NCAR

Clutter Mitigation Decision (CMD) system for the NEXRAD ORDA

NEXRAD TAC Meeting

Norman, OK

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Motivation

Better Data Quality: Mitigation (filtering) of AP clutter without weather attenuation

- Currently: Only detect AP clutter in RPG
  - No “correction” only censoring of data
  - Clutter filter either *on or off* everywhere
- However: The new fast RDA (e.g. RVP8) makes possible:
  - *Real time clutter identification and filtering*
  - Spectral processing with FFTs, etc (e.g., GMAP)

Data Quality Goals

Real time detection and *correction* of AP clutter (and NP)

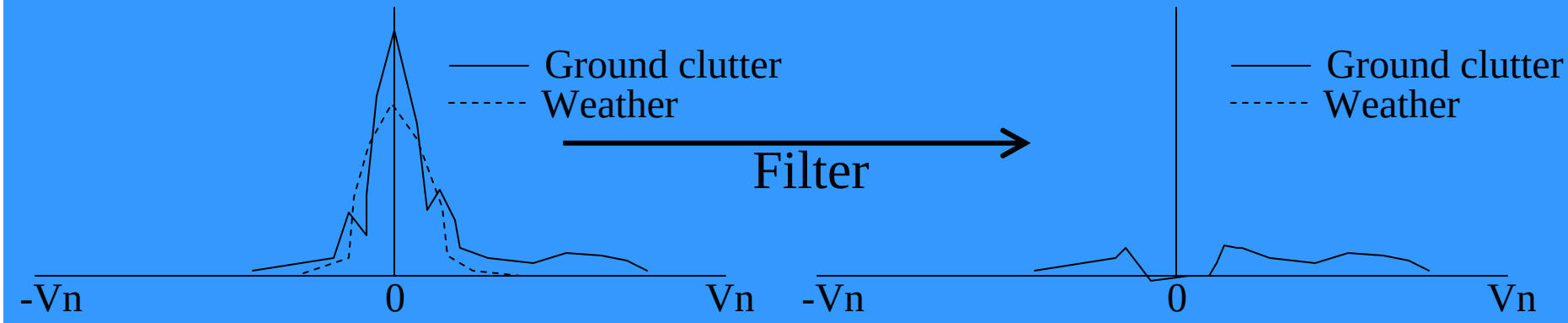
1. Remove clutter signatures from radar displays (and products)
2. Recalculate radar moments *after filtering* so that underlying weather signatures are revealed
    - For example, providing better precipitation estimates

What Happens if GMAP is Applied Everywhere?

- GMAP can eliminate clutter signal and then estimate any attenuated weather echo if the weather spectrum width is wide.
  - Works well for wide spectrum width weather (e.g. convection)
- However, this reflectivity compensation scheme does not work well for narrow spectrum width weather (e.g. stratiform rain/snow) that is at or near zero velocity
- GMAP also causes reflectivity bias when folded velocities appear at 0 m/s. (i.e., $\pm 2V_N$)
  - This is common in long PRT surveillance scans (small V_N)
  - This is less common in short PRT Doppler scans (large V_N)

Clutter with Weather Spectrum Example

- Narrow width, zero velocity weather echoes overlaid with clutter are unrecoverable



In such cases the best that can be done is to detect which signal dominates and act accordingly

CMD

- Differentiates between zero velocity weather and clutter
- Identify “gates” dominated by clutter
- CMD allows application of GMAP *only* to clutter identified gates thus preserving weather echoes
- Together, CMD and GMAP identify and remove clutter at the RDA
  - Alleviates need for manual clutter filter control
  - Clutter echoes never reach RPG

CMD Fuzzy Logic Algorithm

- Compute feature fields
  - Z SPIN (measures gradient sign changes in range)
  - Z texture (measures squared difference in dBZ with range)
  - CPA (clutter phase alignment – measures phase variation)
- Apply membership functions
- Combine SPIN and texture using fuzzy OR rule
- Fuzzy combination of feature fields
- Produce clutter map
- Dual-Pol CMD already implemented and used operationally during REFRACTT 06

Clutter Phase Alignment - CPA

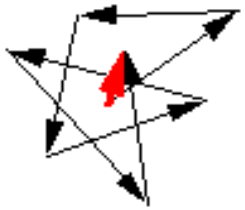
$$CPA = \frac{\left|\sum hh_i\right|}{\sum\left|hh_i\right|}$$

Time series of I&Q

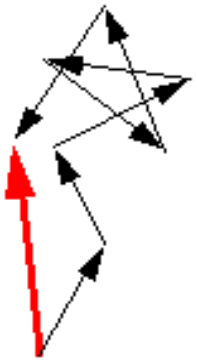
- In clutter, the phase of each pulse in the time series for a particular gate is almost constant since the clutter does not move much and is at a constant distance from the radar.
- In noise, the phase from pulse to pulse is random.
- In weather, the phase from pulse to pulse will vary depending on the velocity of the targets within the illumination volume.

CPA Phasor Diagrams

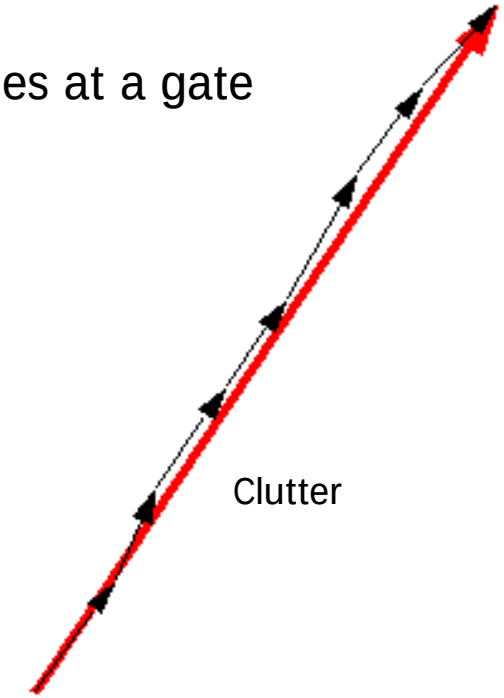
Adding the complex I&Q samples at a gate



Noise or
weather with
non-zero velocity



Weather mixed
with clutter



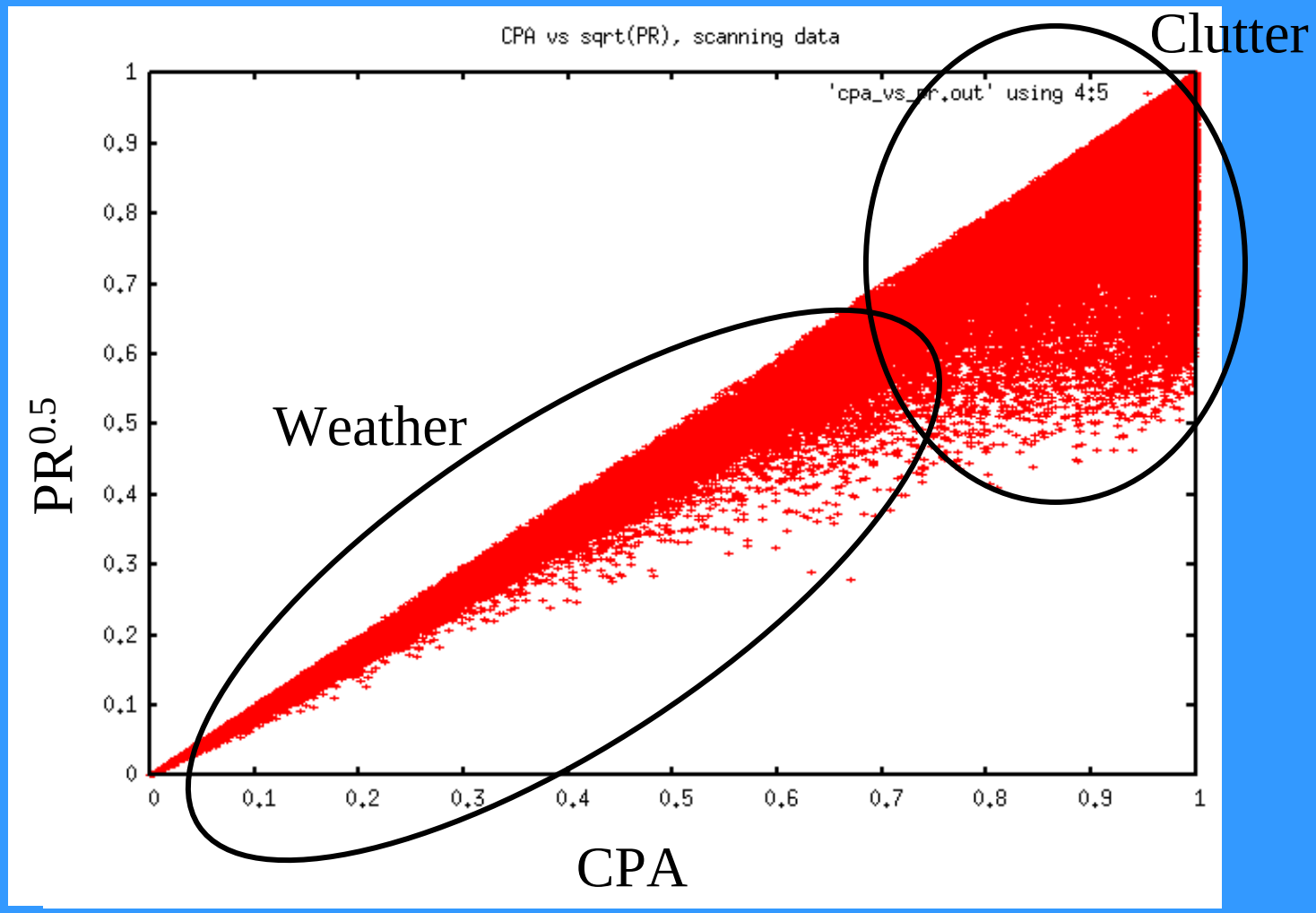
Clutter

CPA and Power Ratio (PR)

$$CPA = \frac{\left|\sum hh_i\right|}{\sum \left|hh_i\right|} \geq \left[\frac{\text{Zero Velocity Power}}{\text{Total Power}}\right]^{0.5} = PR^{0.5}$$

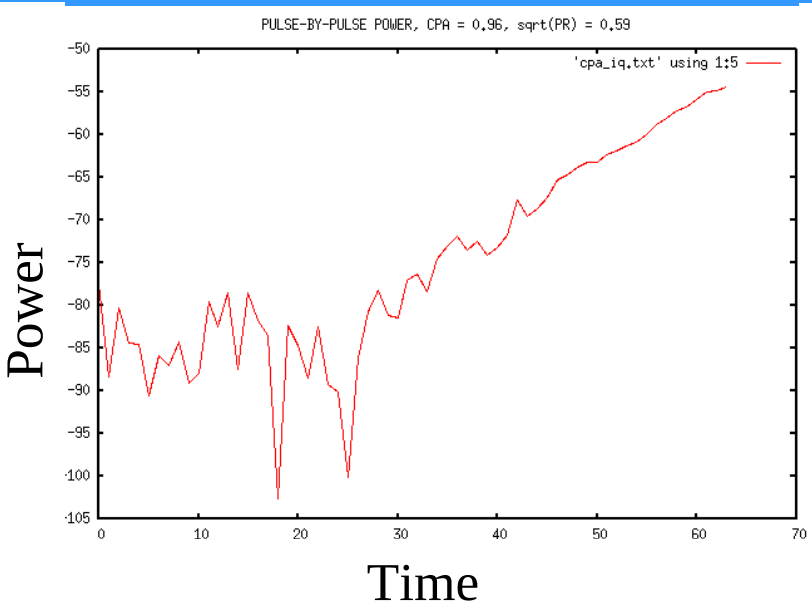
- Can be proven analytically
- CPA and power ratio similar for constant clutter
- *CPA better clutter indicator in strong gradient regions*

