CLEAN-AP/WET Update

Clutter **E**nvironment **An**alysis using **A**daptive **P**rocessing/
Weather **E**nvironment **T**hreshold
(Last Update 2015)

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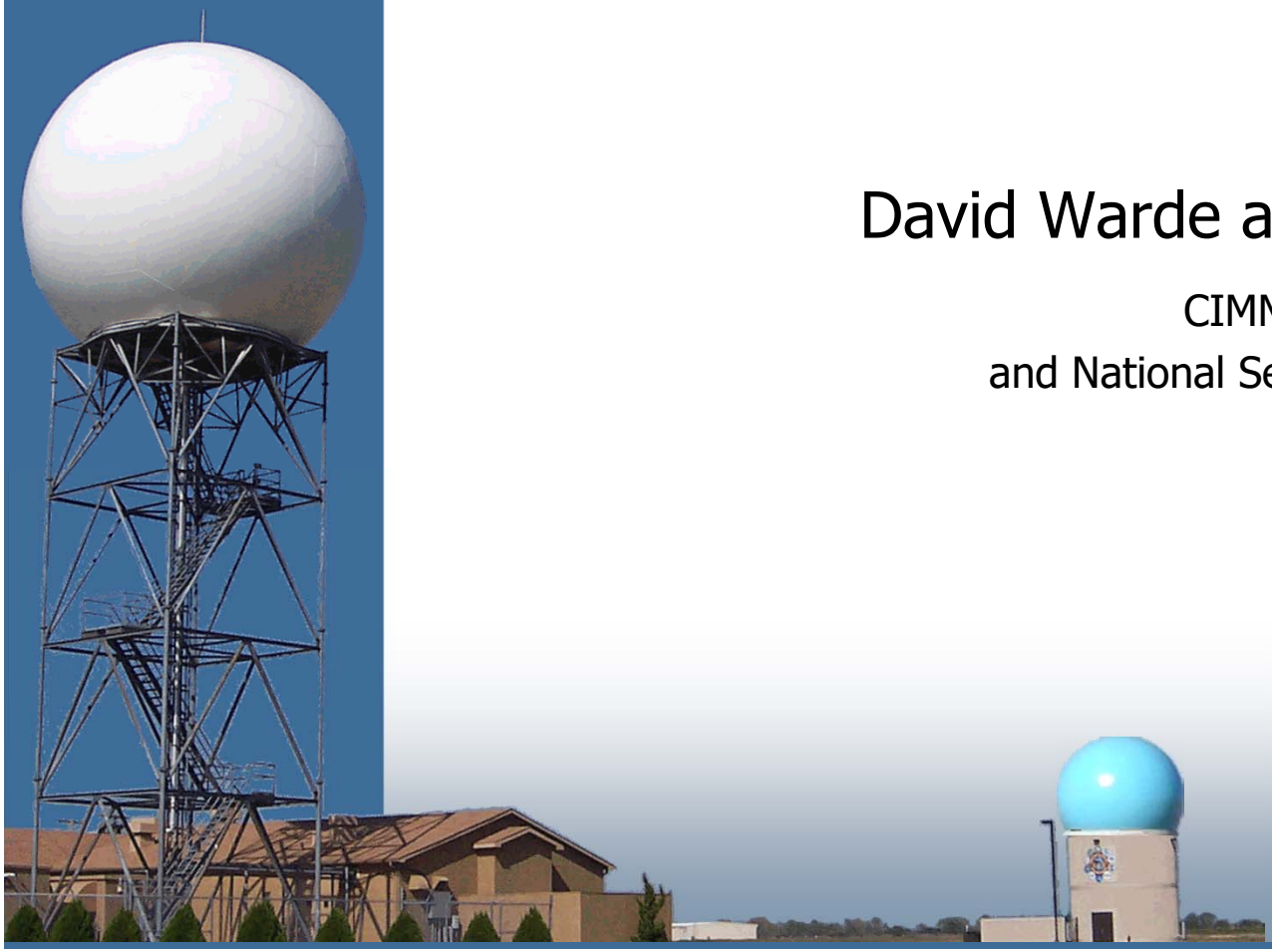


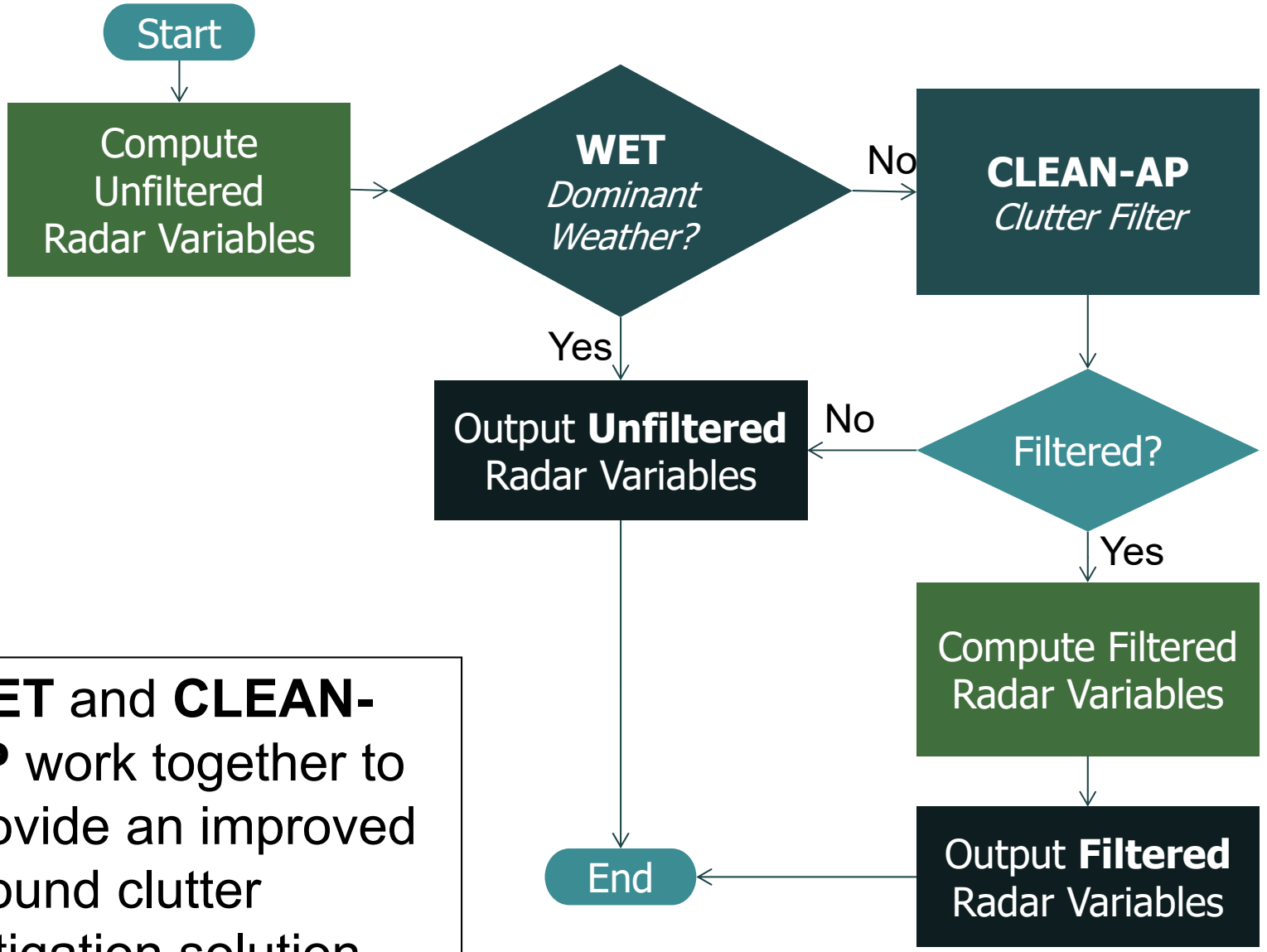
NEXRAD TAC
Norman, OK
29 April 2019

what is CLEAN-AP/WET?

CLEAN-AP is a **real-time**, **automatic**, **integrated** technique for ground clutter **mitigation** that produces meteorological data with **improved quality** and meets NEXRAD technical requirements for clutter suppression.

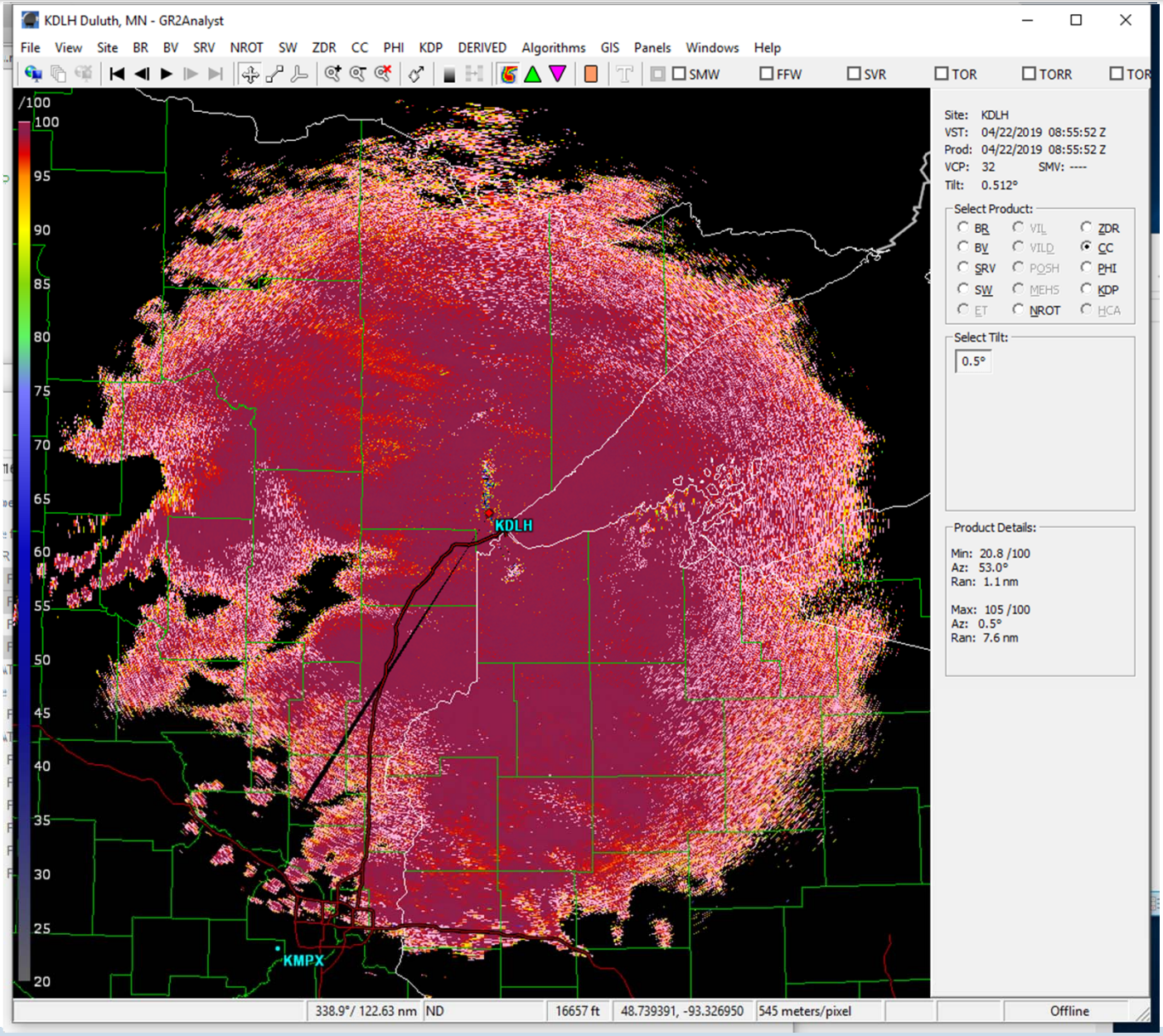
WET **integrated** with CLEAN-AP to assist in the application of the filter which affects **data quality**

