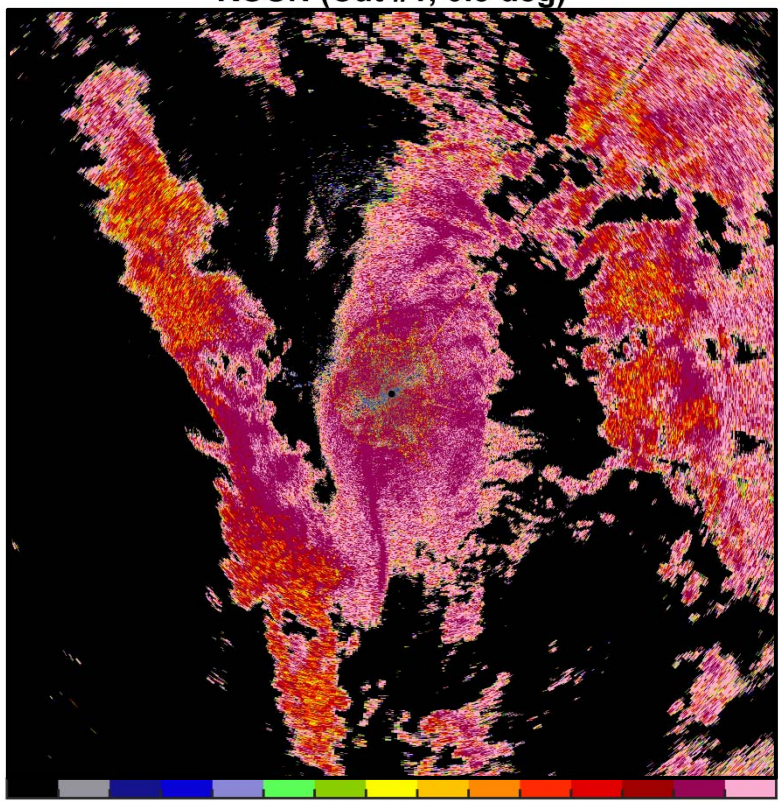


HSE Decisions: Where is the CD Data?

KOUN – VCP11 @ 0.5° – CS 17 Pulses (3.06 ms) & CD 52Pulses (0.83 ms)

Conventional ρ_{hv} Estimator

KOUN (Cut #1, 0.5 deg)

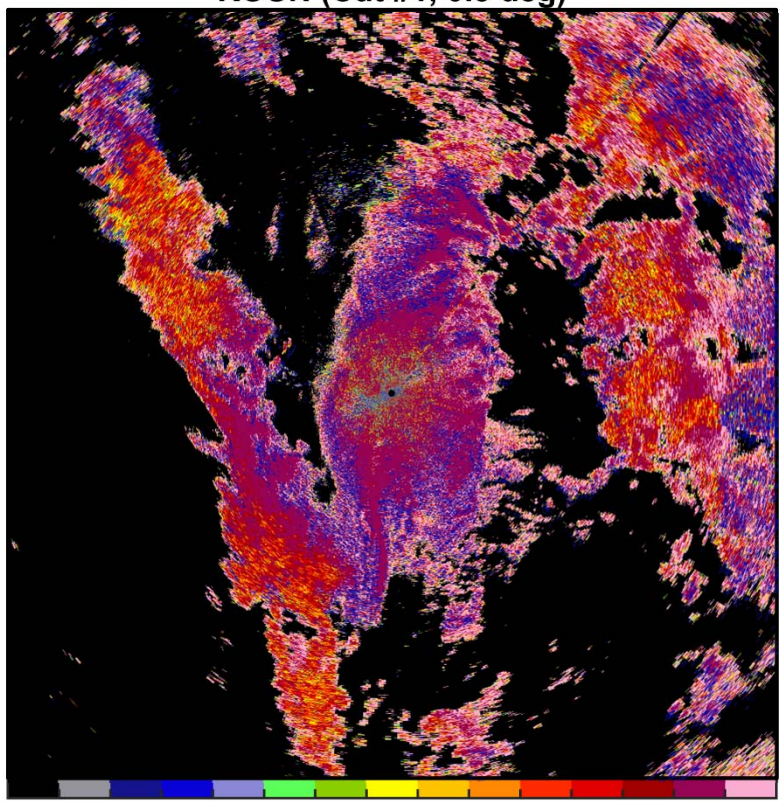


<th 0.20 0.45 0.65 0.75 0.80 0.85 0.90 0.93 0.95 0.96 0.97 0.98 0.99 1.00

CORRELATION COEFFICIENT (unitless)

Hybrid-Scan ρ_{hv} Estimator

KOUN (Cut #1, 0.5 deg)



<th 0.20 0.45 0.65 0.75 0.80 0.85 0.90 0.93 0.95 0.96 0.97 0.98 0.99 1.00

CORRELATION COEFFICIENT (unitless)

Percentage of estimates improved 18.05% (Bins: 47,611/263,808)

(not only *pink fringe* reduction)