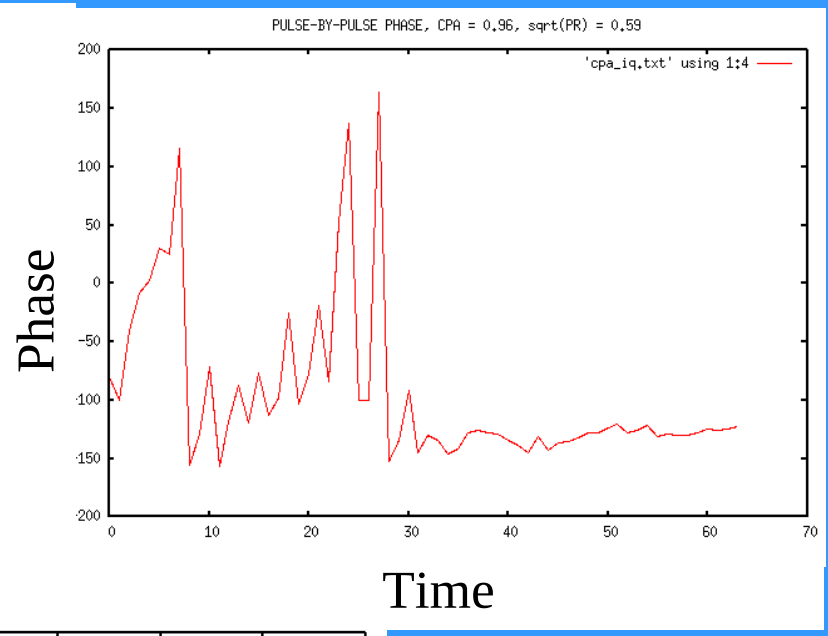
Power Ratio versus CPA

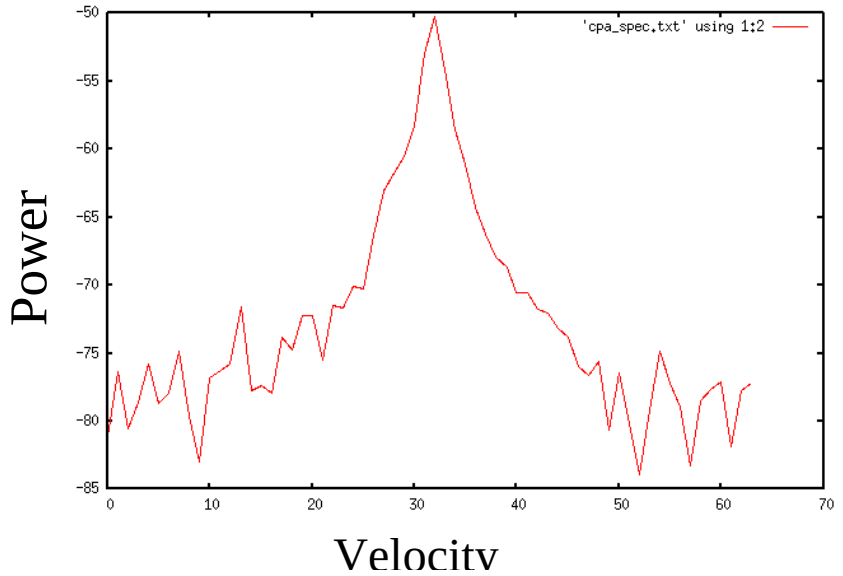


Example in Reflectivity Gradient

CPA = 0.96, $PR^{0.5}$ = 0.59

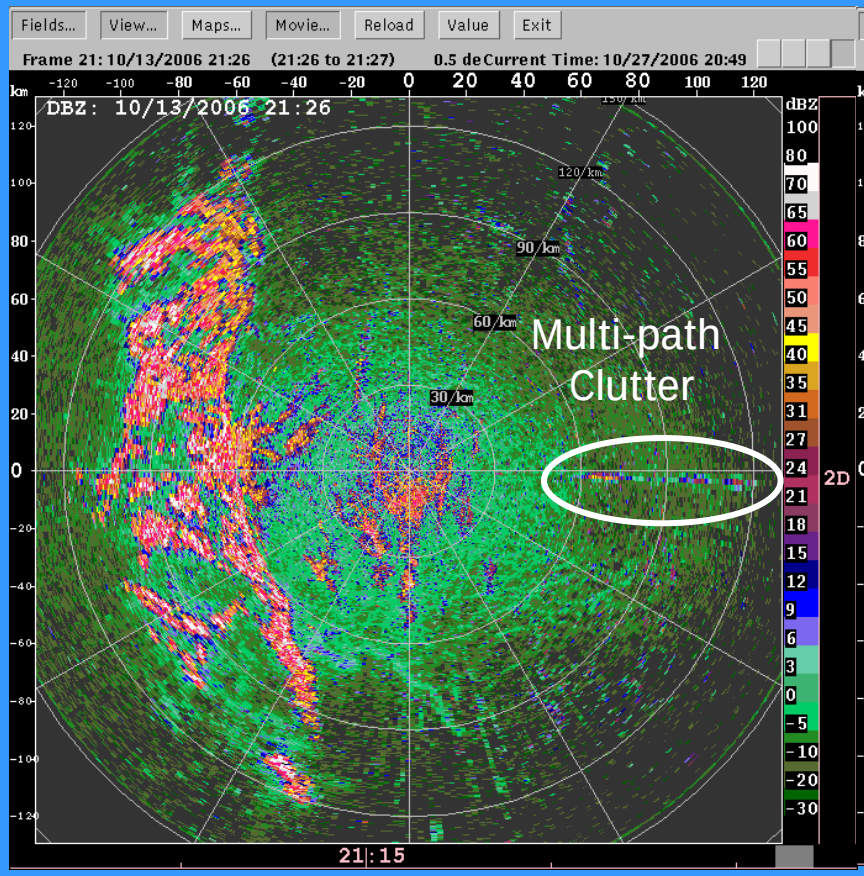




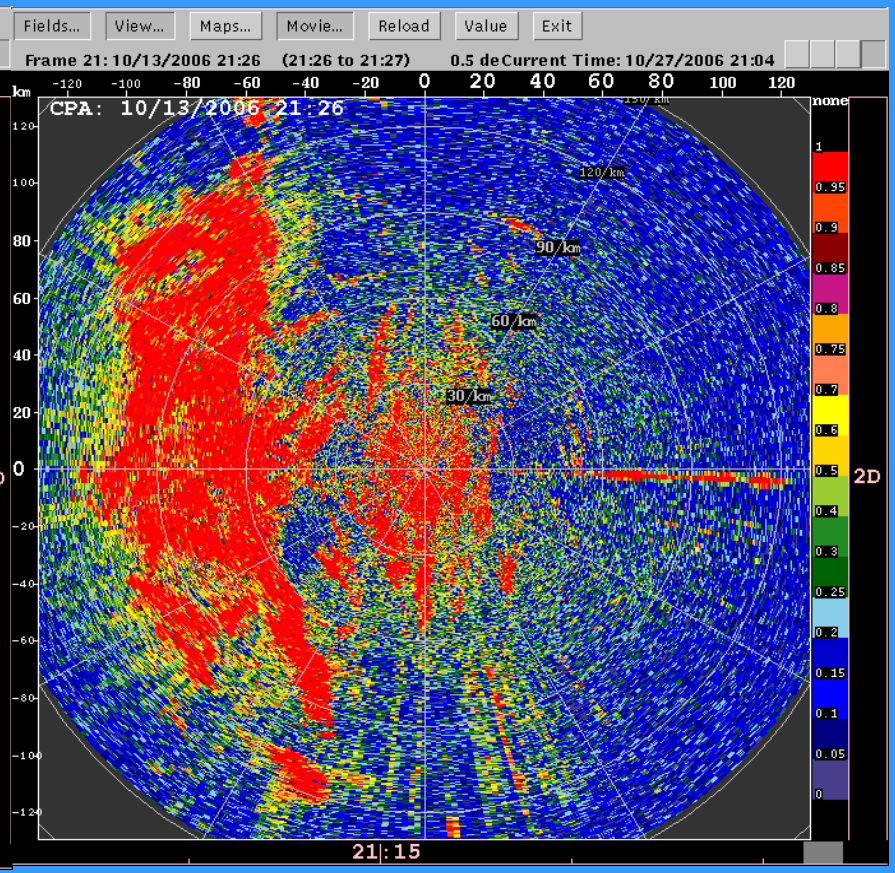


CPA Feature Field

Example of CPA on a clear day – Denver Front Range NEXRAD - KFTG



DBZ



CPA

CMD Example Data Sets

- During the REFRACTT Experiment of the summer of 2006, there was an A1 (time series) recorder at KFTG, Denver
- This provided many data sets for CMD testing and development
- Importantly, such processed data set can be compared *directly* to the actual KFTG Level II data recorded by the NWS (i.e., what forecasters actually saw)
- One can see clearly the data quality improvements afforded by CMD through these comparisons

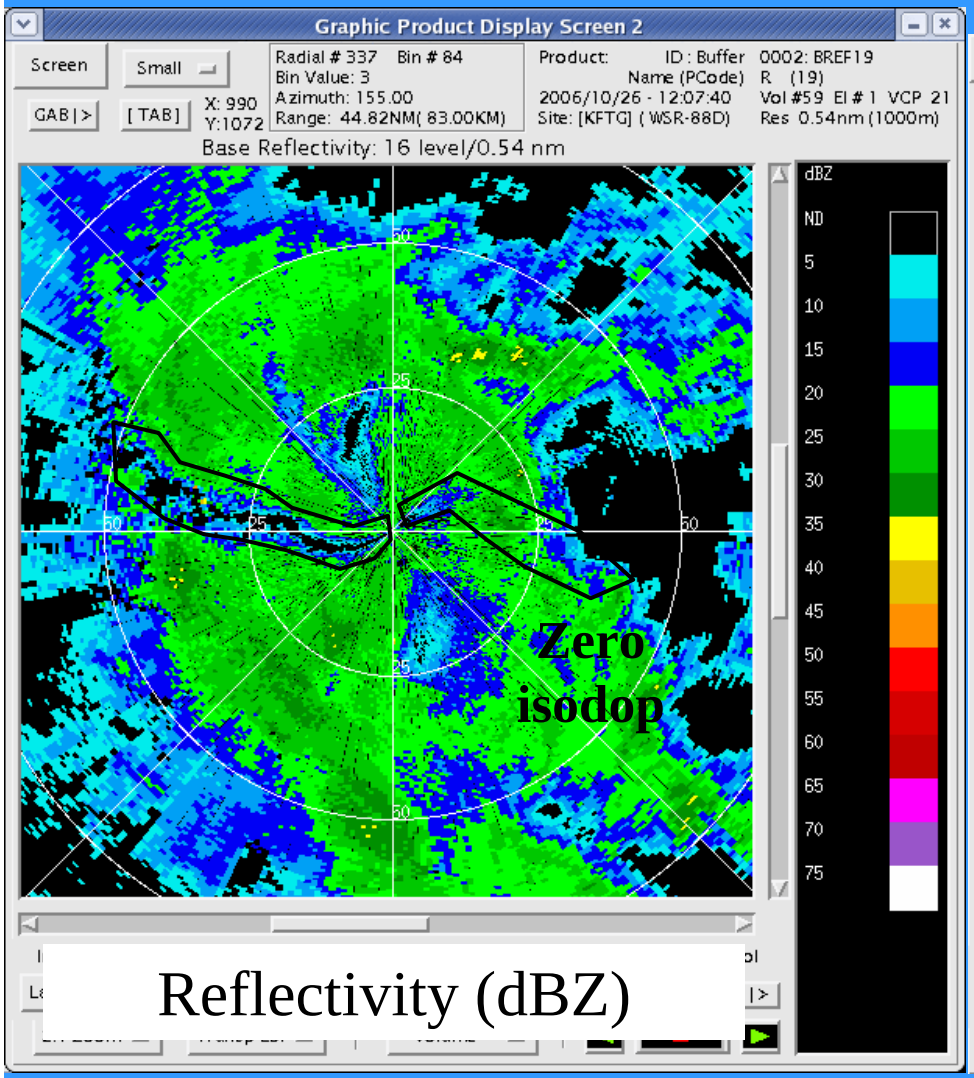
KFTG Time Series Data Sets

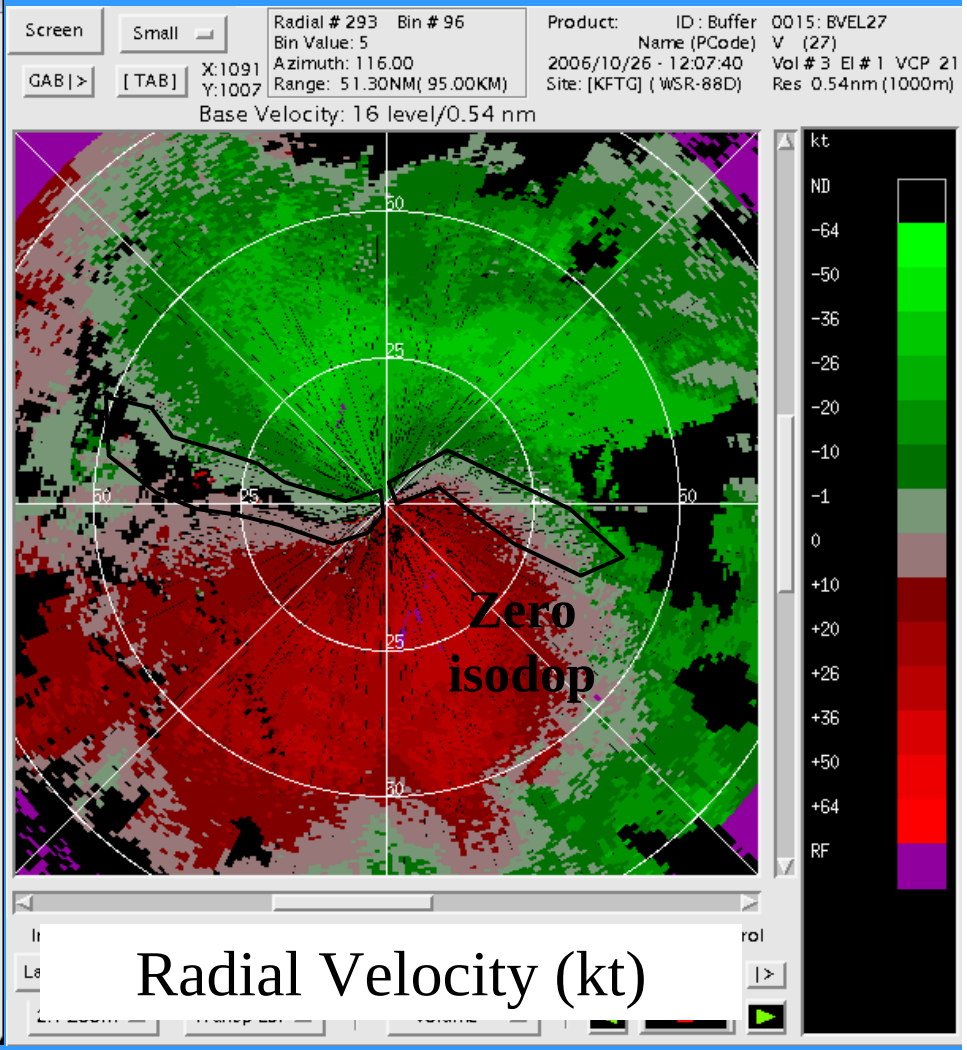
- 21 Sept 2006 – Scattered showers
  - 03:00 UTC
  - 05:30 UTC
- 09 Oct 2006 – Stratiform rain
  - 18:00 UTC
  - 22:00 UTC
- **10 Oct 2006 – Stratiform**
- 13 Oct 2006 – Clear case
- 17 Oct 2006 – Snow over mountains
- **26 Oct 2006 – Widespread stratiform snow**
- 12 Nov 2006 – Snow

CMD Test Procedure

- Long PRT (surveillance) scan
  - Unfiltered I and Q
  - Processing used 16 samples
  - Indexed beams
  - CMD feature fields computed on single beam data
- CMD clutter map produced
- GMAP filter used on CMD clutter map
- Results compared to:
  - Unfiltered data from time series
  - Archive II (A2) data downloaded from NCDC

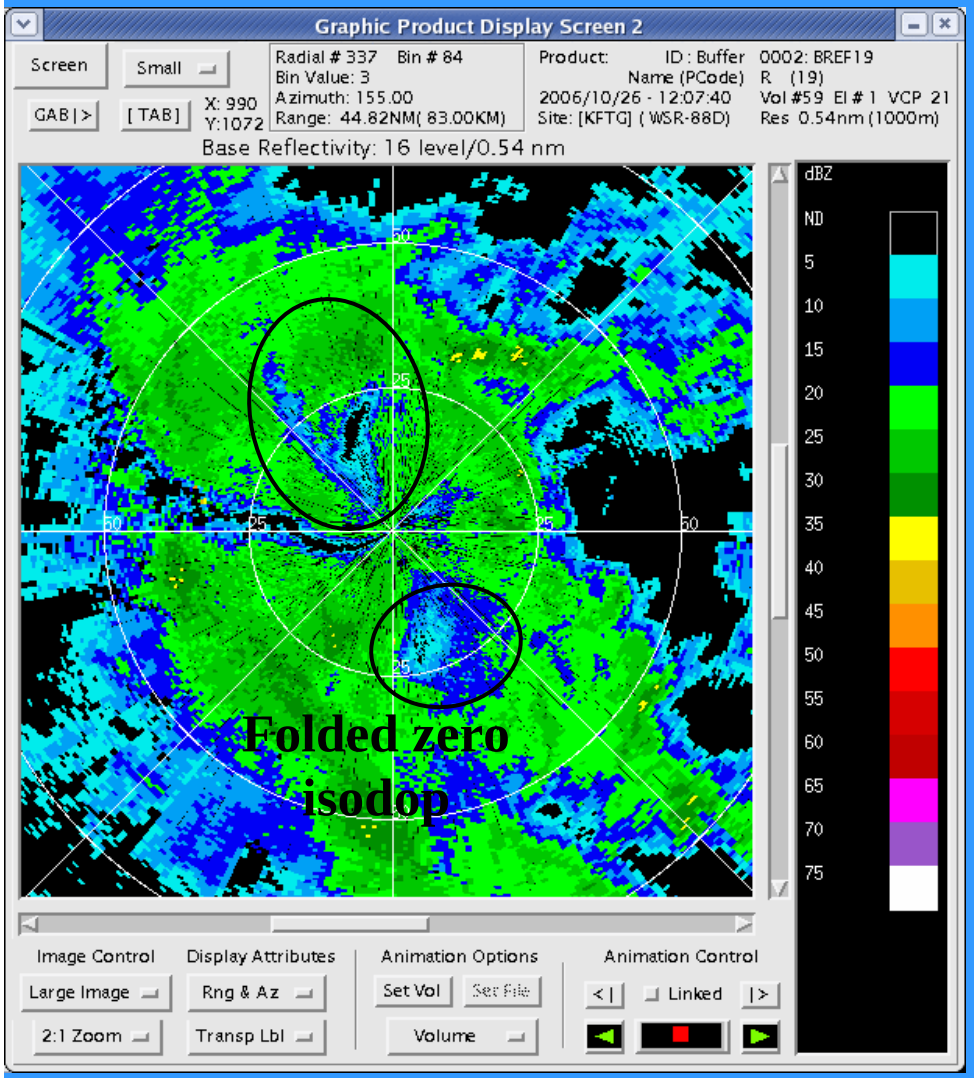
KFTG, 26 October 2006
A2 Data Downloaded From NCDC