complete mitigation solution

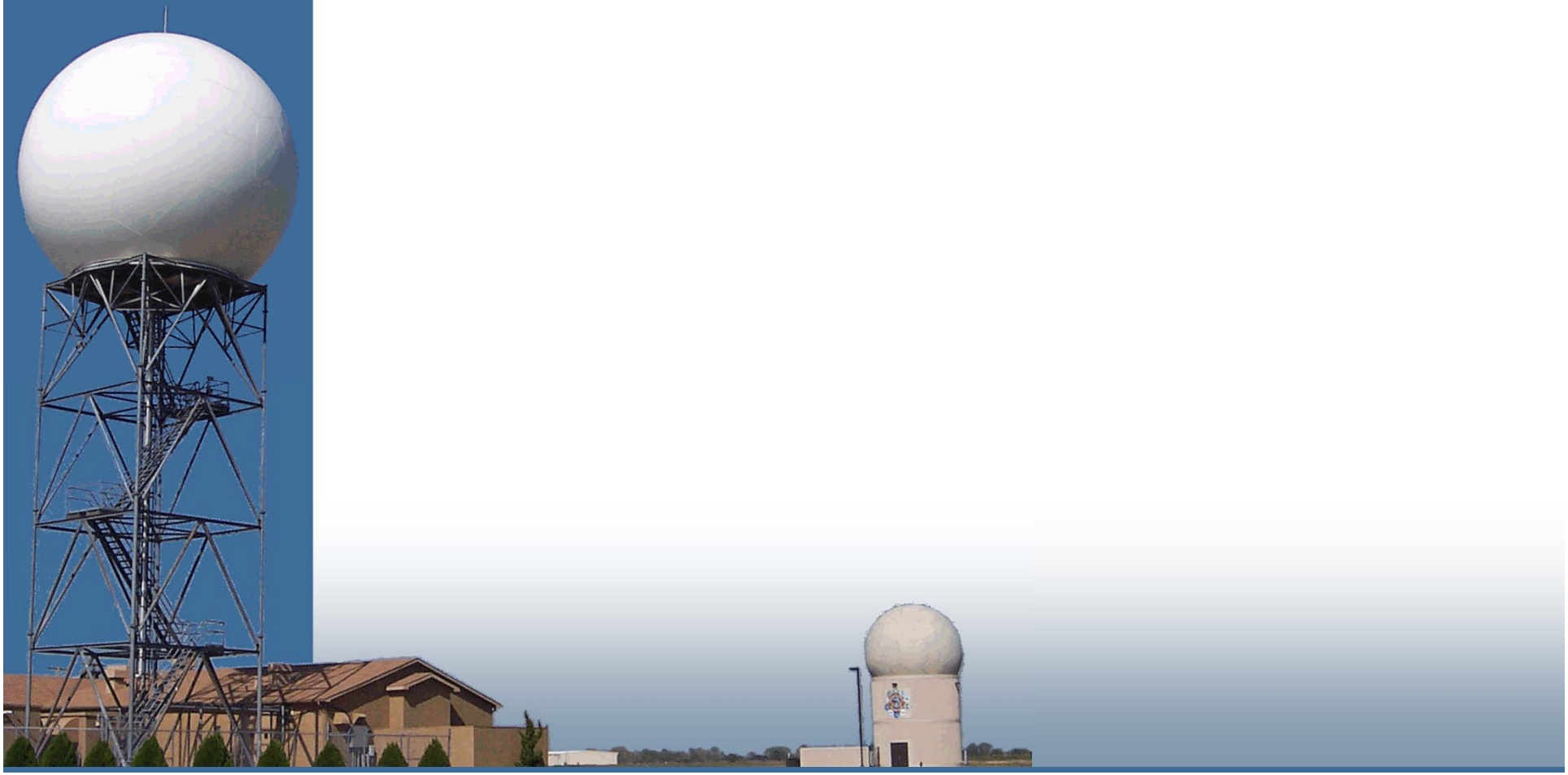


WET and **CLEAN-AP** work together to provide an improved ground clutter mitigation solution

Duluth (Clutter Fingerprint)

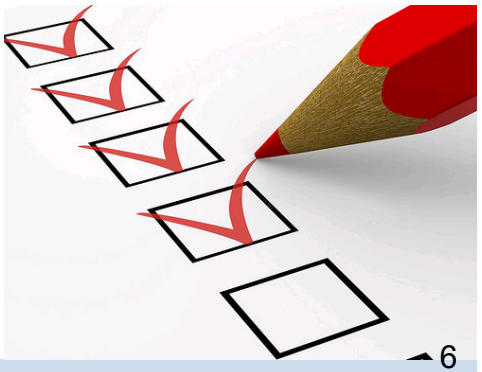


A little bit of history…



milestones (I)

- Developed CLEAN-AP concept (Spring '08)
  - Filed invention disclosure with OU's OTD
- Evaluated performance using simulations (Spring '08)
- Implemented in real time on the NWRT PAR (Fall '08)
- Compared with current WSR-88D clutter mitigation (Fall '09)
  - KEMX (Tucson, AZ)
  - KTLX (Oklahoma City, OK)
  - KABX (Albuquerque, NM)
  - KCRI (ROC testbed)
- Presented at November 2009 TAC meeting
  - initially presented CLEAN-AP
    - "… the technique shows potential utility…"
    - "… encouraged by early results…"
    - "… [have not] shown the scientific details behind the algorithm…"
    - "… [need] case comparisons with CMD…"

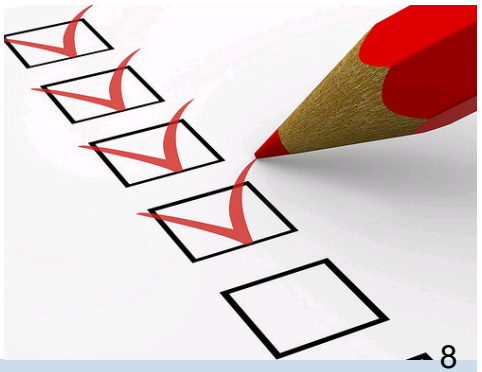


milestones (II)

- Extended to **dual-polarization** (Spring '10)
  - KOUN (S-band) and OU' (C-band)
- Developed clutter model (Spring '10)
  - Form/Function/Fit for RVP8
- Presented at fall 2010 ROC/NSSL/NCAR TIM
  - presented more technical details and data cases
  - received positive feedback from ROC eng and agency reps
- Delivered **CLEAN-AP algorithm description** (Fall '10)
  - NSSL Report 14 (confidential attachment)
- Extended to **staggered PRT** (Fall '10)
- Presented at March 2011 TAC meeting
  - decision briefing
    - *"The TAC members agreed to move forward with conducting an engineering evaluation on CLEAN AP."*

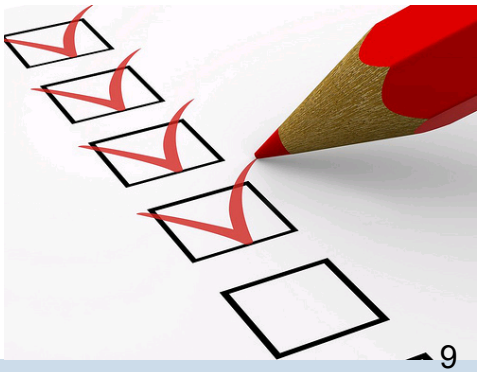
milestones (III)

- Documented CLEAN-AP performance (Winter ’11)
  - NSSL Report 15
- Delivered **staggered PRT CLEAN-AP algorithm description** (Spring ’12)
  - NSSL Report 16 (confidential)
- Collaborated with McGill University to integrate CLEAN-AP into their clutter mitigation algorithm (Summer ’13)
  - Radar conference paper
- Improved clutter-extent determination and interpolation scheme (Fall ’13)
  - Journal paper
- **CLEAN-AP** licensed to **Baron Services, Inc.** (Spring ’14)
  - Exclusive licensing agreement with OU
  - Deployed throughout world: Baron Gen3 radar

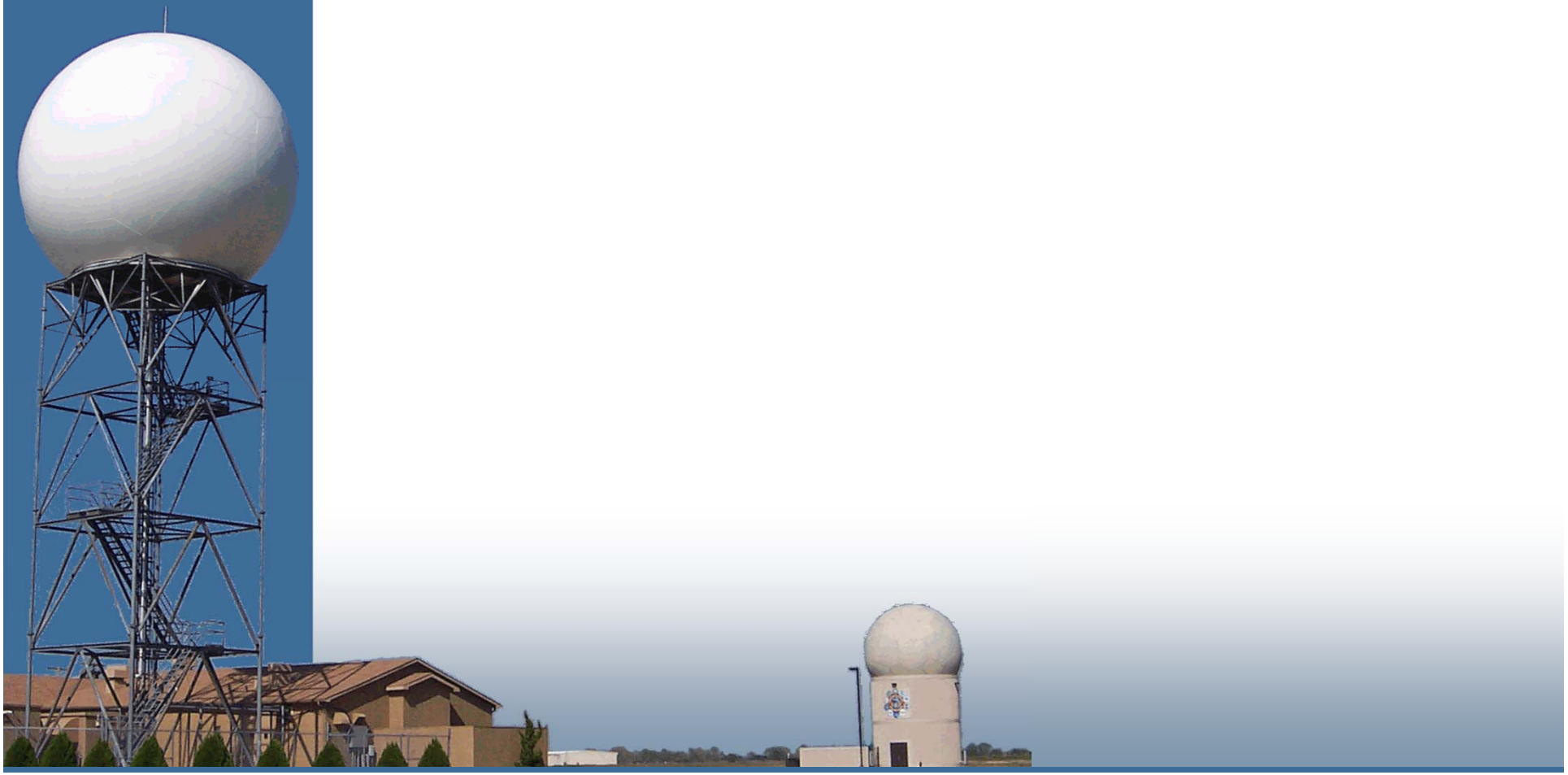


milestones (IV)

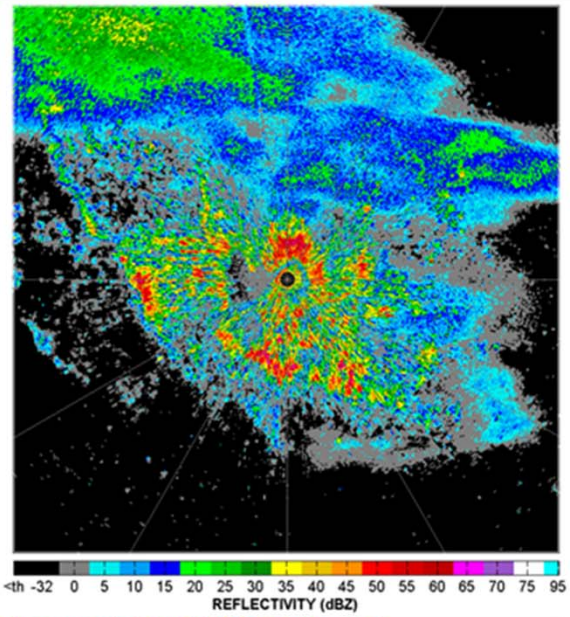
- Collaboration with **UK MET Office** (2015 – Present)
  - Implemented CLEAN-AP/WET into Cyclops Processor
  - Improved QPE (ERAD 2018)
  - Engineering Evaluation
- Integrated **WET** into **CLEAN-AP**
  - NSSL Report 17
- Delivered **SPRT** (updated) and **SZ-2** (new) **CLEAN-AP algorithm descriptions** (Spring '17)
  - Stand alone NSSL reports (confidential)
- Assisting ROC engineers with **implementation**, **validation**, and **testing**
  - ROC DQ subcommittee for SPRT

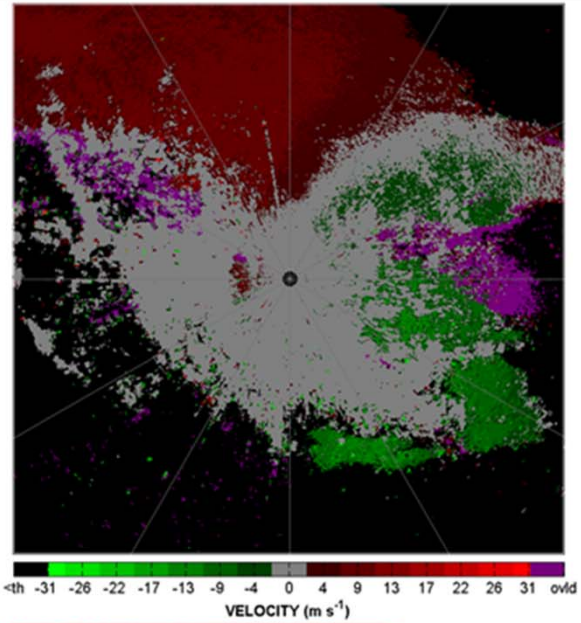


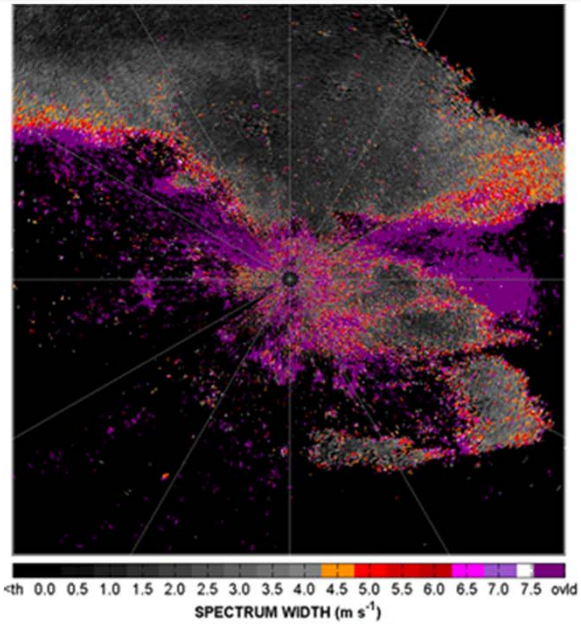
Case Examples

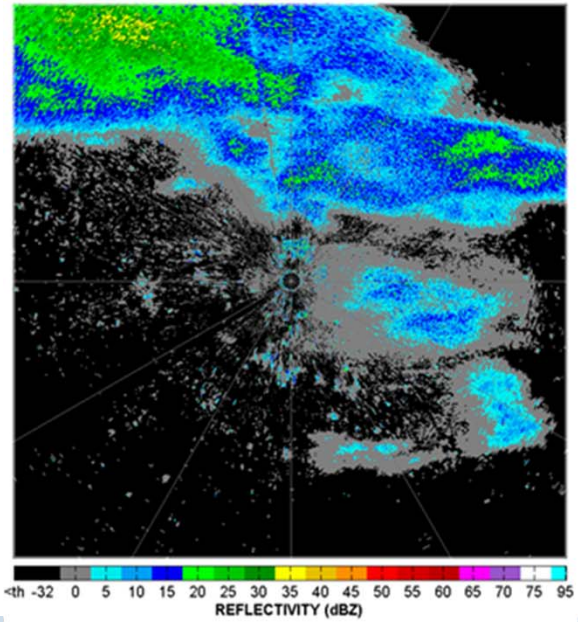


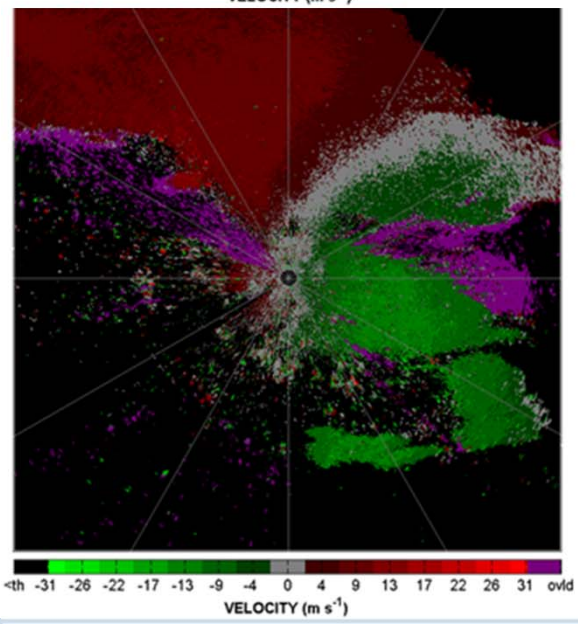
KVNX – 8 Mar 2011 (Uniform PRT)

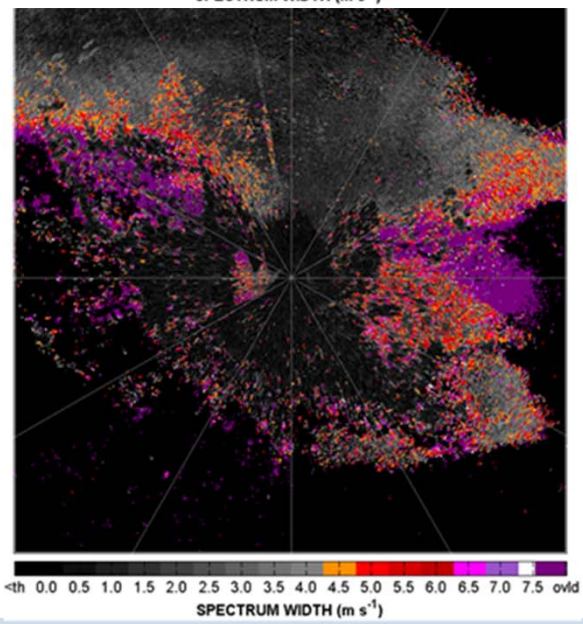












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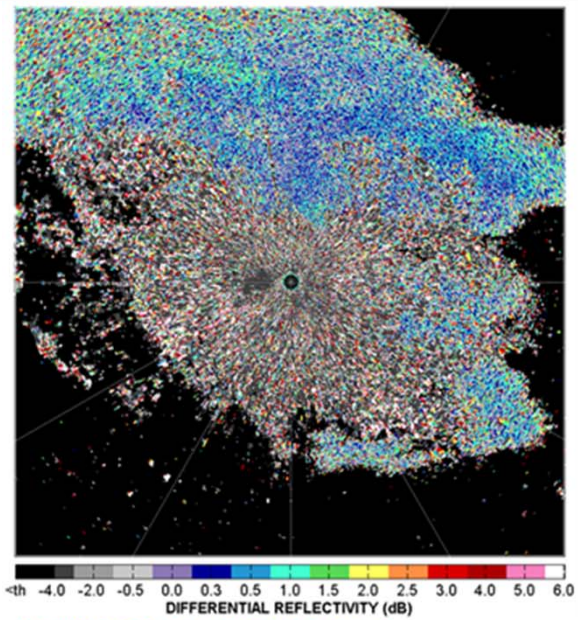
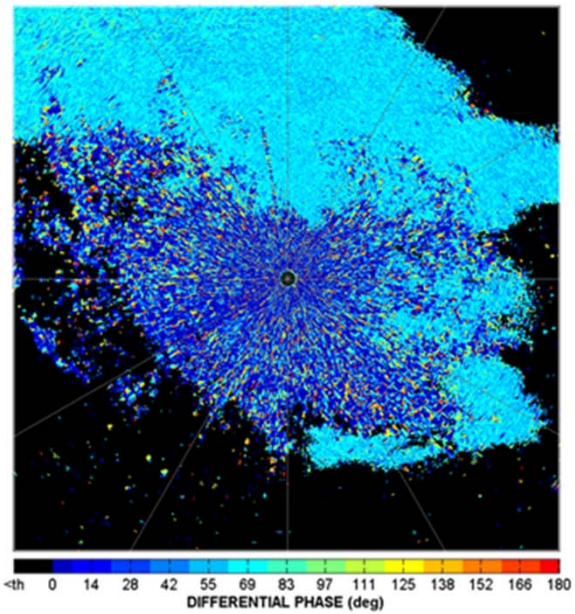
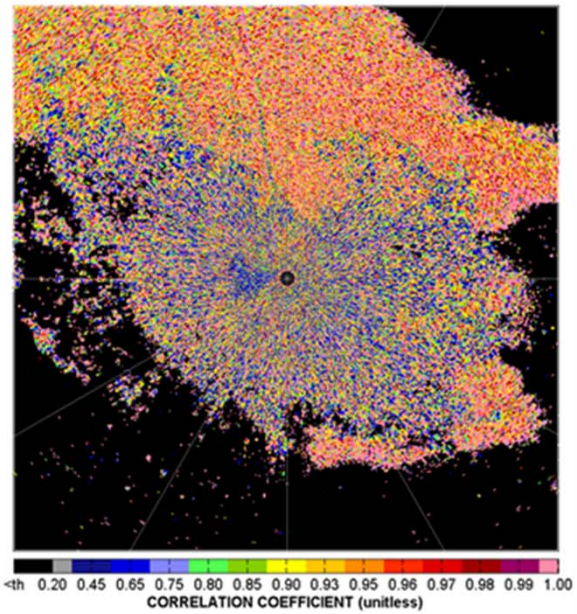
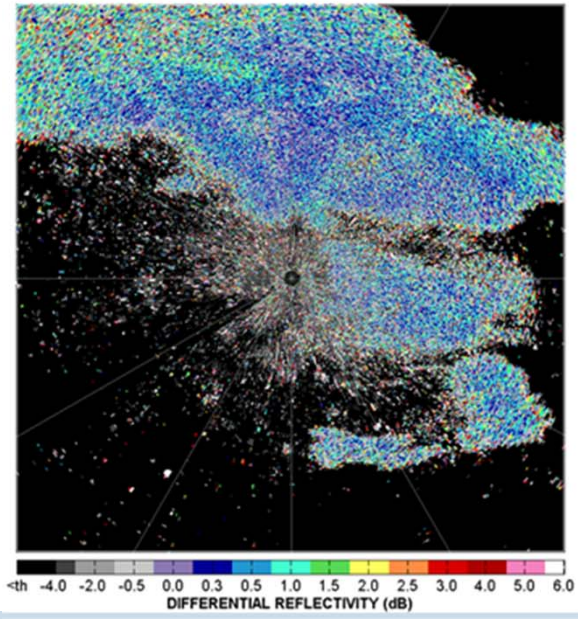
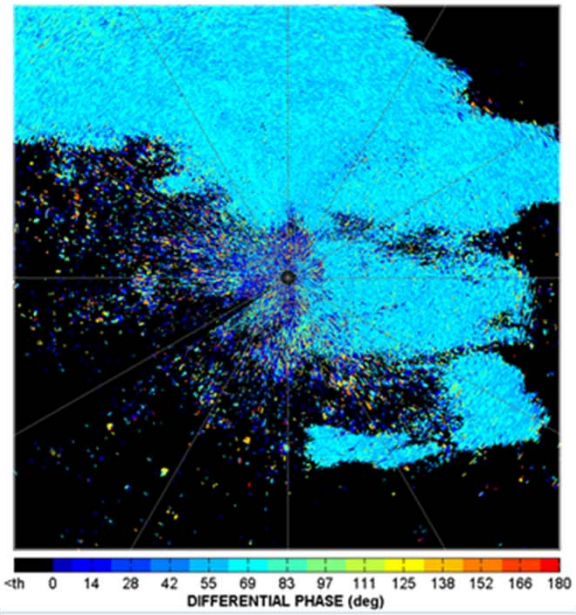
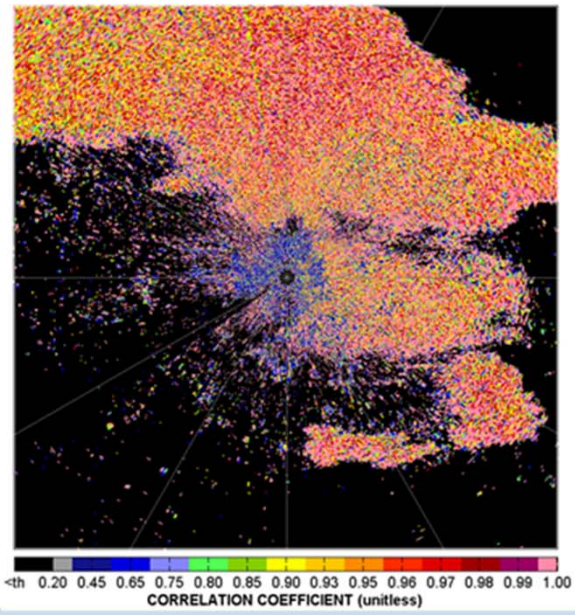