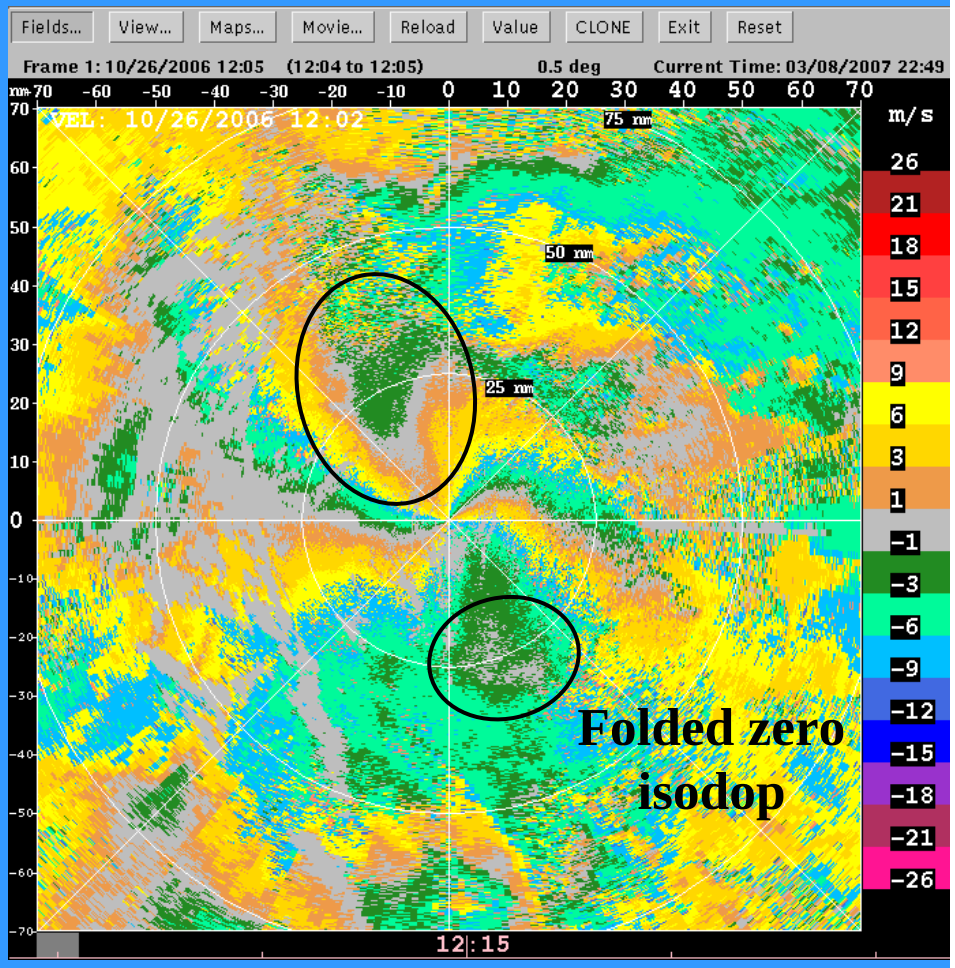




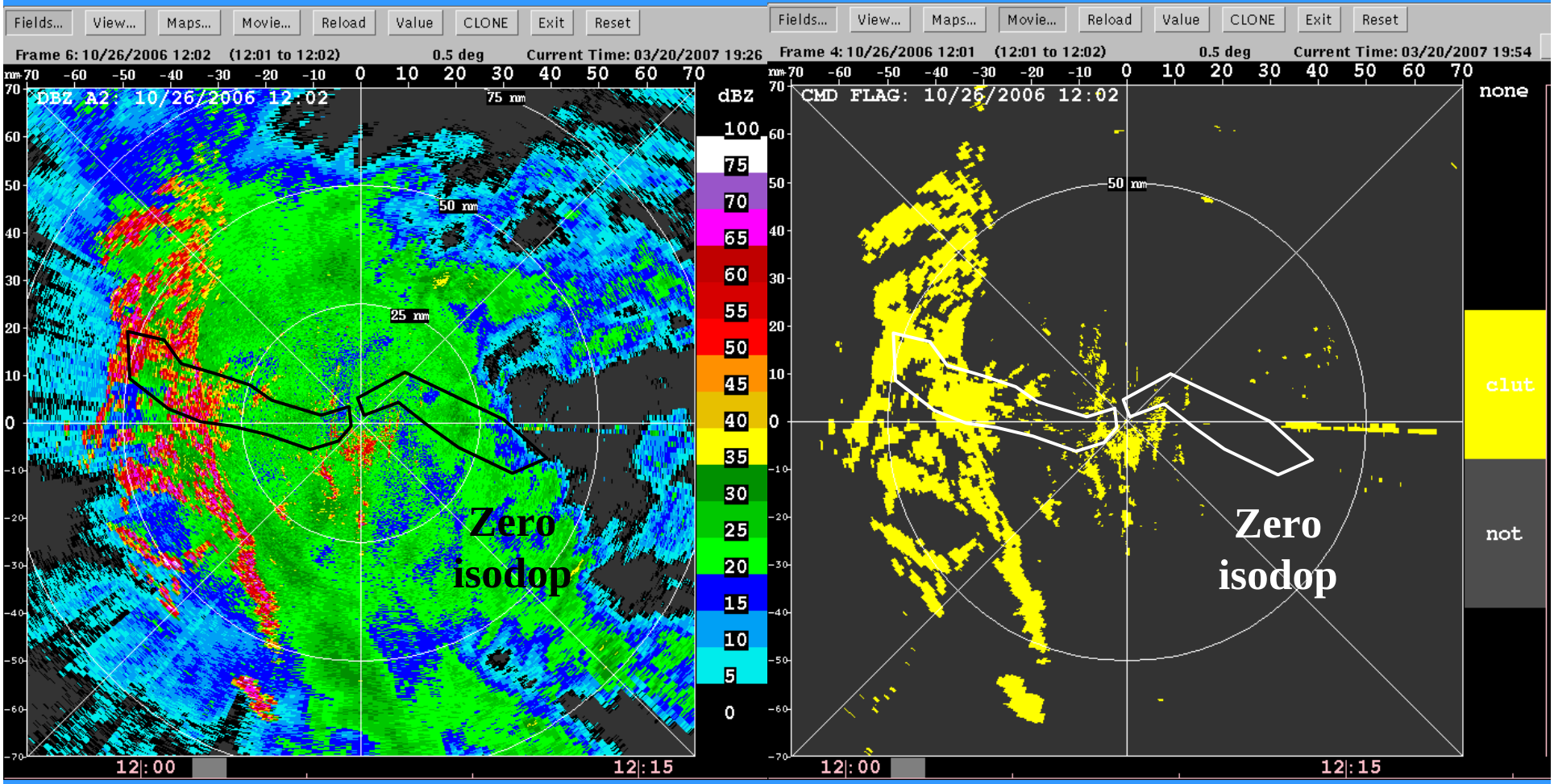
Archive II Z

Unfiltered Vr (from Surveillance)