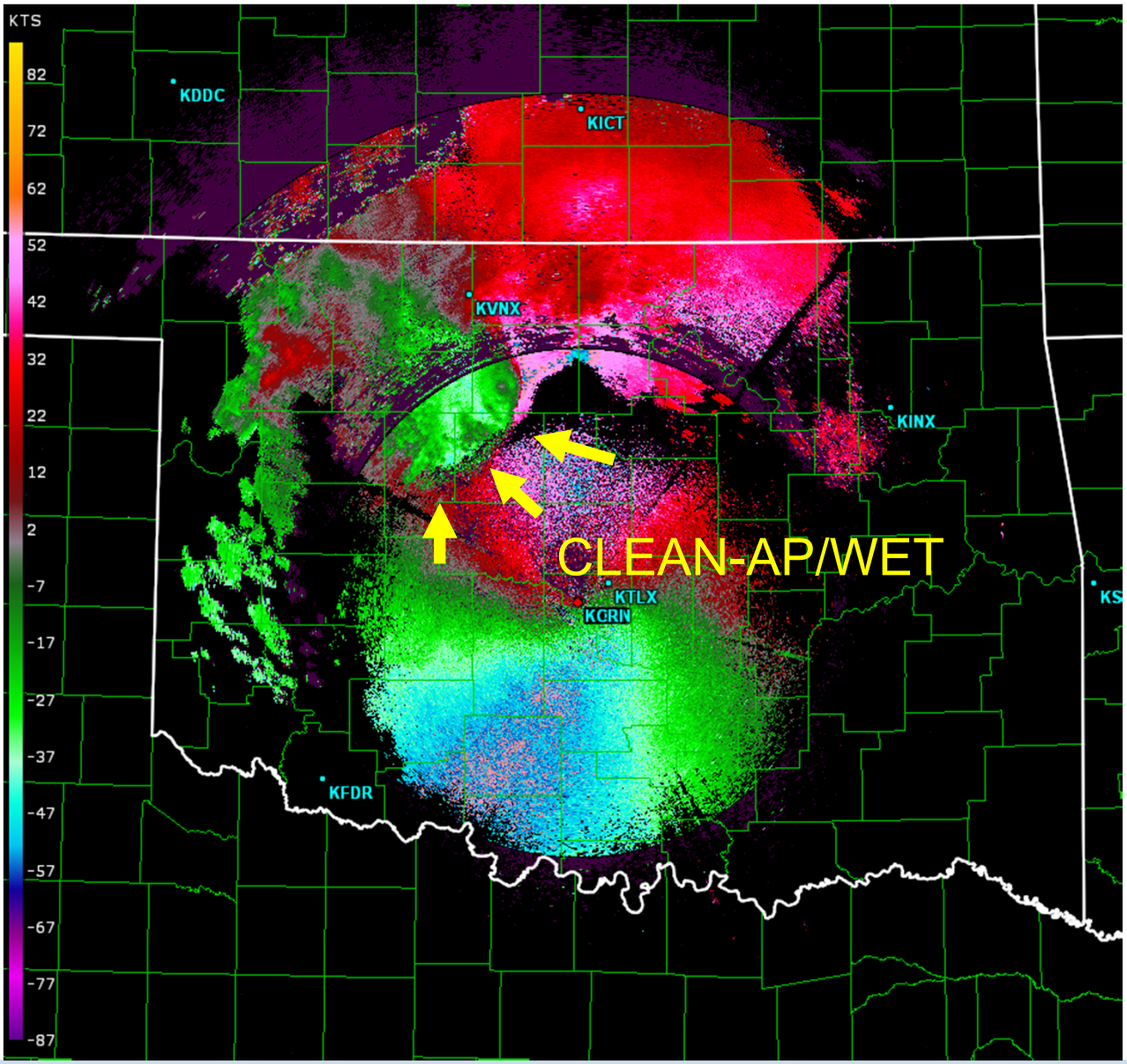








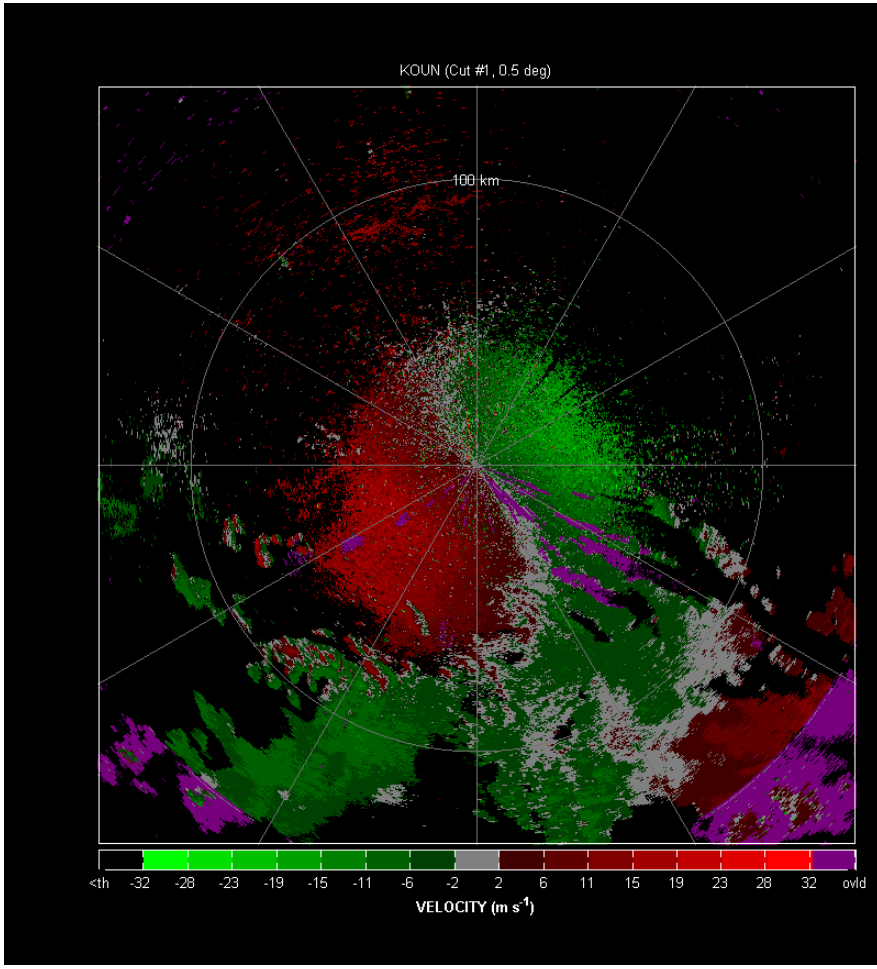
KOUN – 19 May 2010 (SZ2 Insects)



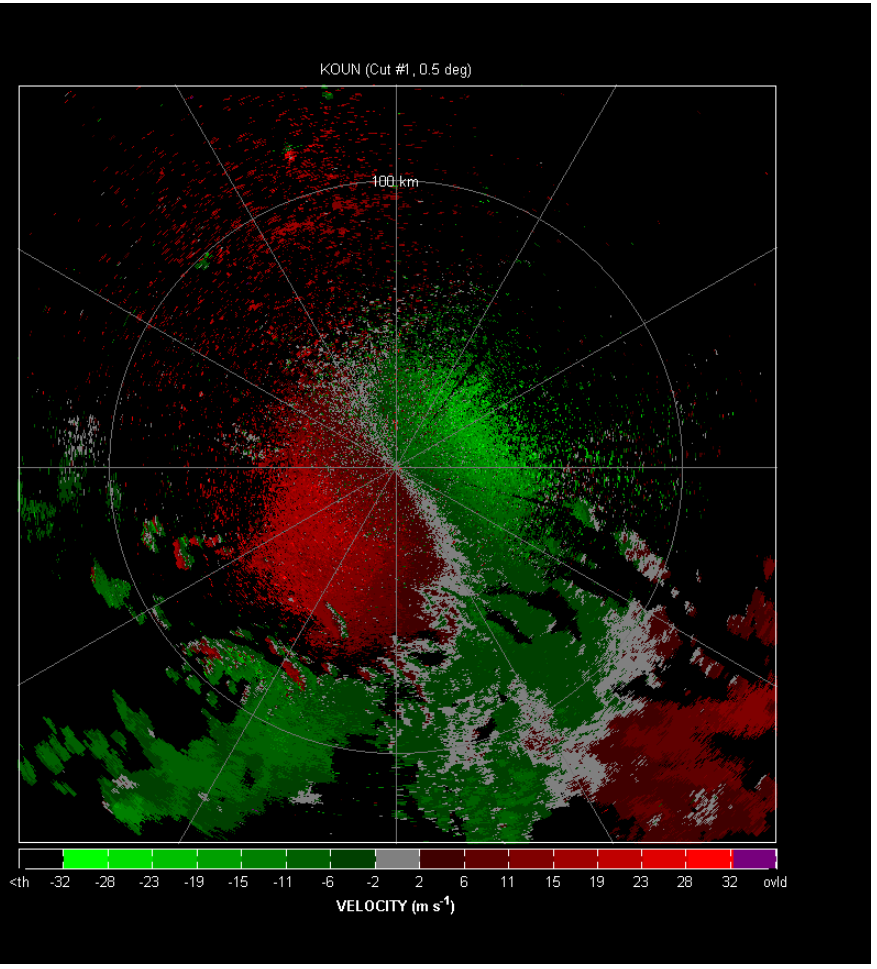
KOUN – 8 April 2012 (SPRT)