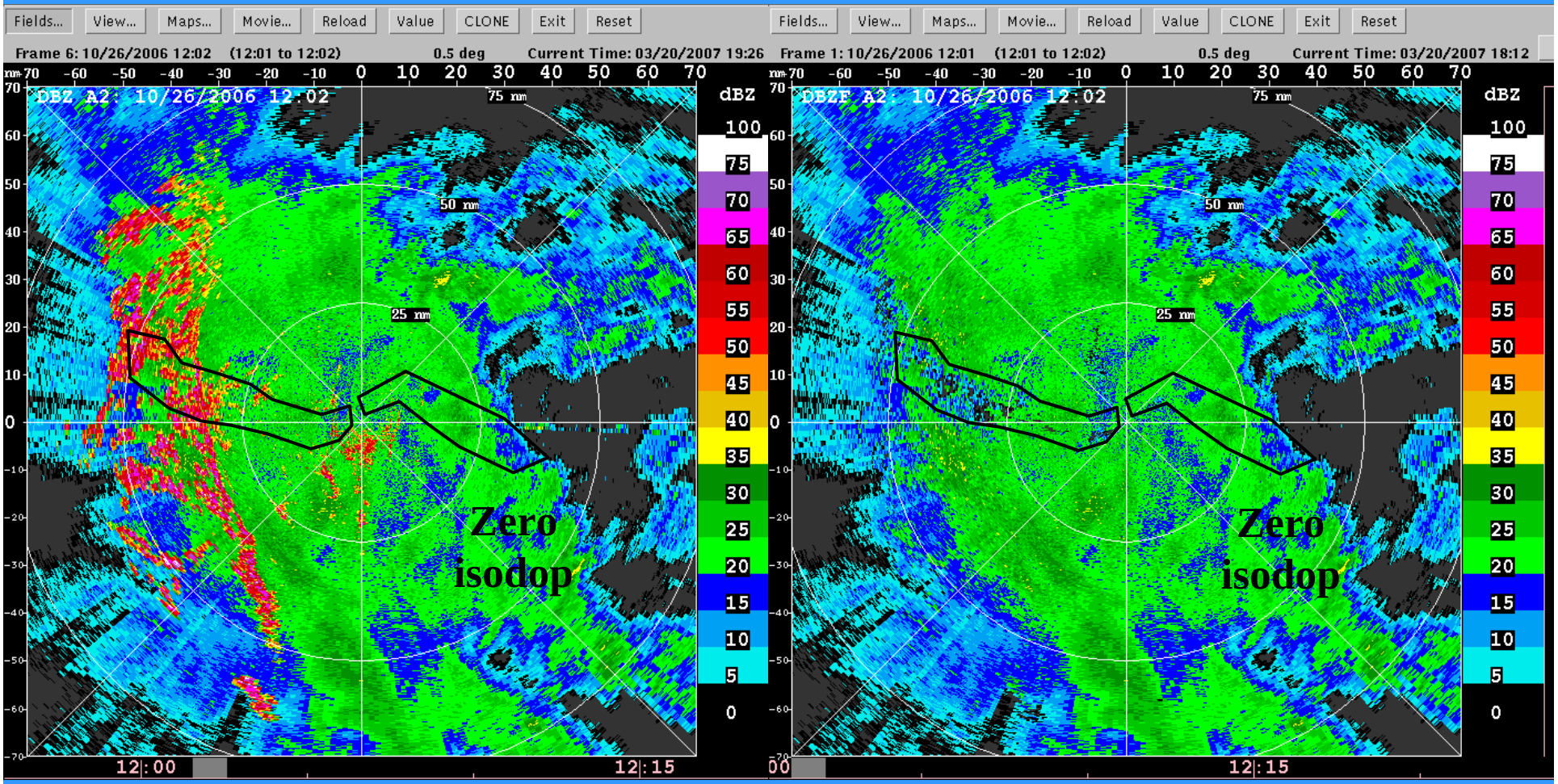


Unfiltered Z and CMD Clutter Map



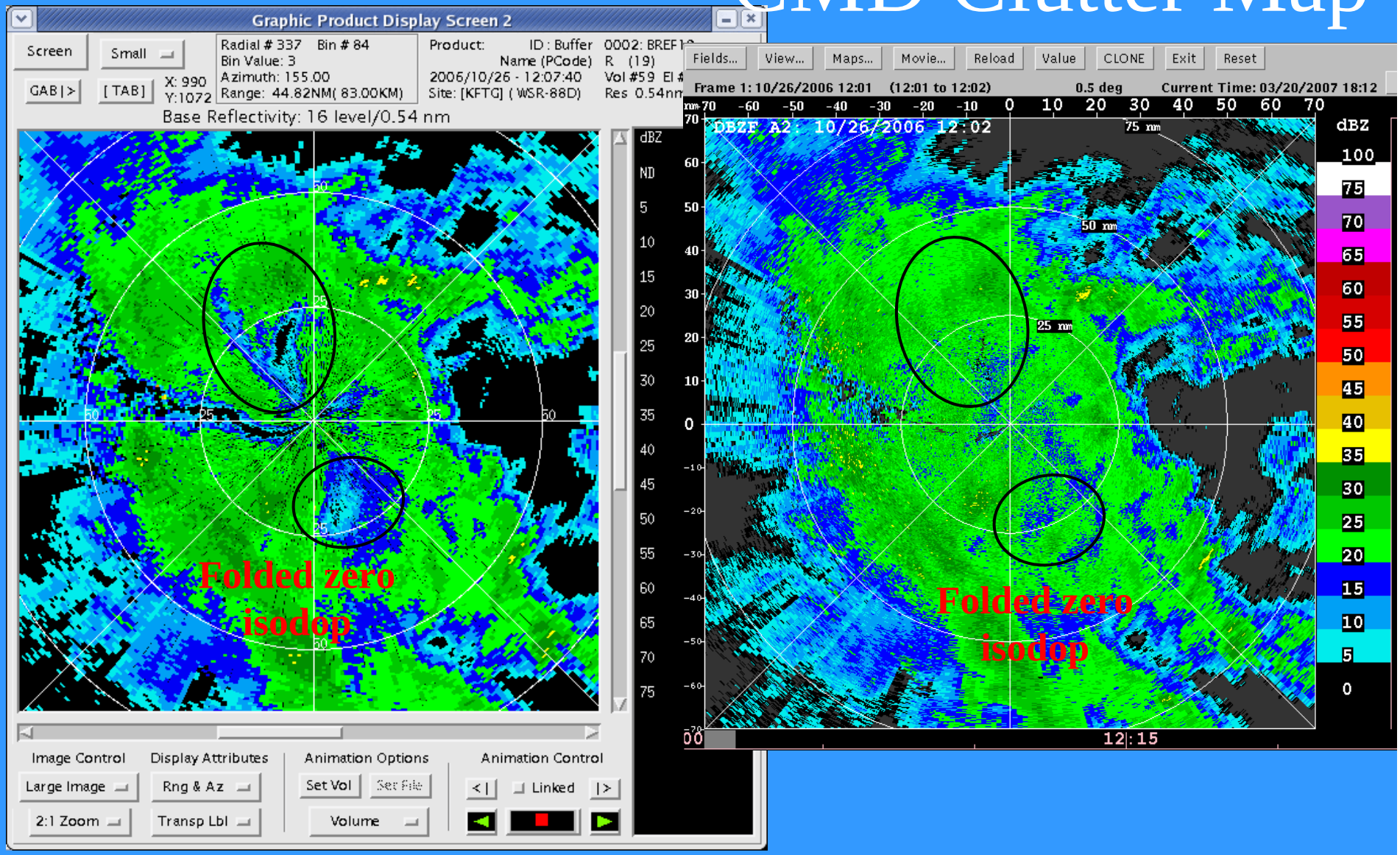
Unfiltered Z

Z Filtered on CMD Clutter Map

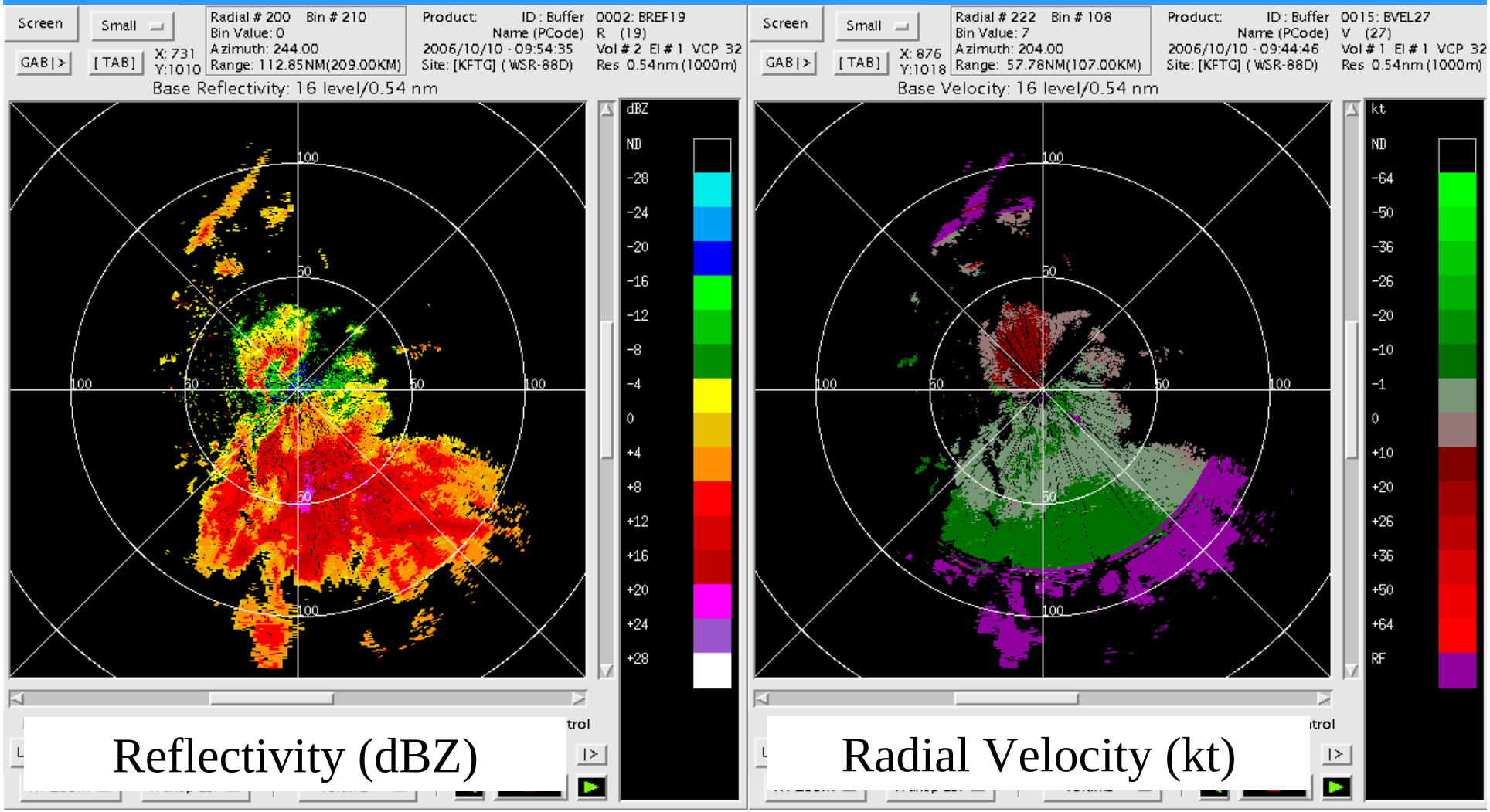


Archive II Z

Z Filtered on CMD Clutter Map

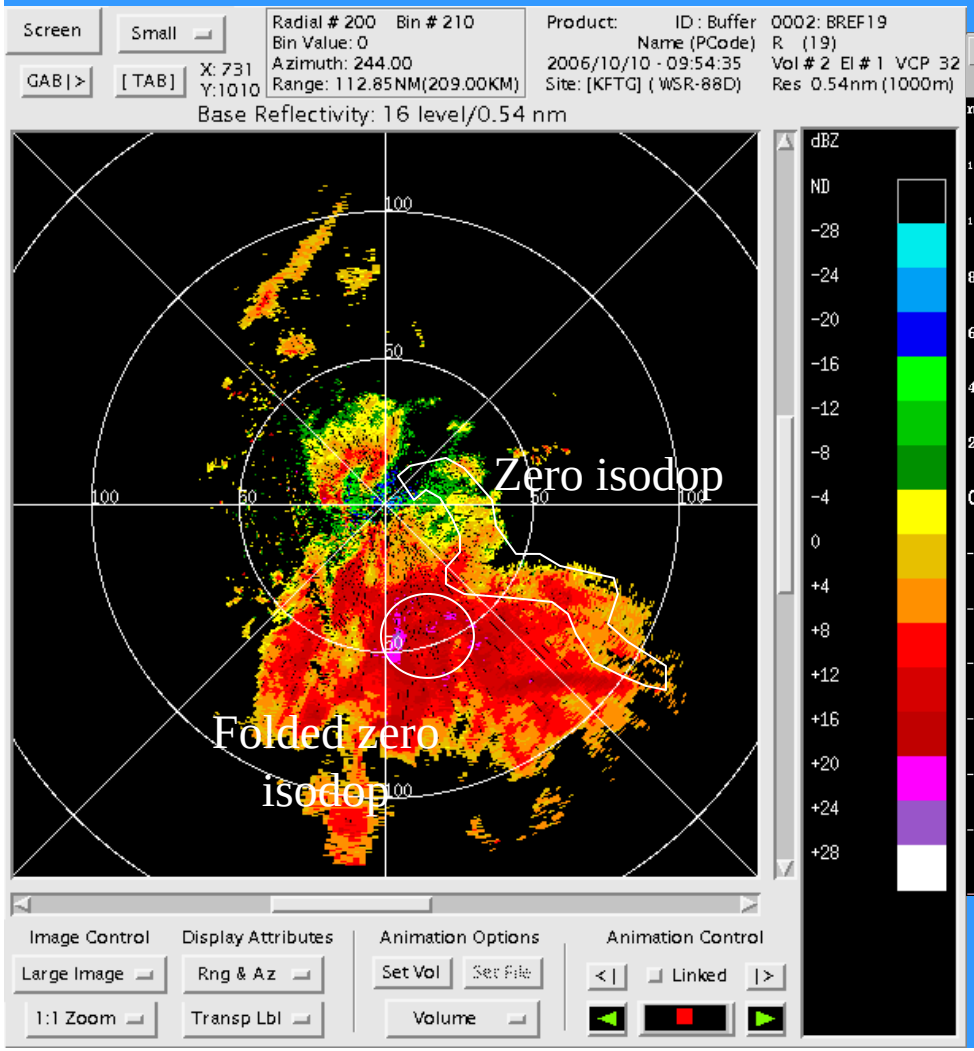


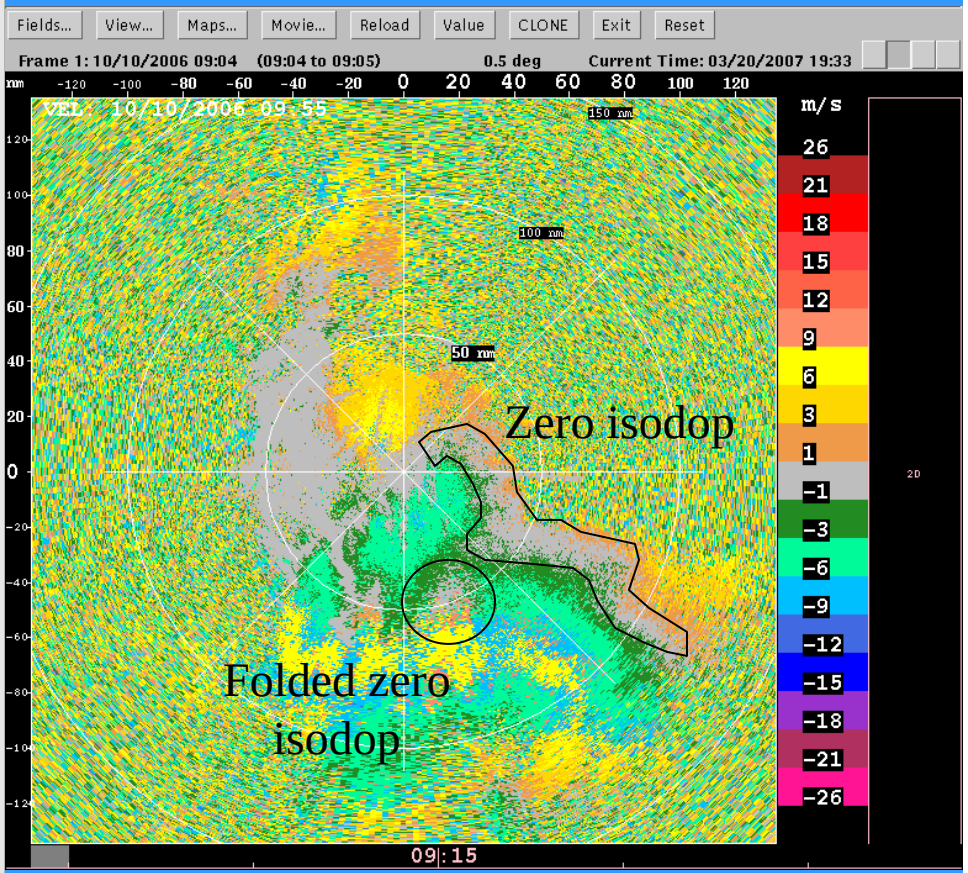
KFTG, 10 October 2006
A2 Data Downloaded From NCDC



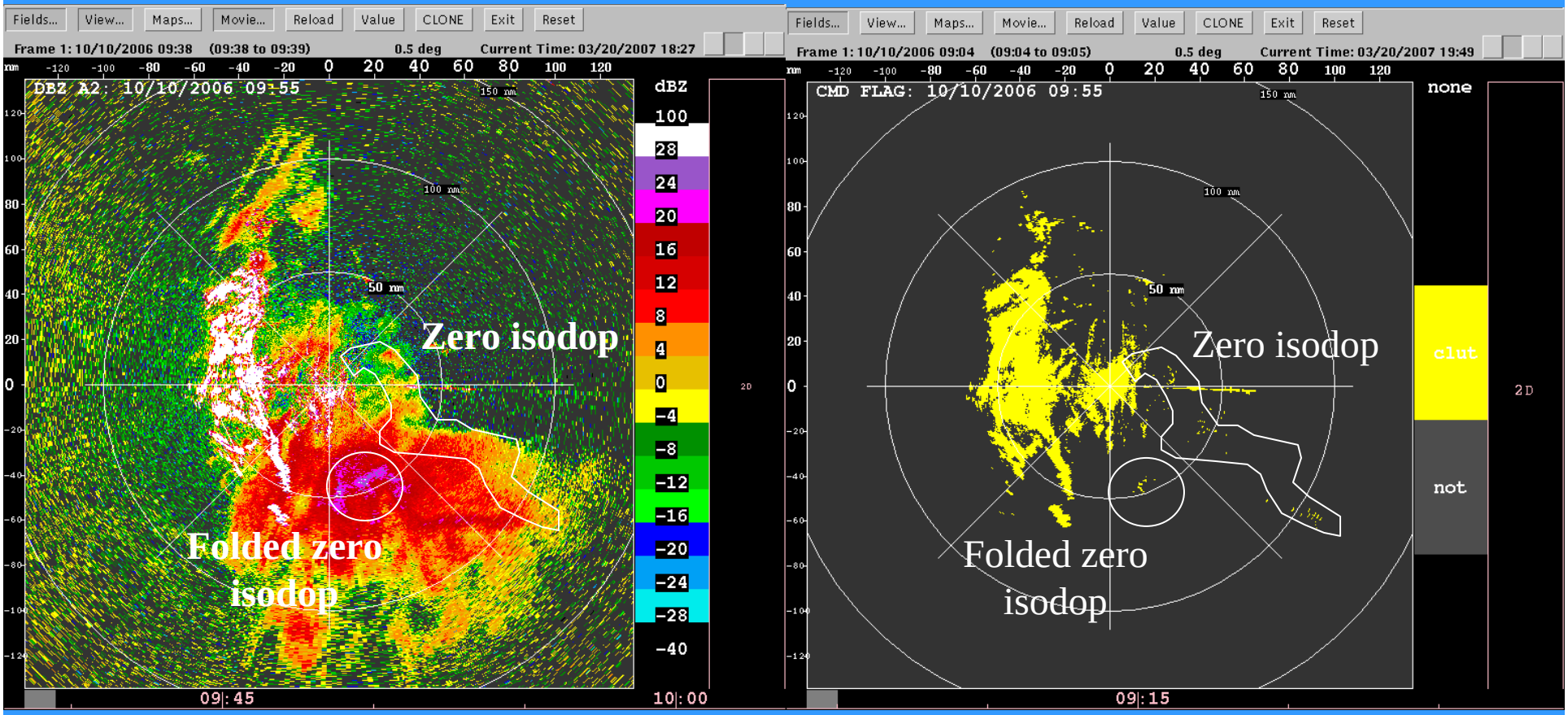
Archive II Z

Unfiltered Vr (from Surveillance)