0.5° Elevation

Split Cut

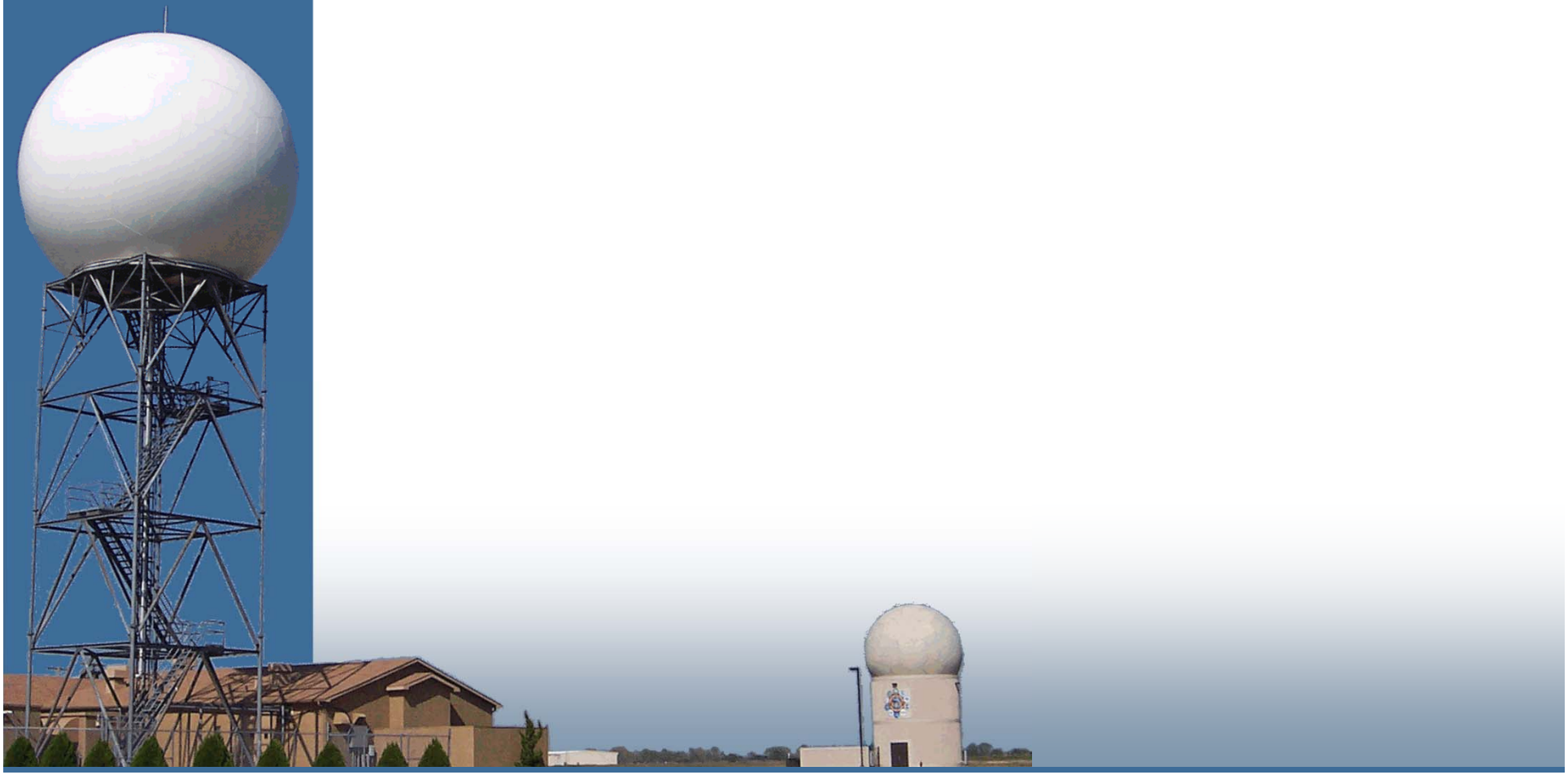


Staggered PRT



Unfiltered

Wrapping Up…



Future Work

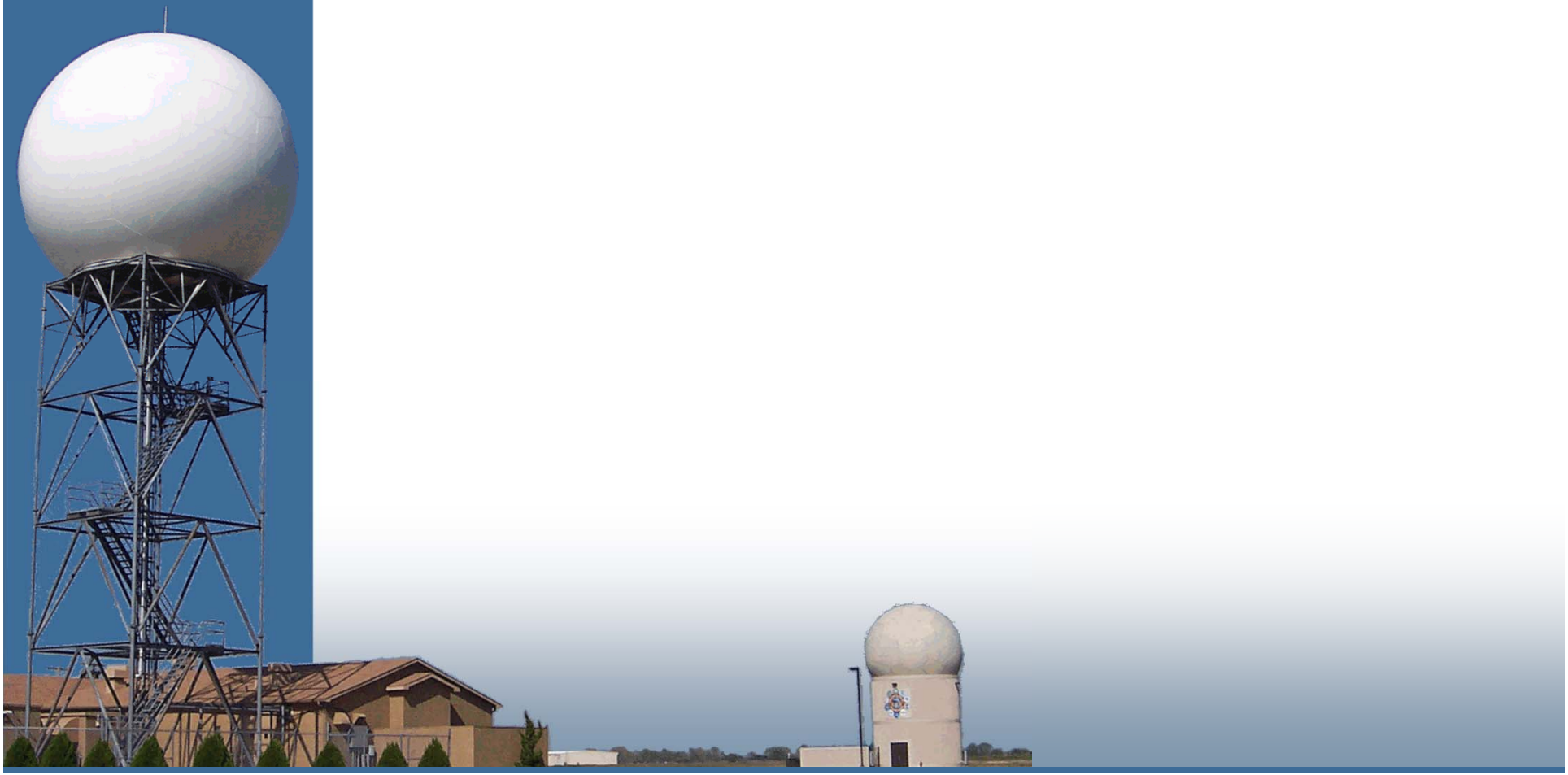
- Continue support of RDA implementation
- Support RDA engineering evaluation

Summary

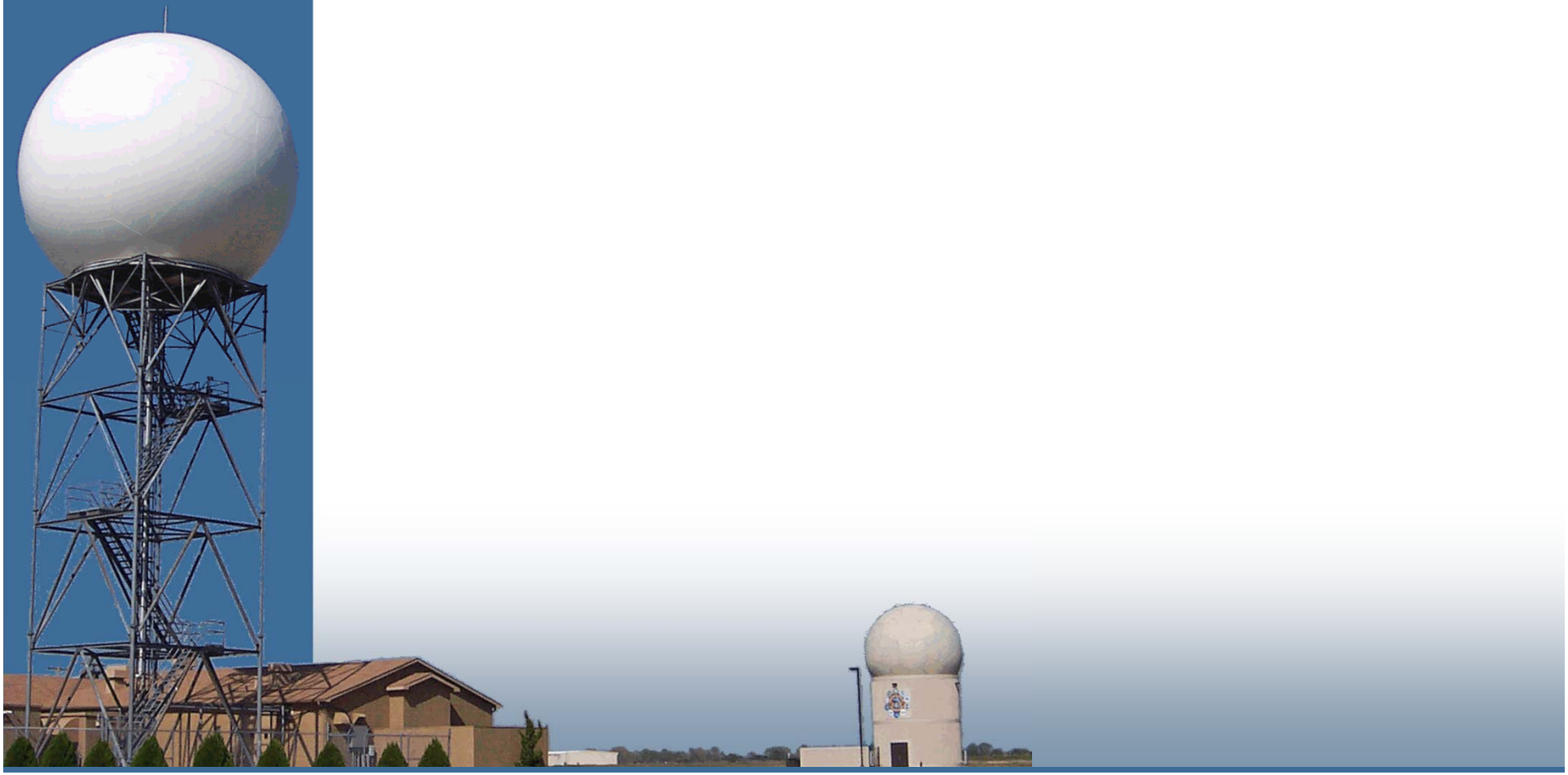
CLEAN-AP/WET are **real-time**, **automatic**, **integrated** techniques for ground clutter **mitigation** that produces meteorological data with **improved quality** and meets NEXRAD technical requirements for clutter suppression.

- **TAC endorsed** engineering evaluation on the WSR-88D (March '11)
- **ROC engineering** evaluation of **CLEAN-AP/WET for SPRT** (Present)
- **Deployed worldwide** (Present)