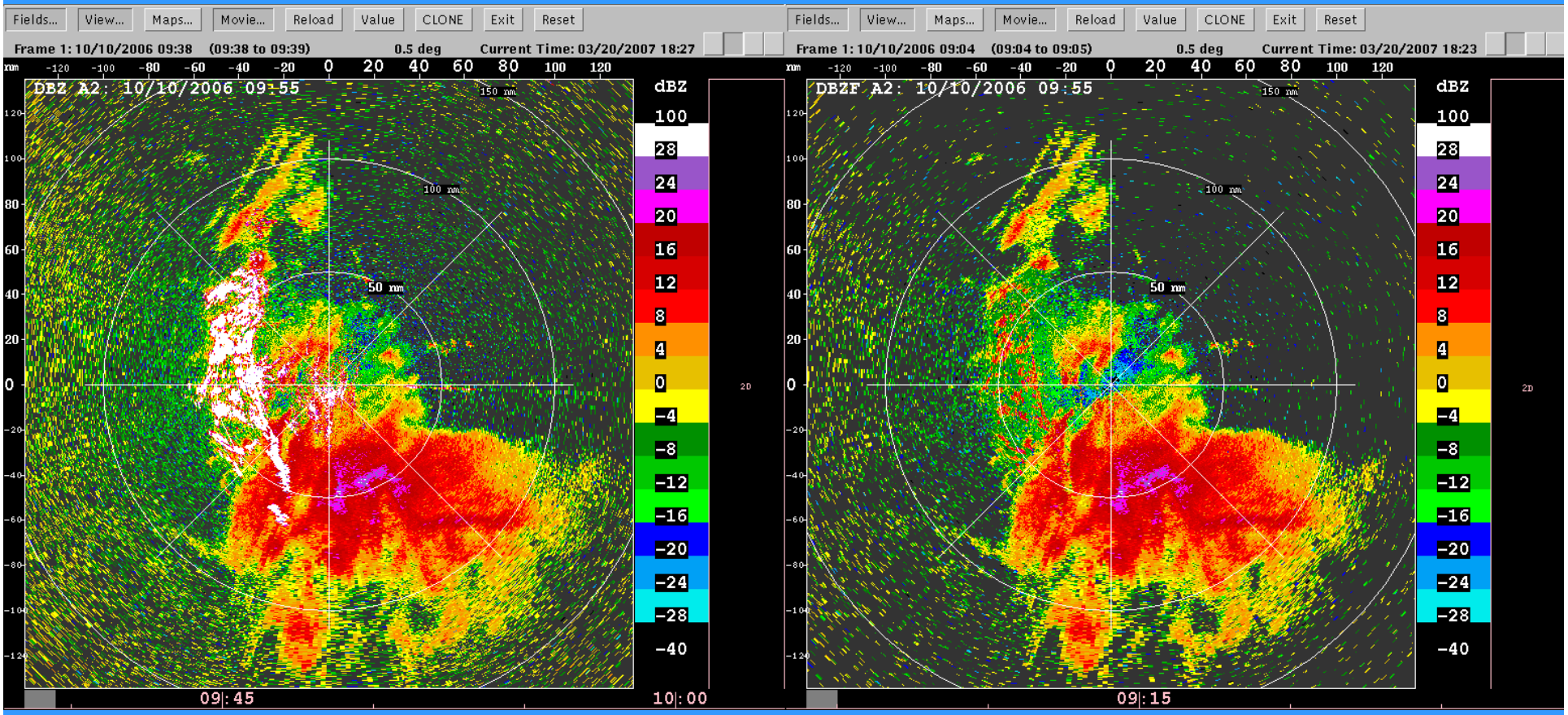


Unfiltered Z and CMD Clutter Map



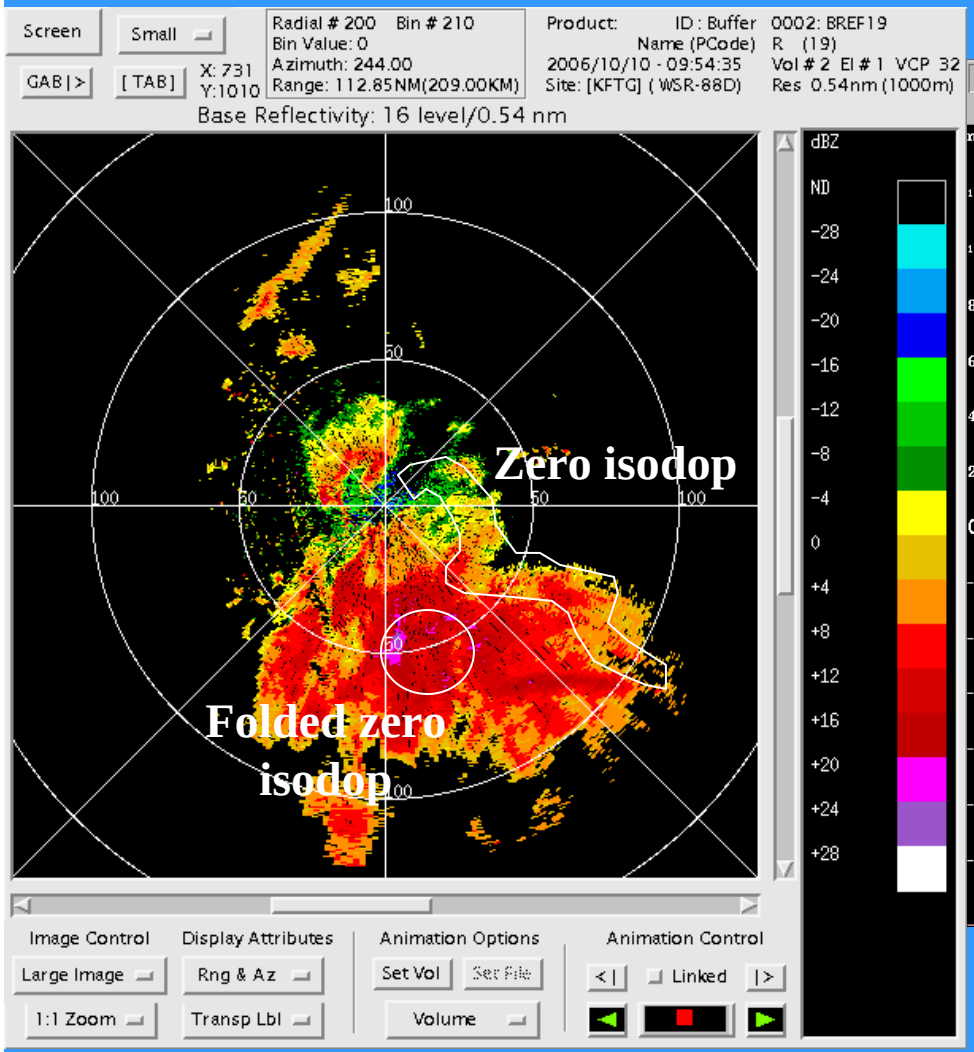
Unfiltered Z

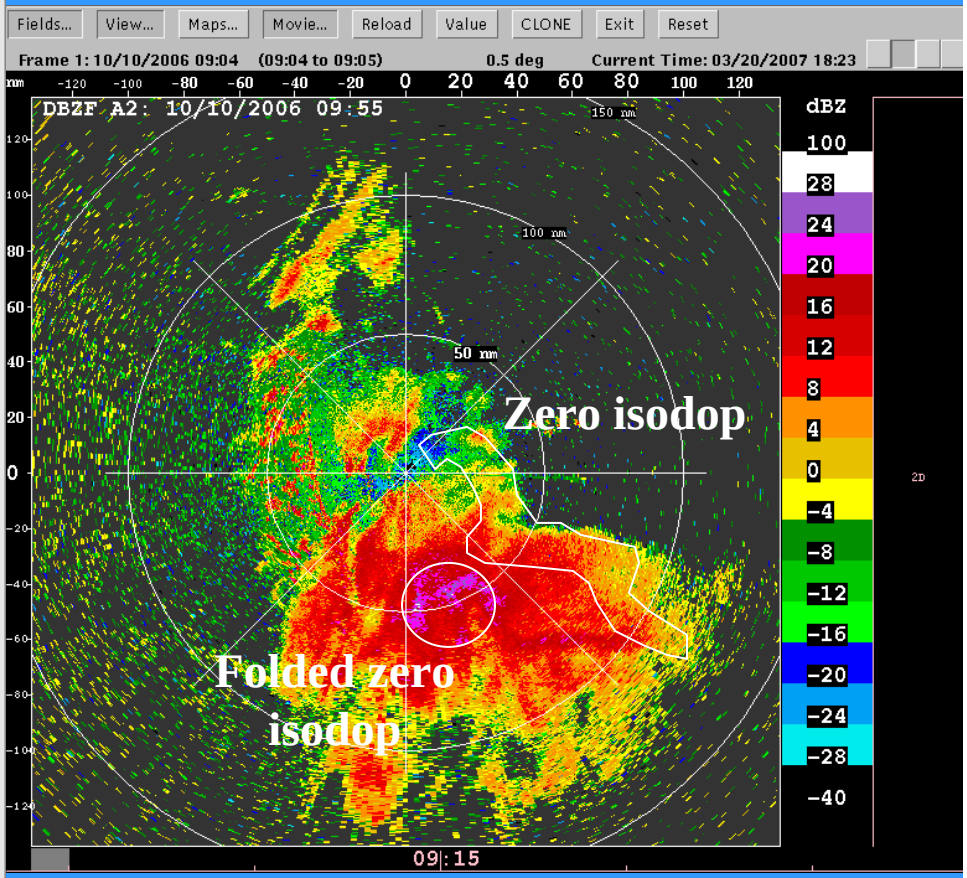
Z Filtered on CMD Clutter Map



Archive II Z

Z Filtered on CMD Clutter Map





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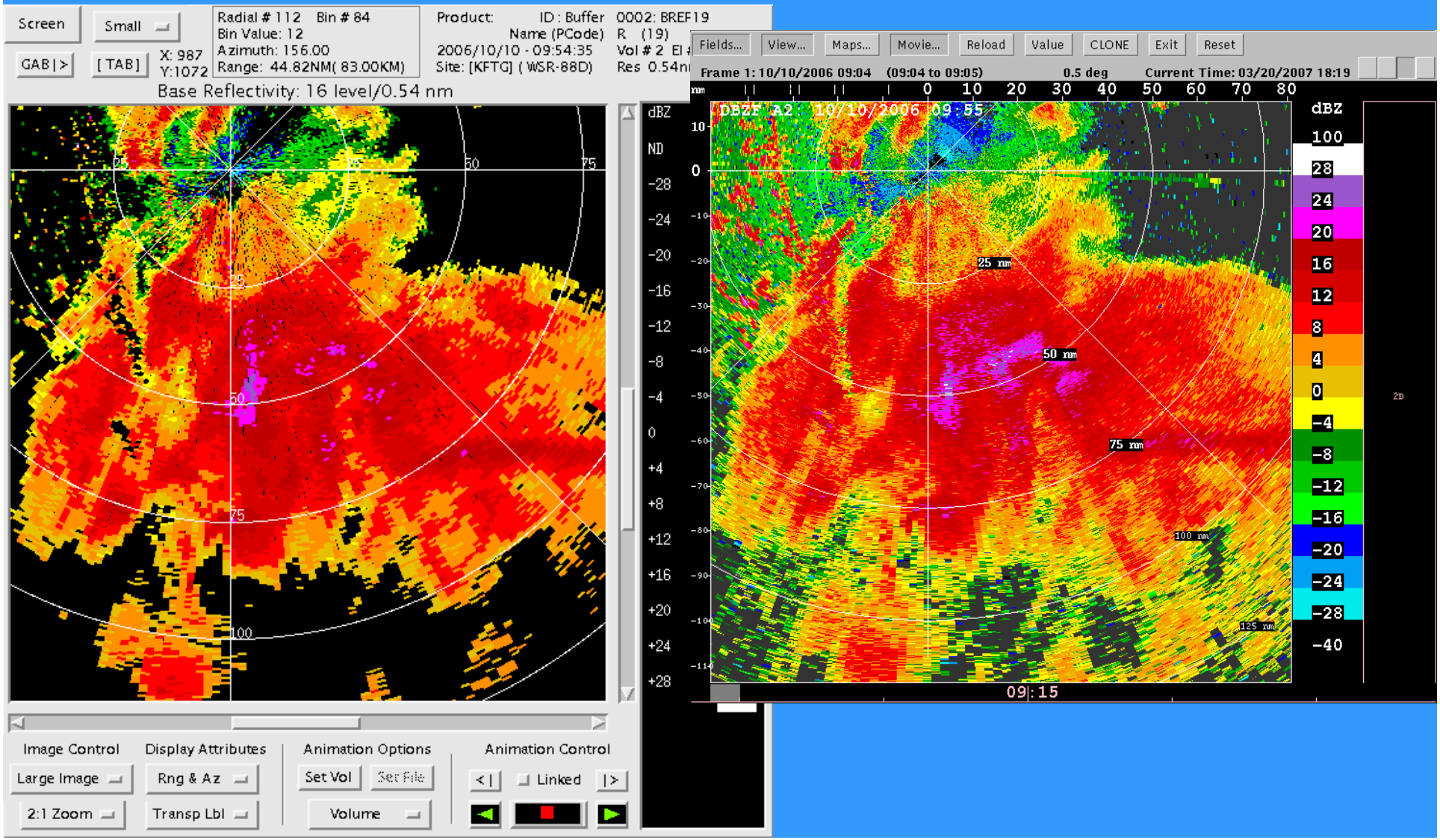
Z Filtered on CMD Clutter Map



Conclusions

- CMD shows excellent skill in identifying gates with clutter and avoiding gates with weather.
- This latest version of CMD uses a single beam for its computations – no adjacent beams are required.
- The addition of the Clutter Phase Alignment (CPA) feature field has resulted in a marked improvement in skill.
- Although the algorithm is already performing well, the addition of dual polarization fields will enhance the robustness of the algorithm.
- The algorithm is already set up for dual polarization fields, and was tested with good results in dual polarization mode on SPOL throughout the 2006 summer season during the REFRACTT field experiment.

CMD Evaluation Approach

- Processing Time Series Data
- Utilities for Creating Clutter Map with CMD Algorithm
  - Generate Map from time series with MATLAB code
  - Use CMD map with RVP8 Replay
- Analyzed Performance of Initial Algorithm Versions
  - Results fed back to NCAR
  - Presented at 23 IIPS Conference
  - Performance acceptable (P_d high, P_{md} low, P_{fa} low)
- Feedback on Performance and Potential Implementation Aspects Resulted in Current Algorithm Design
- Future: Detailed analysis using final algorithm

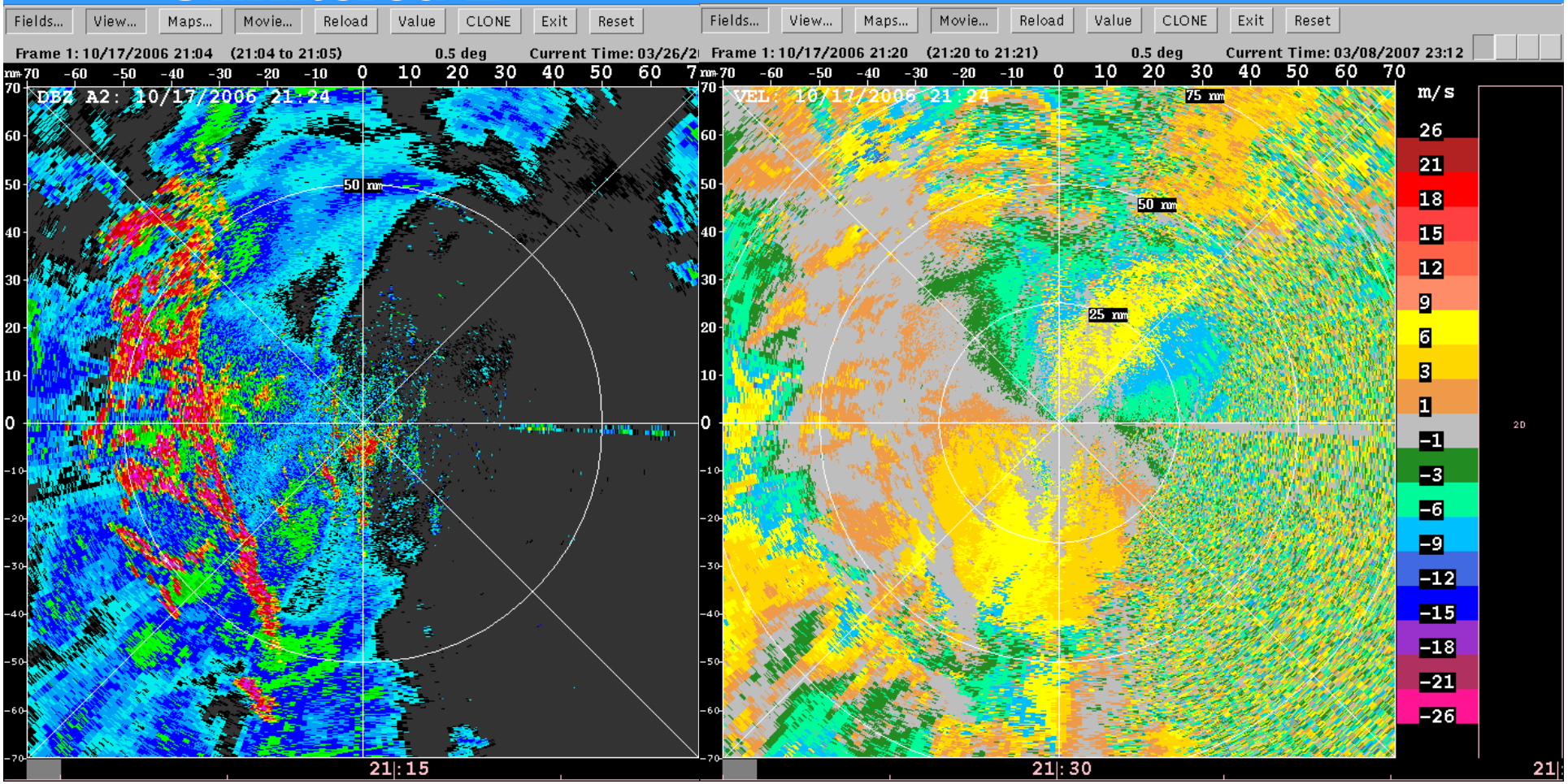
Operational Discussion

- Plan to Keep Within Current Clutter Filter Management Concepts
  - Five segments: only one CMD created map per segment
  - Operator Option to add Zones
  - Merge with Baseline Map
- Recommend Replacing Off-Line Clutter Map Generation with CMD Algorithm for NP Clutter
- Recommend Implementing at Lowest Segment
  - Use on Split Cuts alone avoids Sigmet software modifications
  - Most AP occurs at the lower elevations (low grazing angle increases probably of AP clutter)
- Appears Possible to Integrate with RVP8 and ORDA
- Can Deploy Prior to Build 13 if Requested

KFTG, 17 October 2006

Unfiltered Z

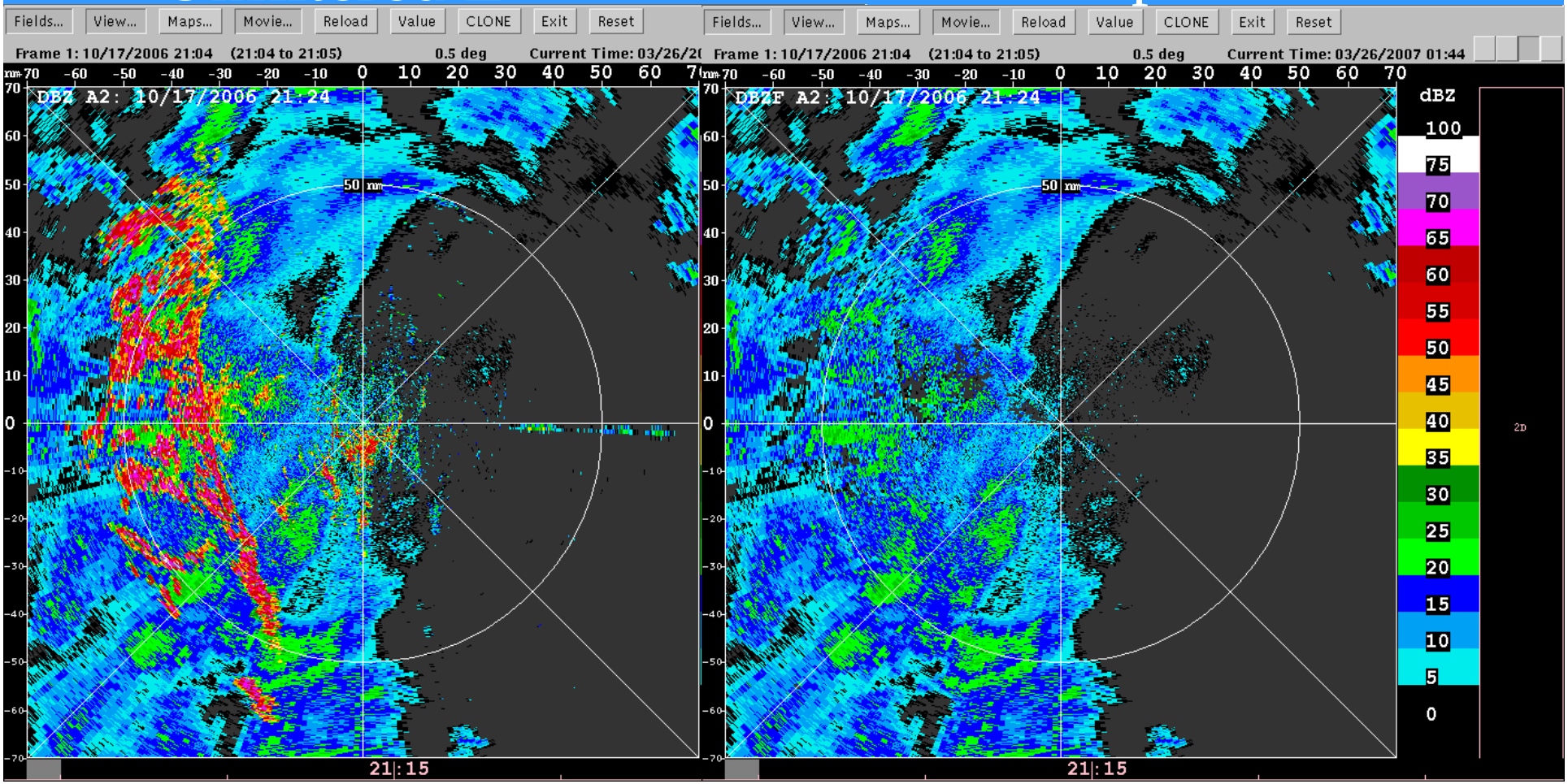
Unfiltered Vr



KFTG, 17 October 2006

Unfiltered Z

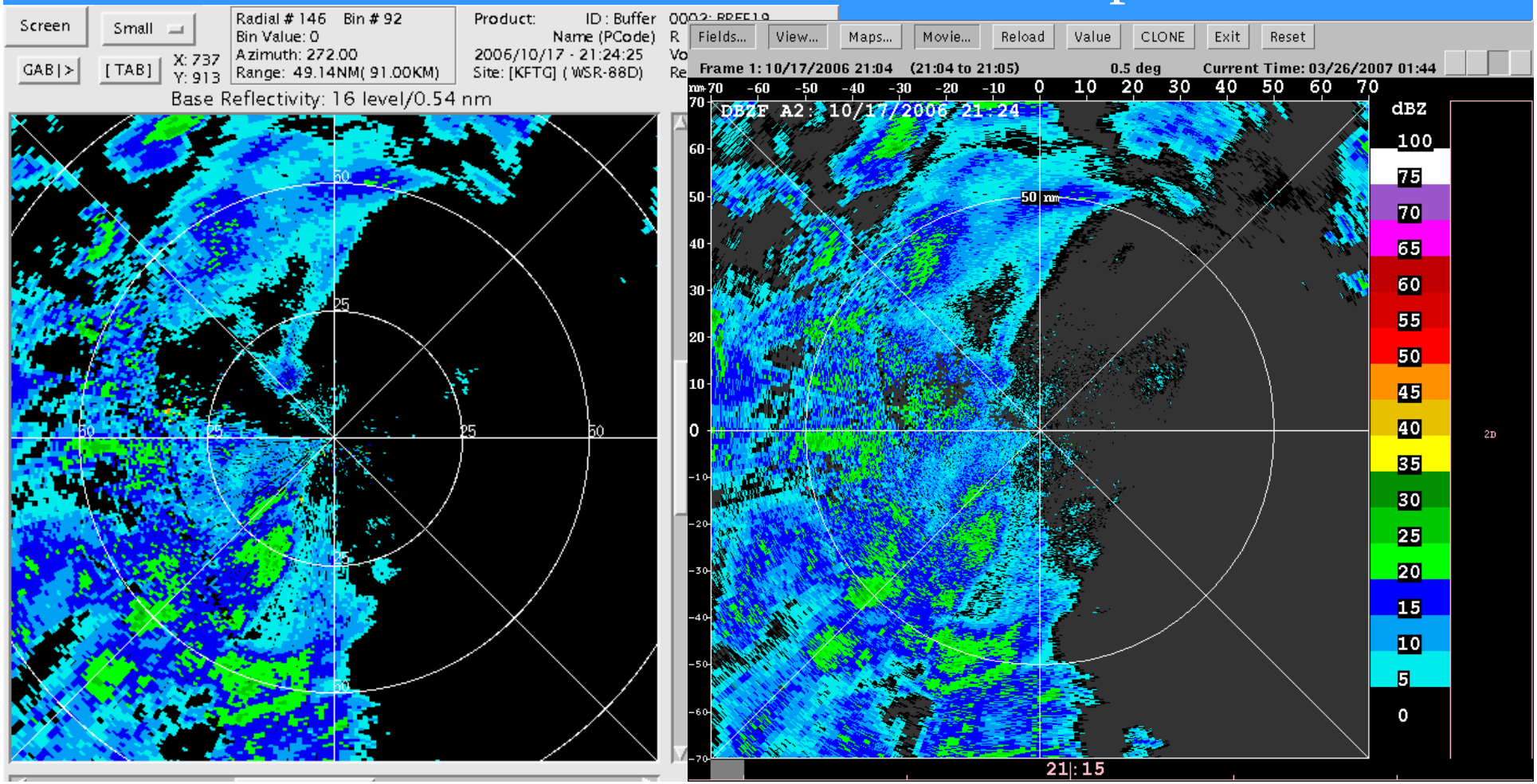
Z Filtered on CMD Clutter Map



KFTG, 17 October 2006

Archive II Z

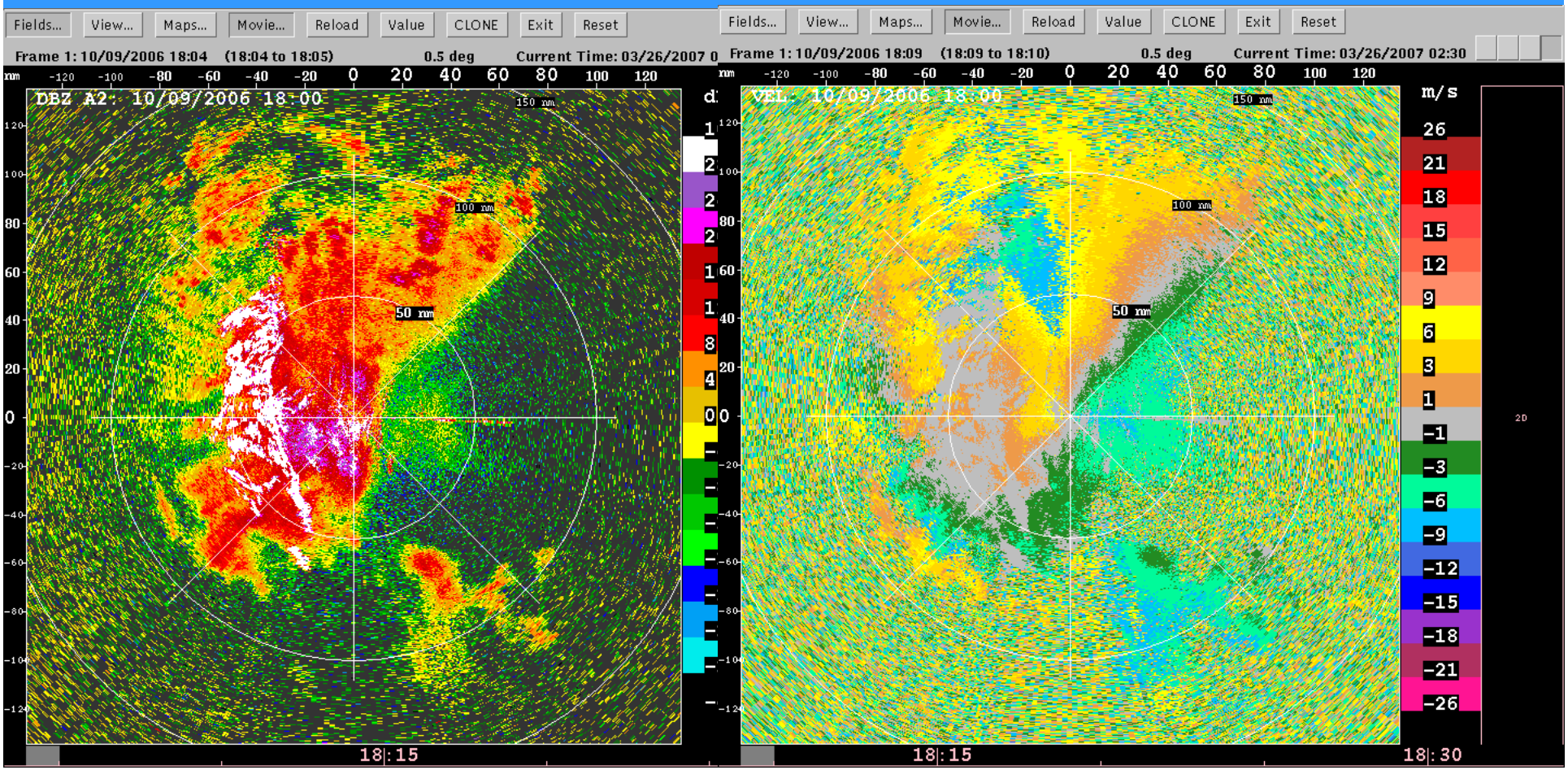
Z Filtered on CMD Clutter Map



KFTG, 09 October 2006, 18:00 UTC

Unfiltered Z

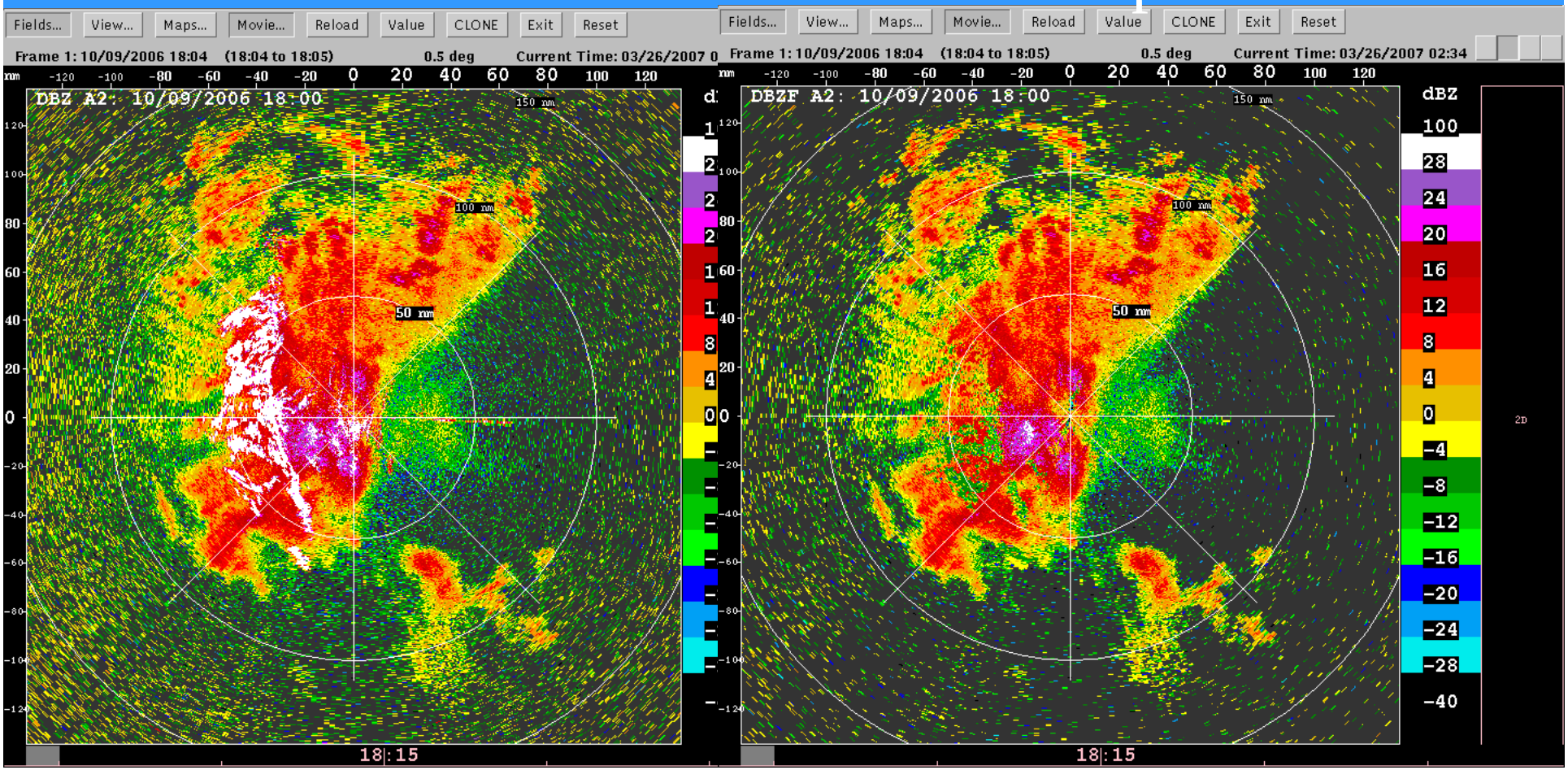
Unfiltered Vr



KFTG, 09 October 2006, 18:00 UTC

Unfiltered Z