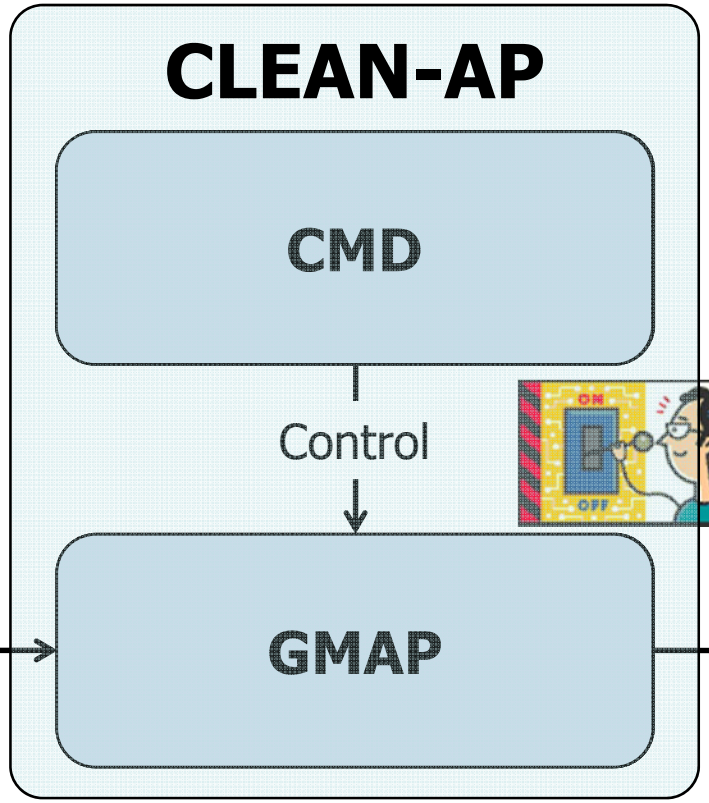
Back Up Slides



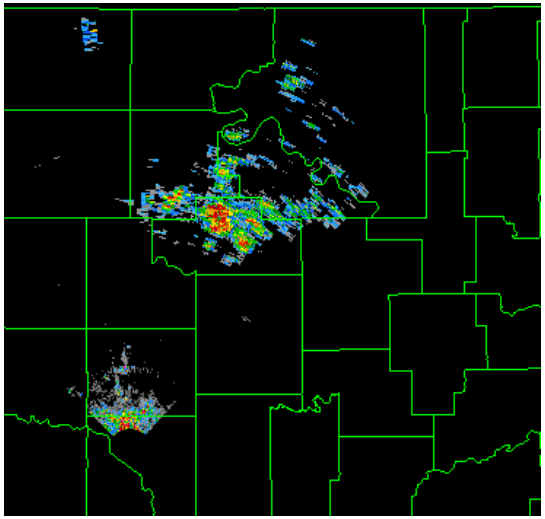
Fundamentals



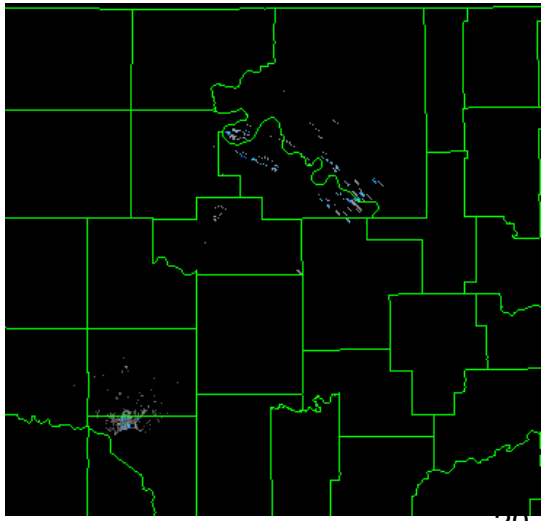
clutter mitigation at the RDA



Unfiltered data

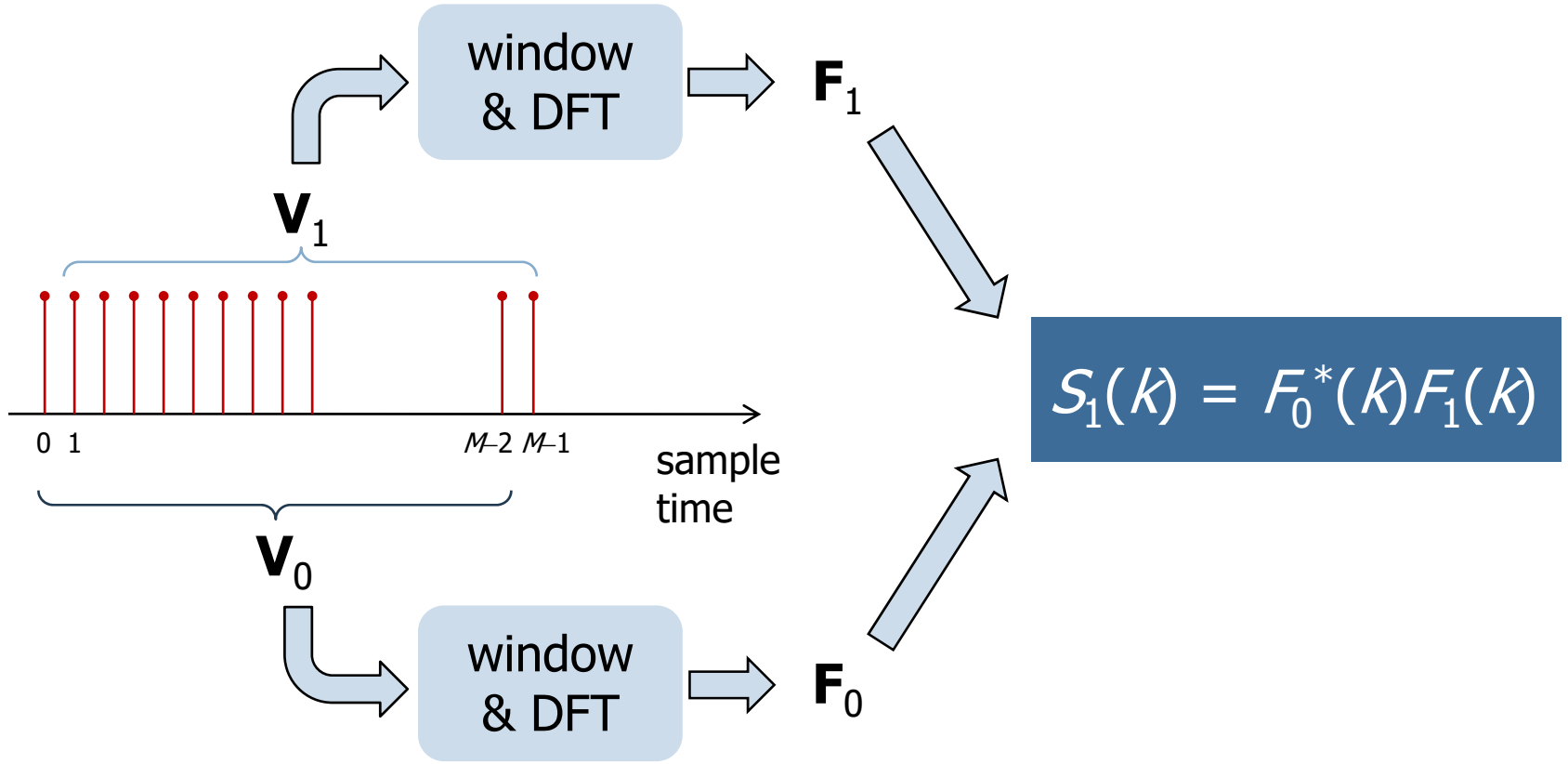


Filtered data



CLEAN-AP's core: the ASD

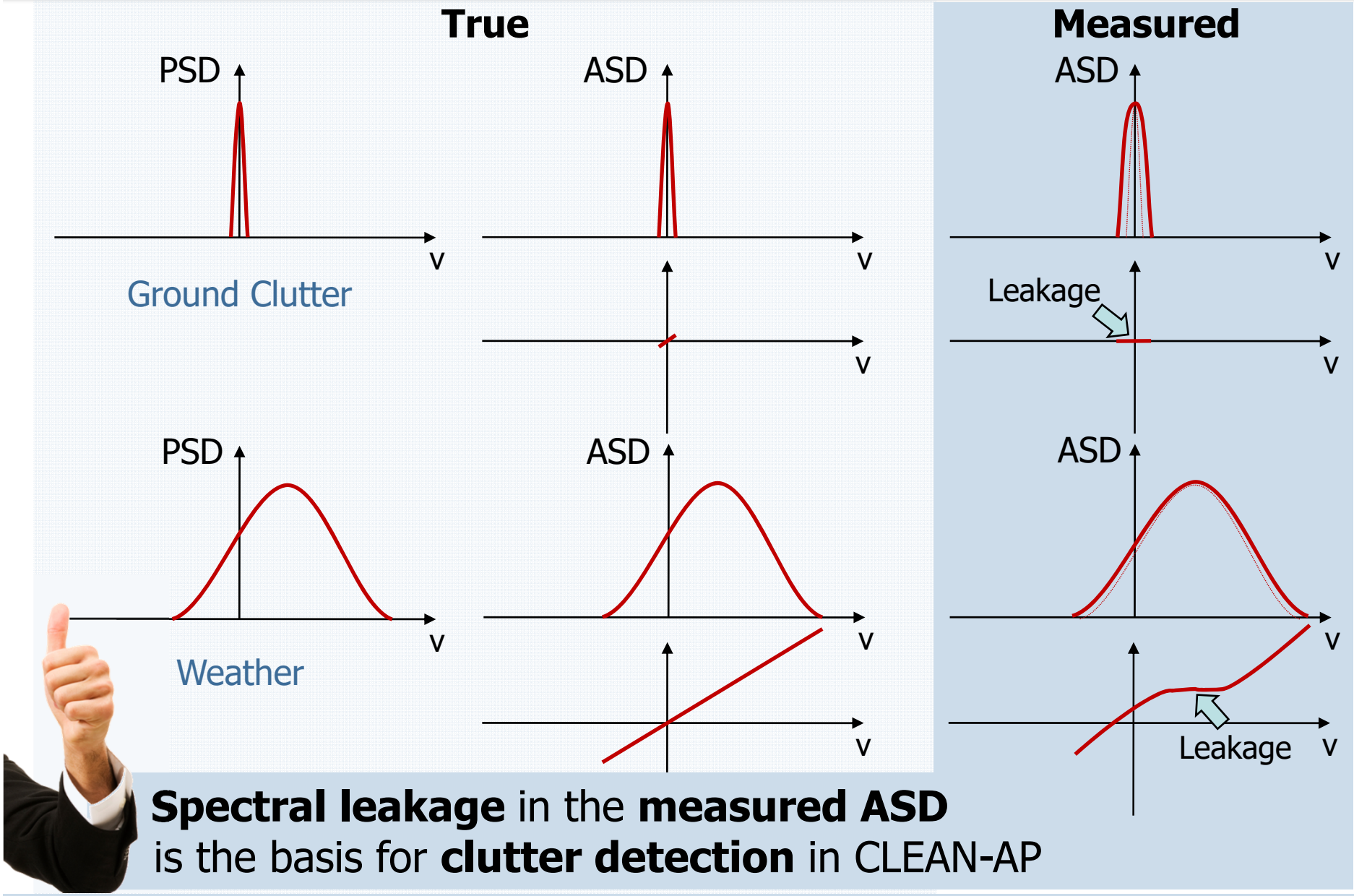
lag-1 **a**utocorrelation **s**pectral **d**ensity



- For <u>periodic</u> signals: $F_1(k) = F_0(k)\, e^{j2\pi k/M}$
  - $S_1(k) = F_0^*(k)\, F_0(k)\, e^{j2\pi k/M}$
  - the magnitude of **ASD** is the **PSD**
  - the argument of the ASD is $2\pi k/M$

} trivial?

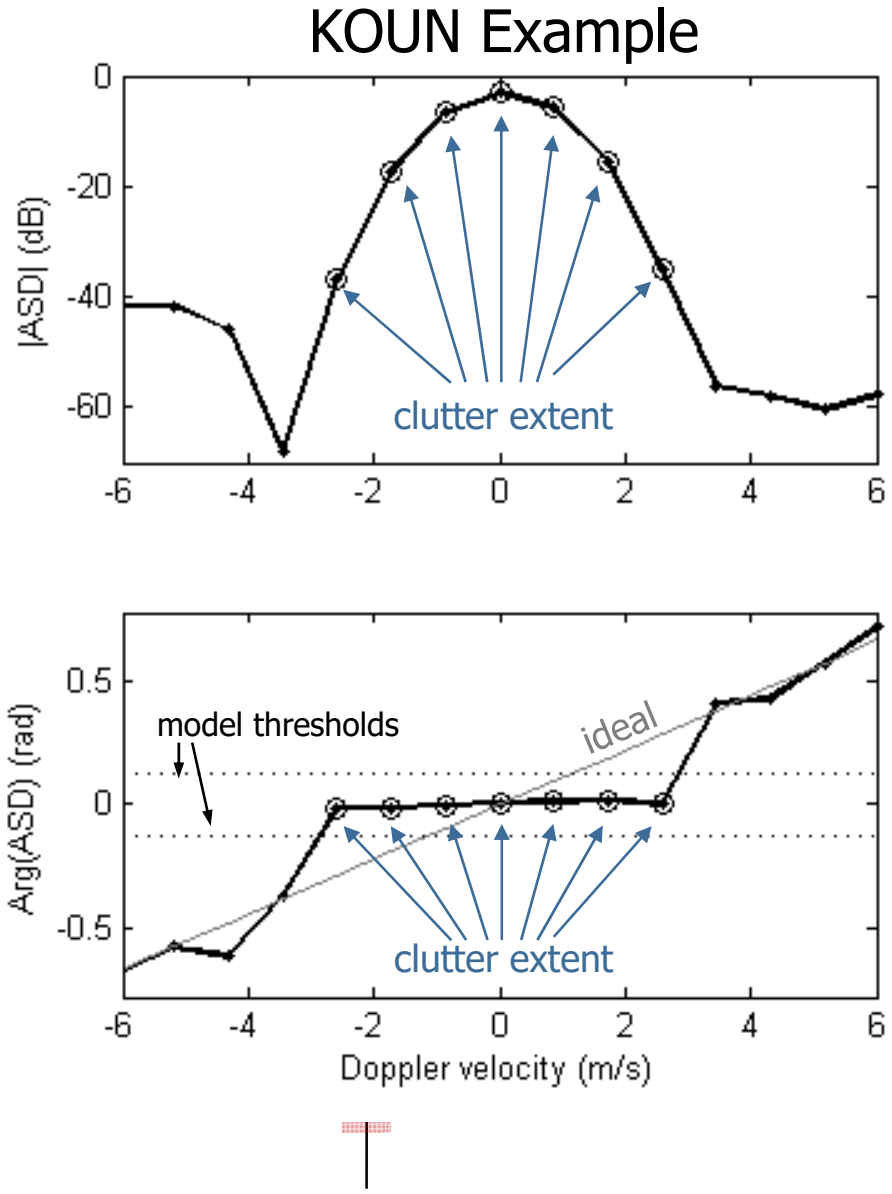
nothing is ideal…



Spectral leakage in the **measured ASD** is the basis for **clutter detection** in CLEAN-AP

how does CLEAN-AP work?

Integrated Detection and Filtering



Detection

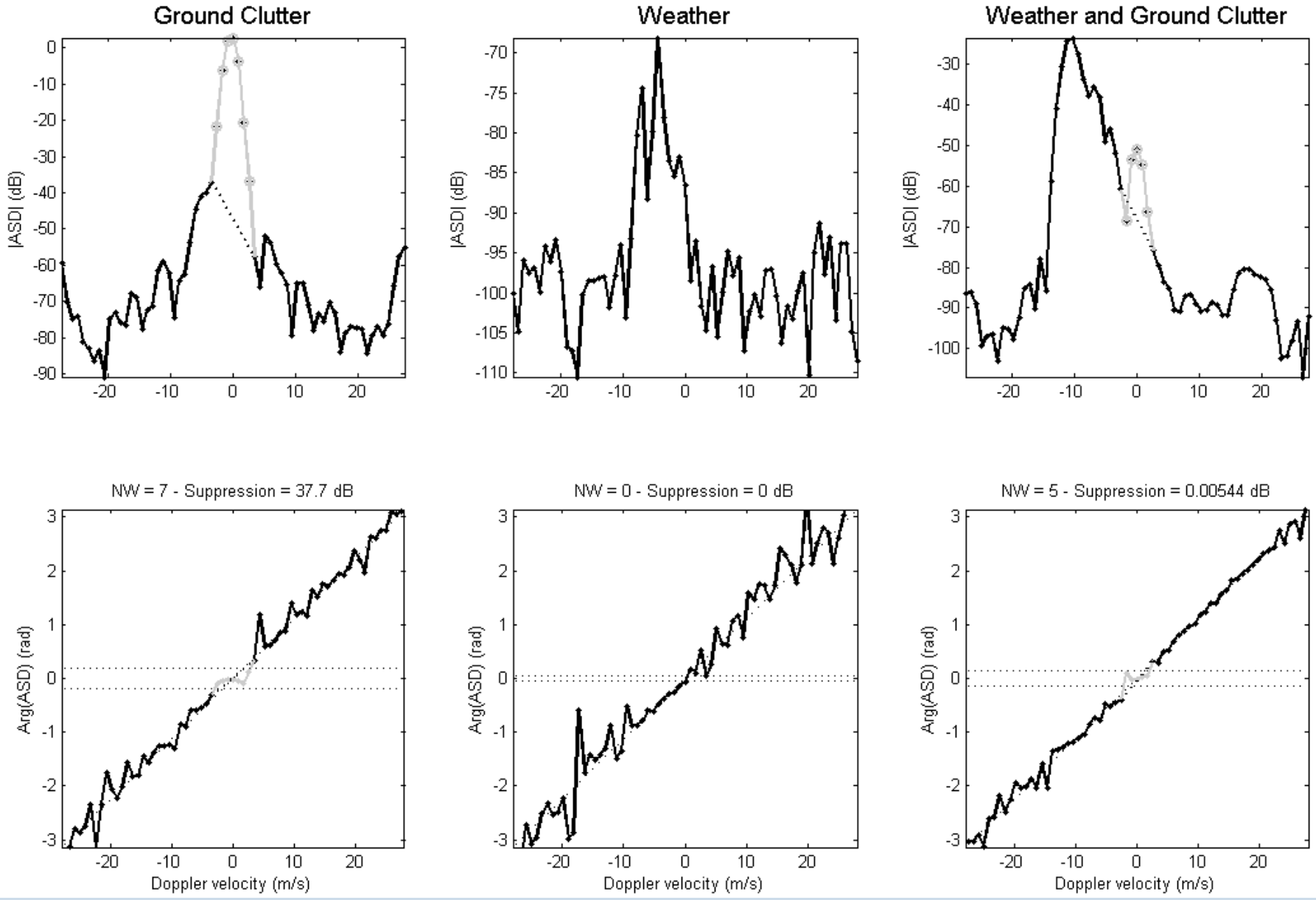
- Select window
  - Estimate CNR
  - Minimum tapering
- Compute ASD
- Identify clutter extent
  - Arg(ASD) ~ 0 due to leakage
  - Threshold from clutter model