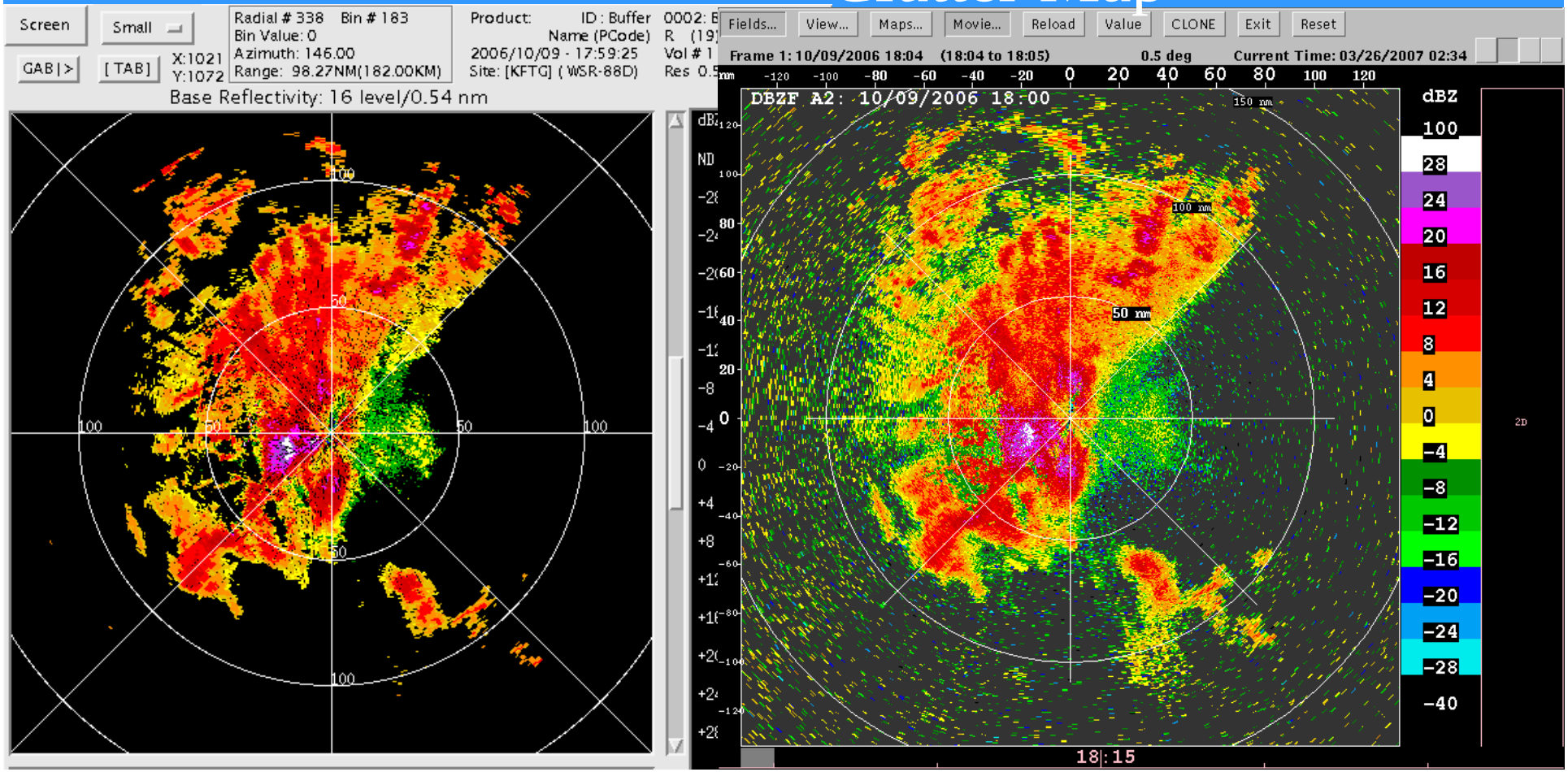
Z Filtered on CMD Clutter Map



KFTG, 09 October 2006, 18:00 UTC

Archive II Z

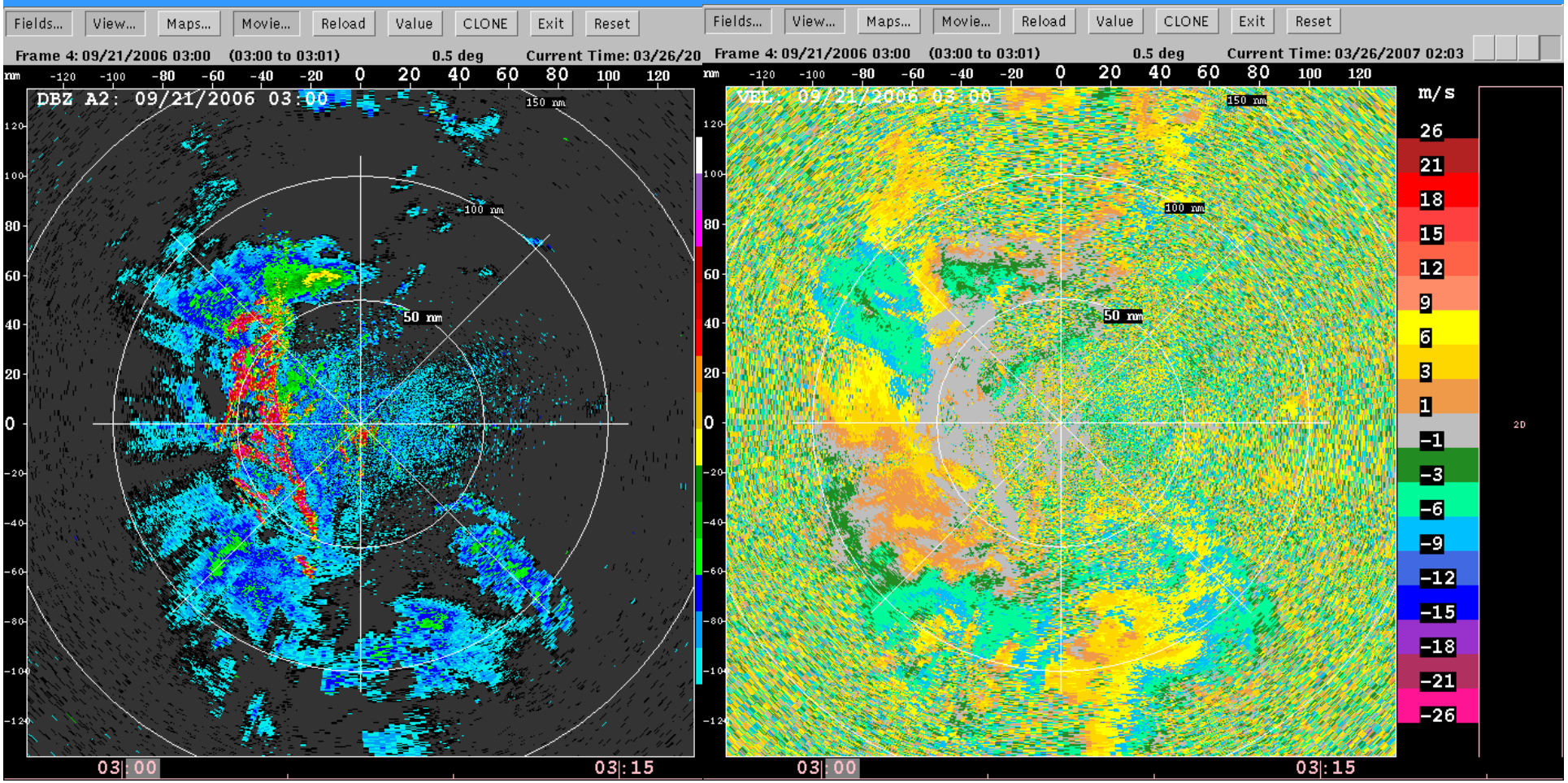
Z Filtered on CMD Clutter Map



KFTG, 21 September 2006, 03:00 UTC

Unfiltered Z

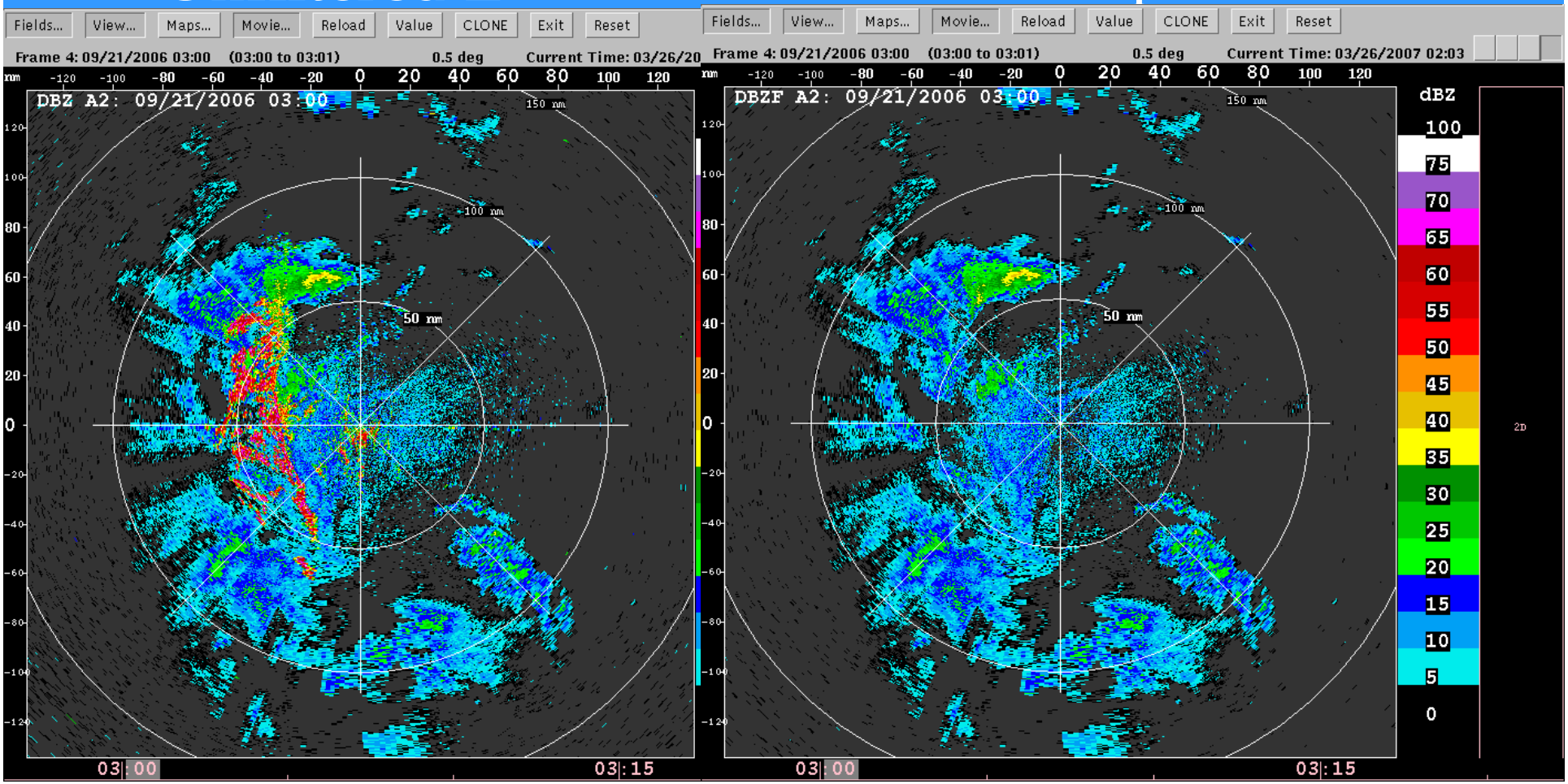
Unfiltered Vr



KFTG, 21 September 2006, 03:00 UTC

Unfiltered Z

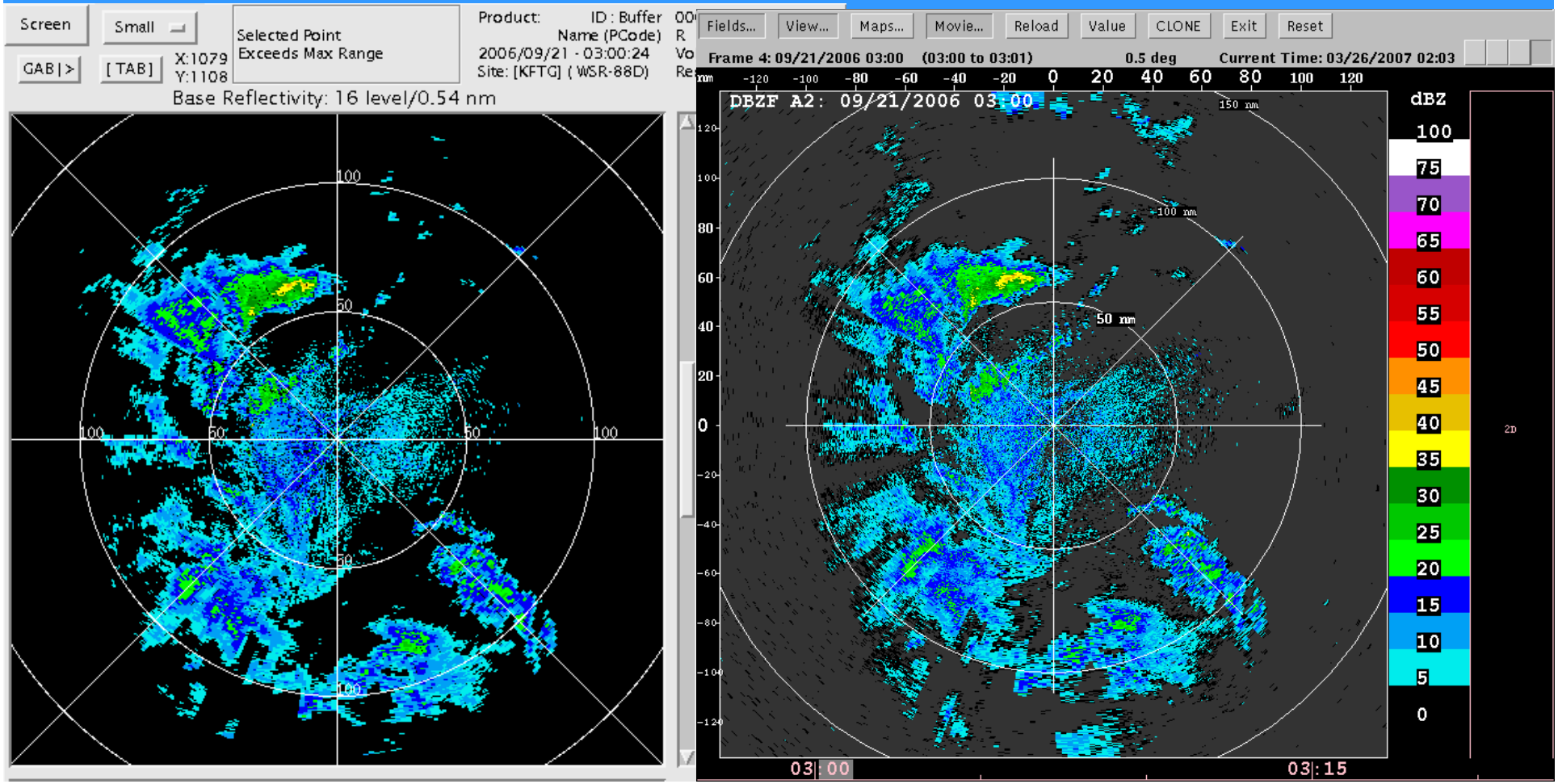
Z Filtered on CMD Clutter Map



KFTG, 21 September 2006, 03:00 UTC