Filtering

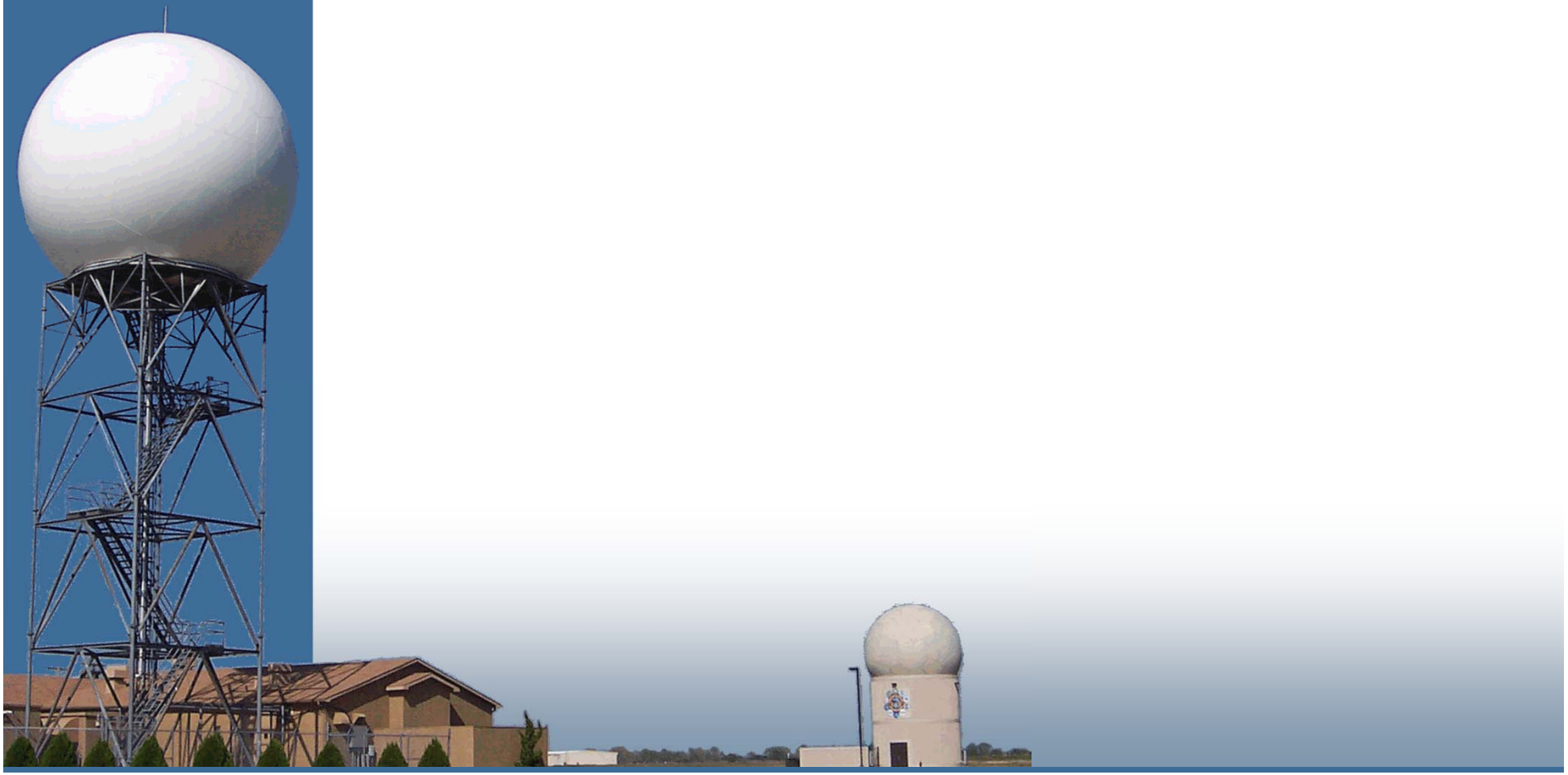
- Remove clutter
- Reconstruct weather
  - Spectral interpolation

- Use filtered ASD to estimate meteorological variables

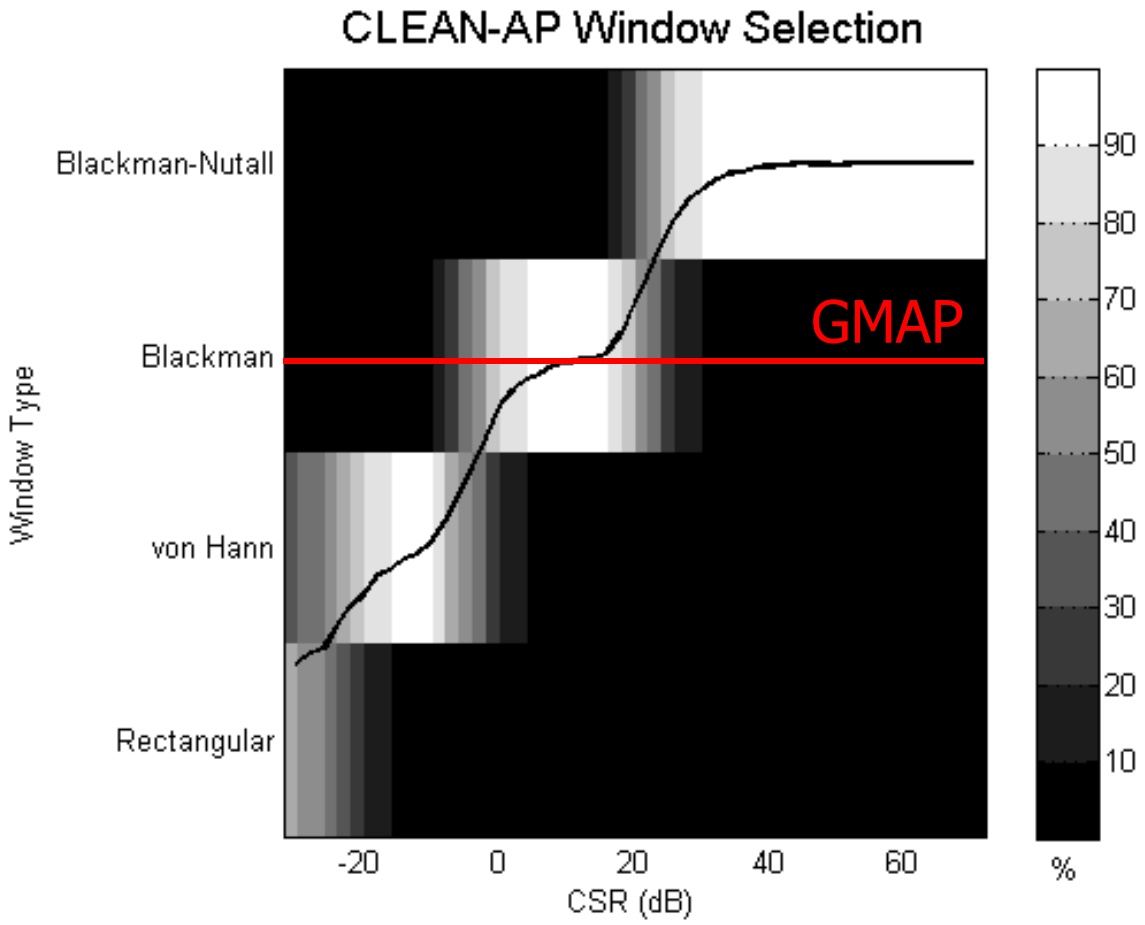
CLEAN-AP Performance Examples



Performance Summary

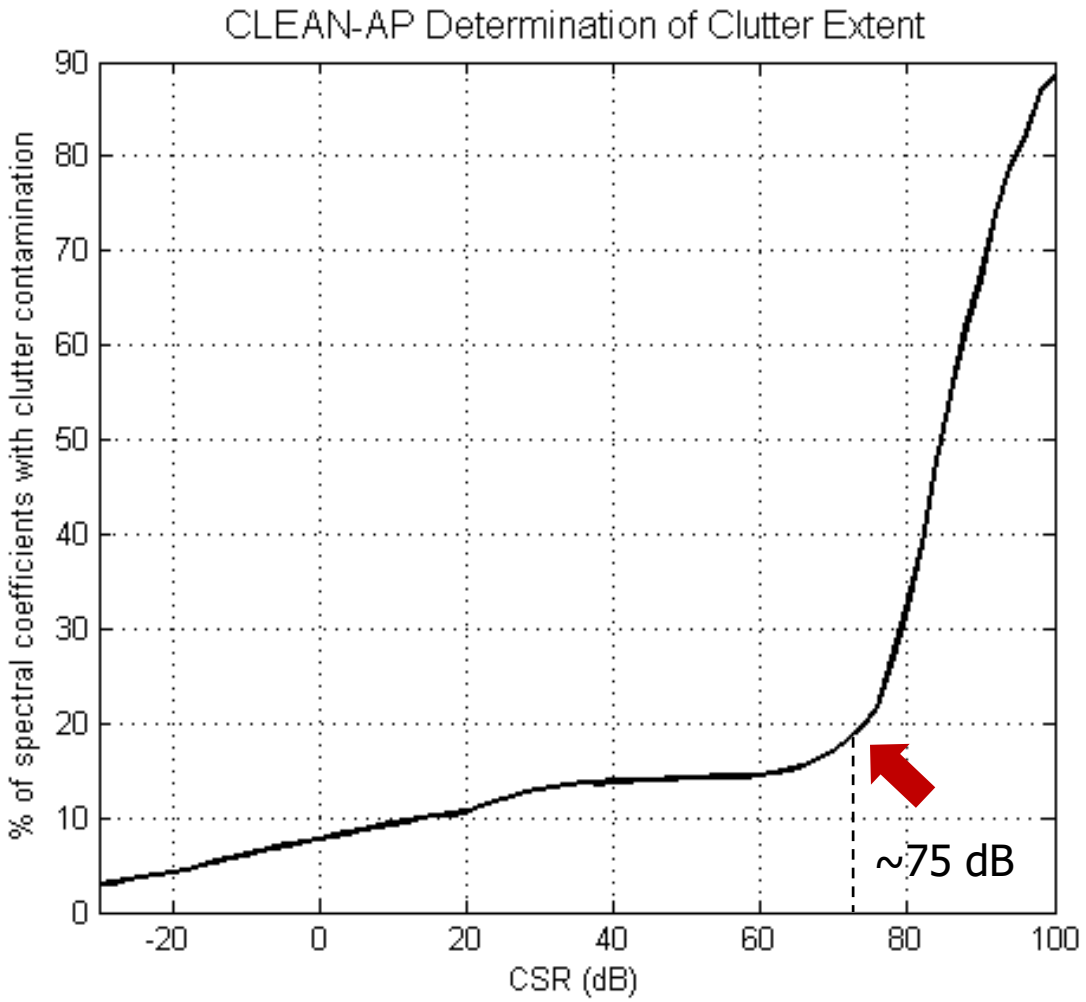


data window selection
CLEAN-AP vs. GMAP



CLEAN-AP picks a window that provides a good **compromise** between **clutter suppression** and **variance of estimates**

determination of clutter extent

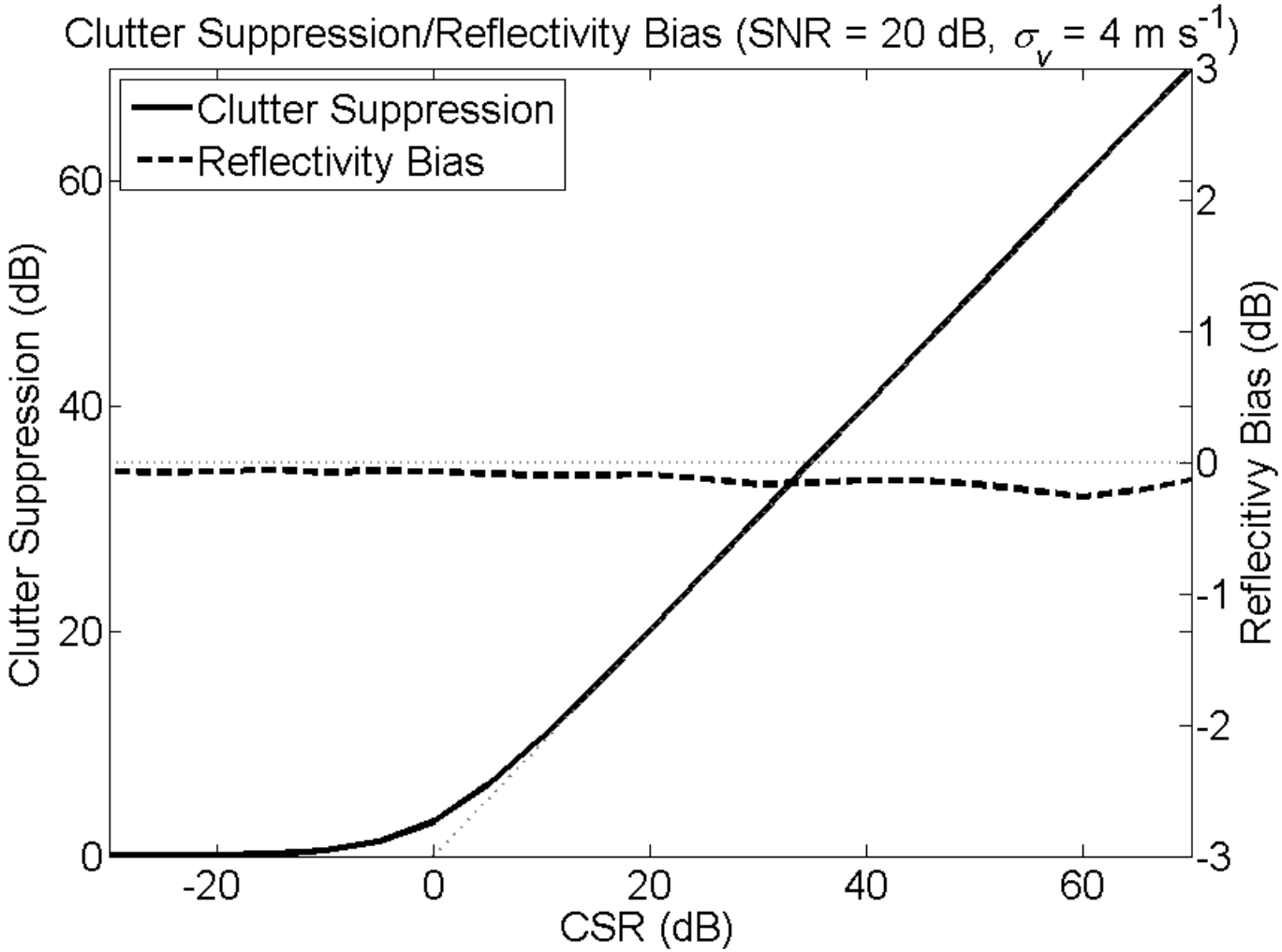


NW determination		
	mag	**phase**
GMAP	✓	
CLEAN-AP	✓	✓

CLEAN-AP uses **magnitude and phase** for **improved clutter extent** determination

Clutter Suppression

Doppler Mode



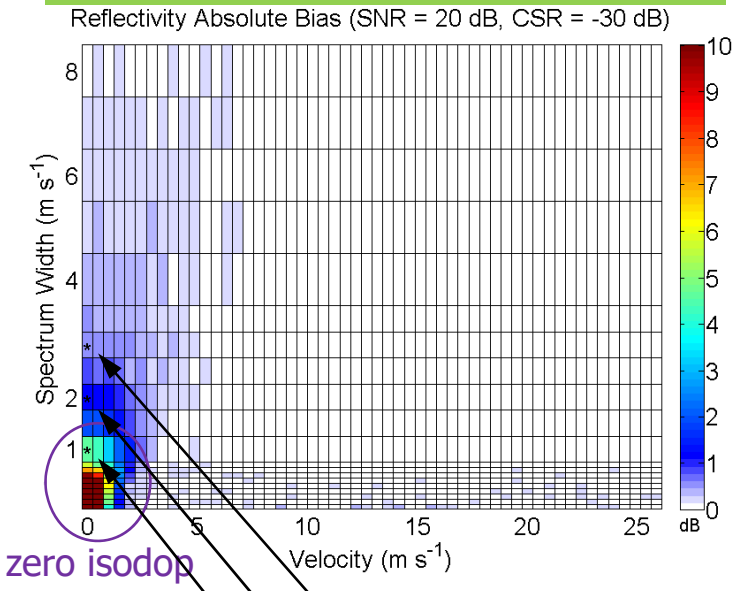
CLEAN-AP has **good clutter suppression** with **negligible biases in reflectivity estimates**

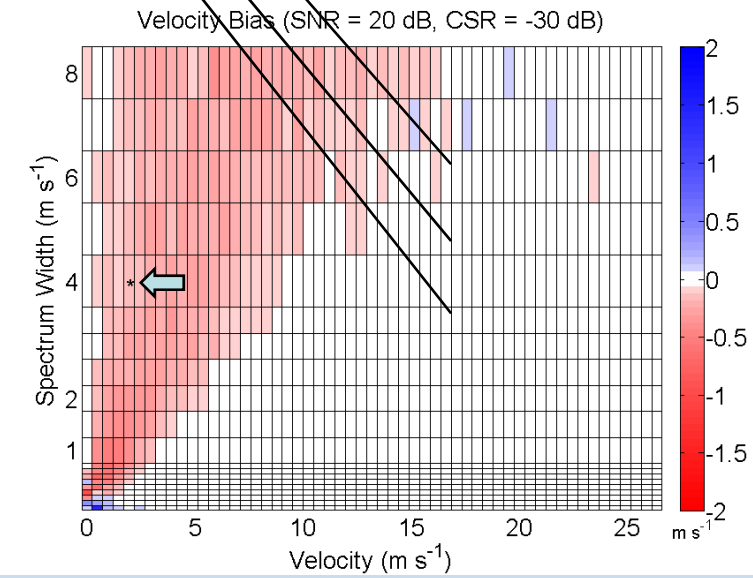
CLEAN-AP effects on weather

Reflectivity

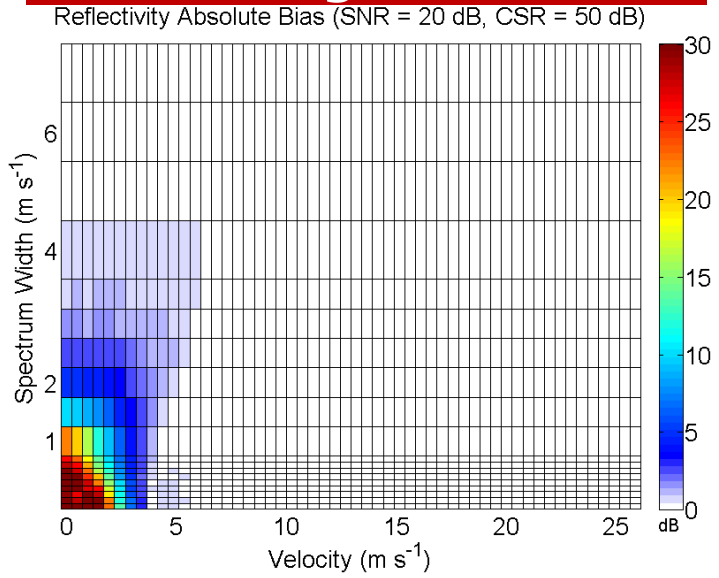
Velocity

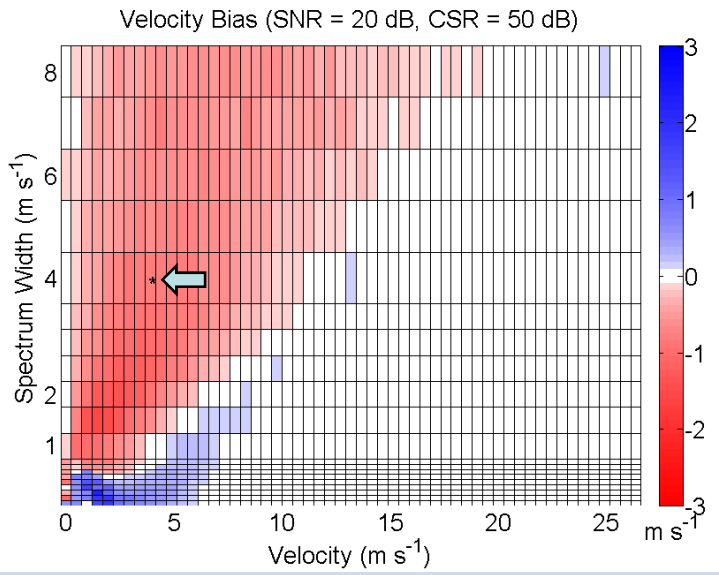
No Clutter



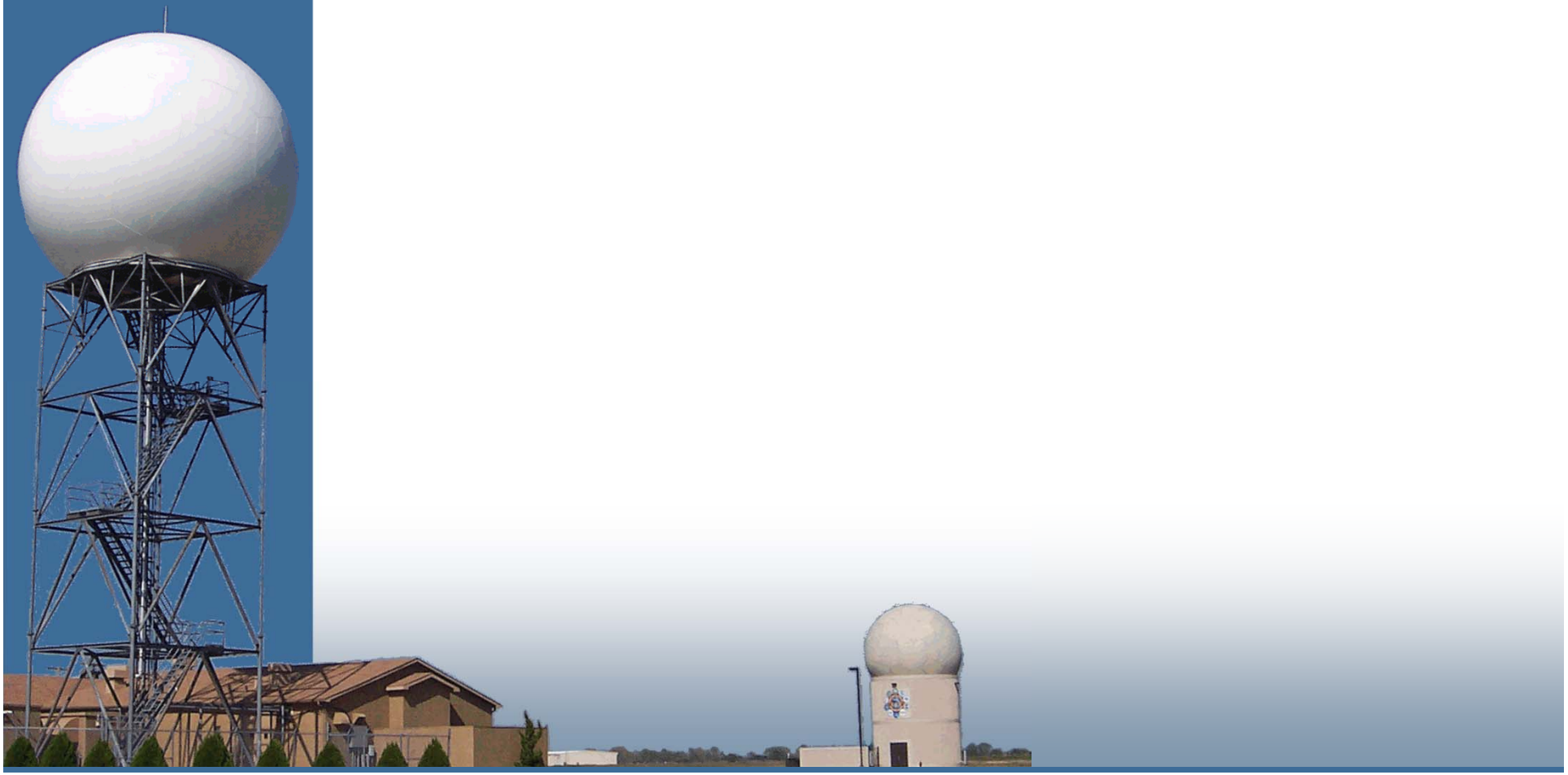


Strong Clutter





More Case Examples



KTLX – 27 Oct 2006