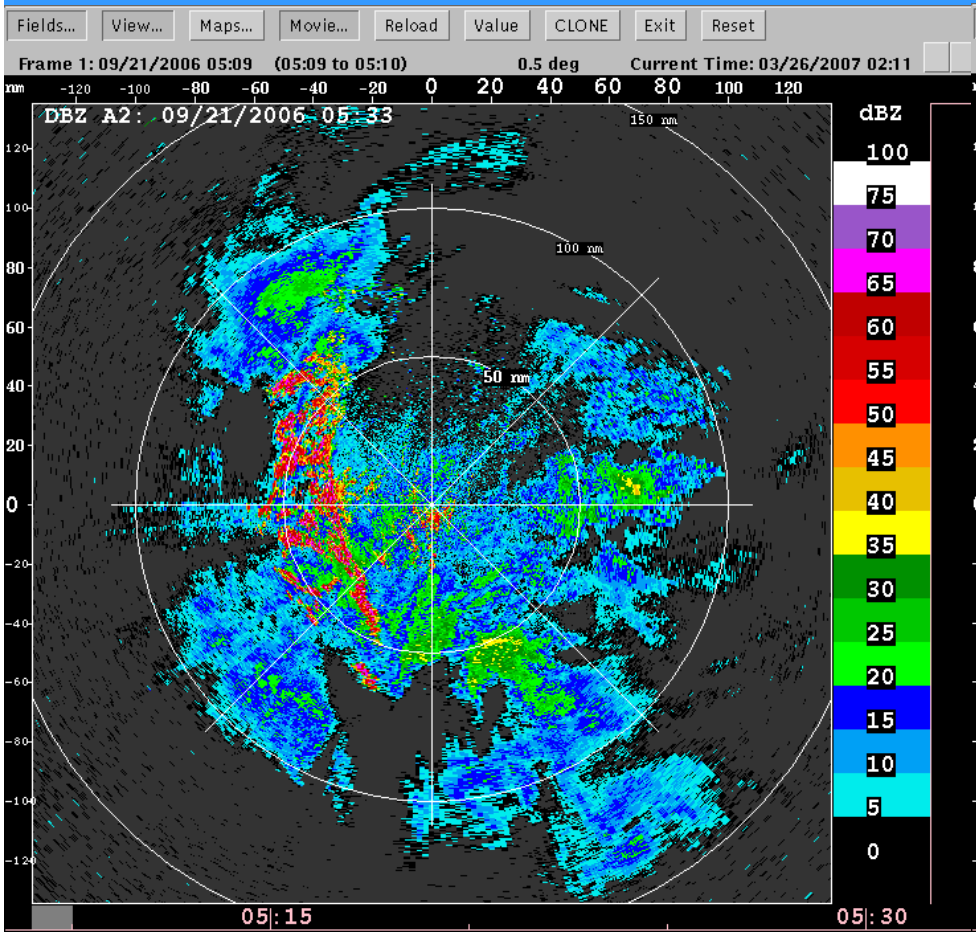
Archive II Z

Z Filtered on CMD Clutter Map

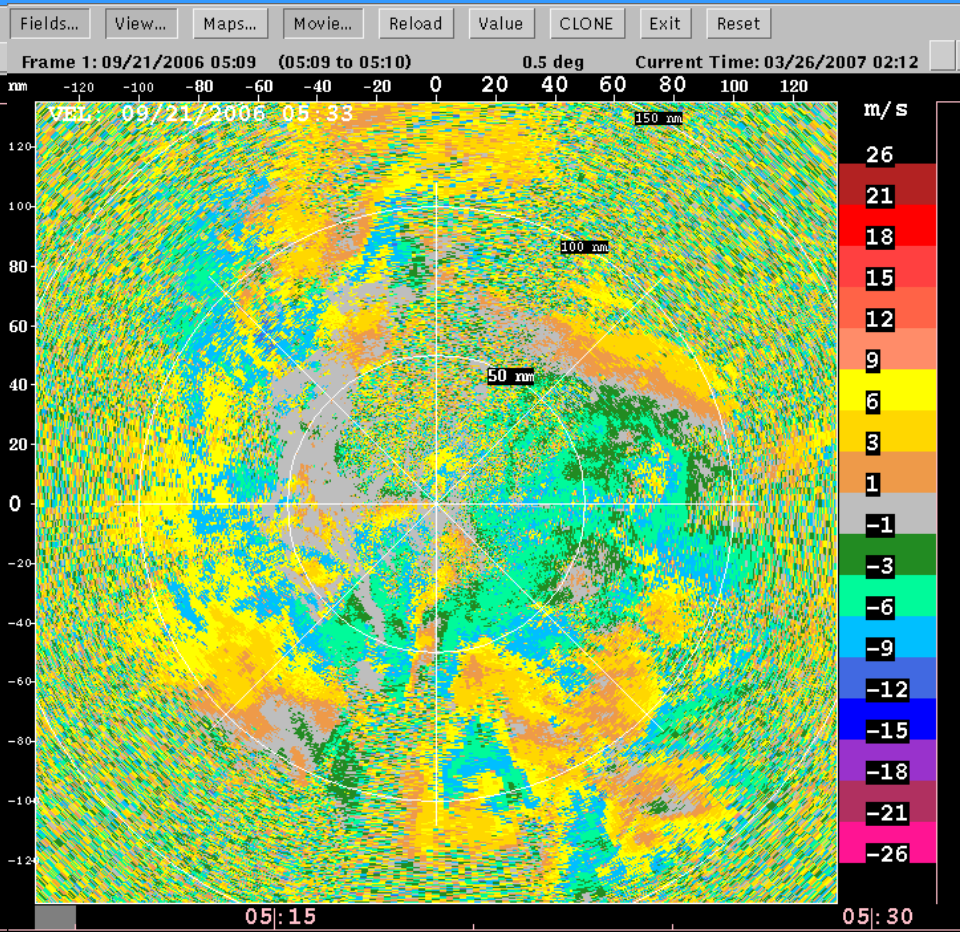


KFTG, 21 September 2006, 05:30 UTC

Unfiltered Z



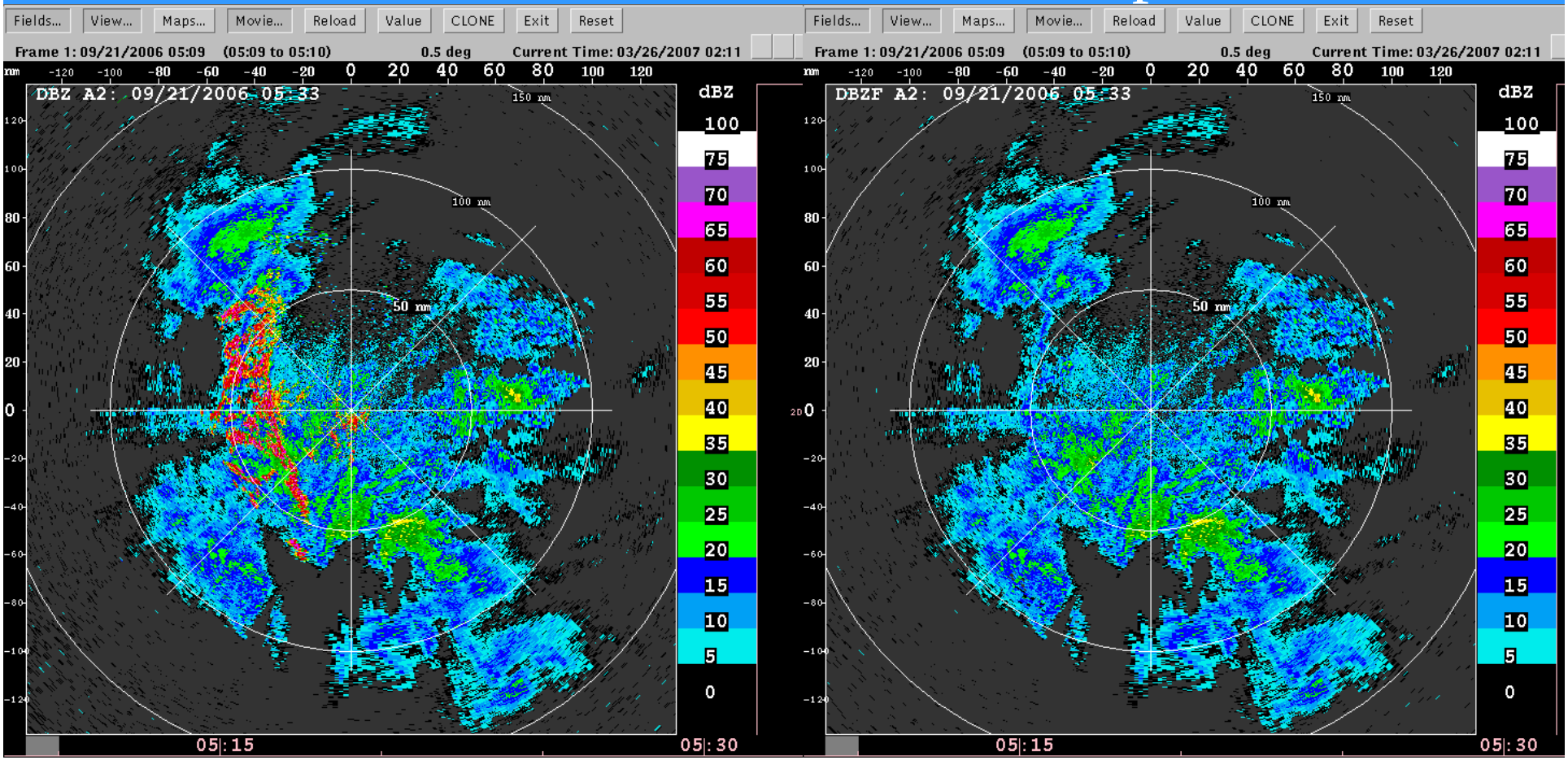
Unfiltered Vr



KFTG, 21 September 2006, 05:30 UTC

Unfiltered Z

Z Filtered on CMD Clutter Map



KFTG, 21 September 2006, 05:30 UTC

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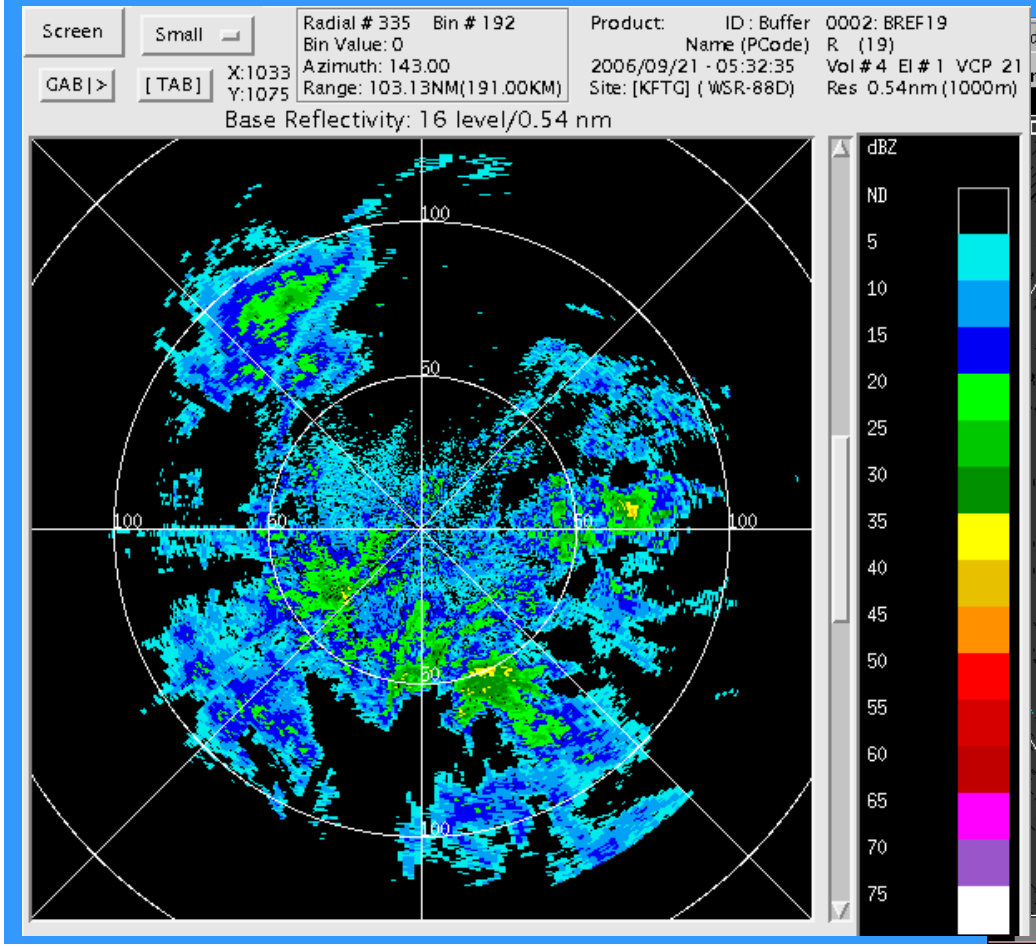

Z Filtered on CMD Clutter Map