Clutter Mitigation Decision (CMD) system for the NEXRAD ORDA

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Motivation

Mitigation of AP Clutter without weather attenuation

- Currently: Only Detect AP clutter in RPG
  - No “correction” only censoring of data
- Future: New fast radar processors (e.g. RVP8) which make possible:
  - Spectral processing with FFTs, etc
  - Spectral clutter filters instead of time domain filters. Simply calculate the spectrum and “notch out” zero and near zero velocity points

Real time detection and

correction of AP clutter

Motivation

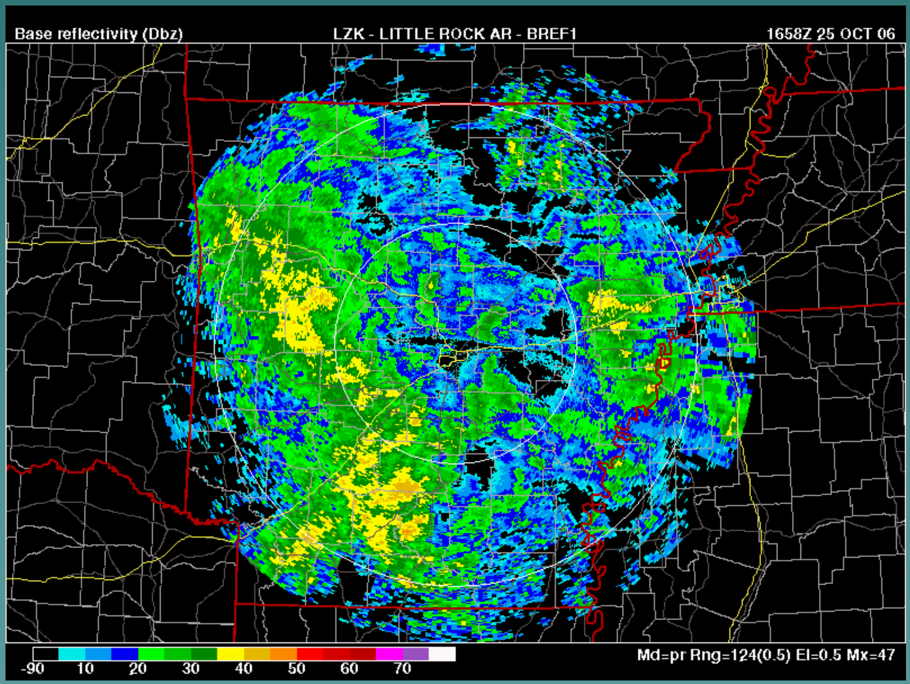
- Adaptive spectral clutter filters show great promise for intelligently filtering clutter power while leaving weather power largely unaffected.

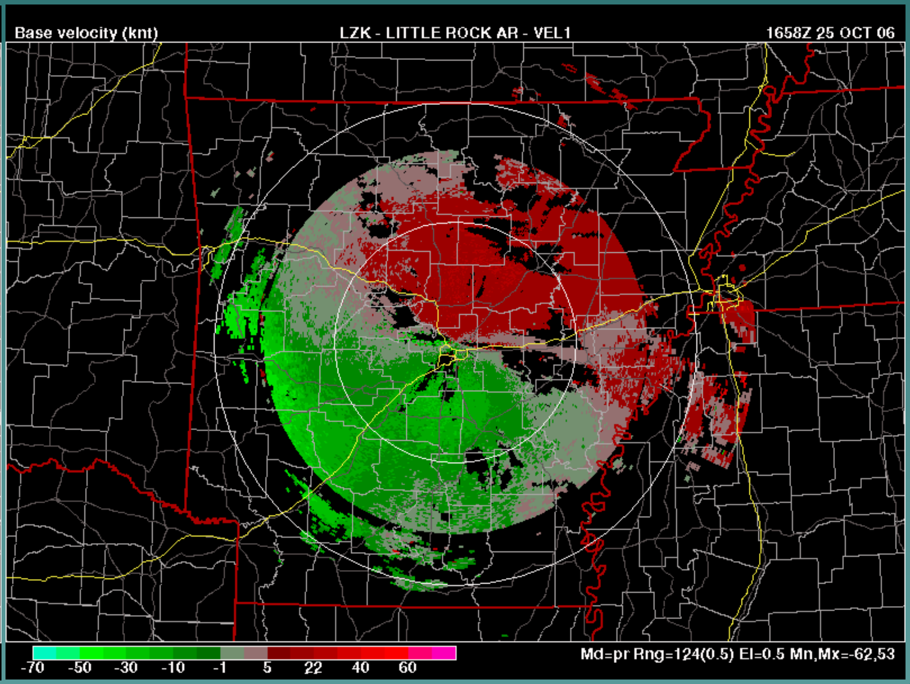
- However, these filters still remove weather power under the following circumstances:
  - the weather return has a velocity close to zero;
  - the weather return has a narrow spectrum width.

- This tends to occur with stratiform weather in the region of the zero isodop.

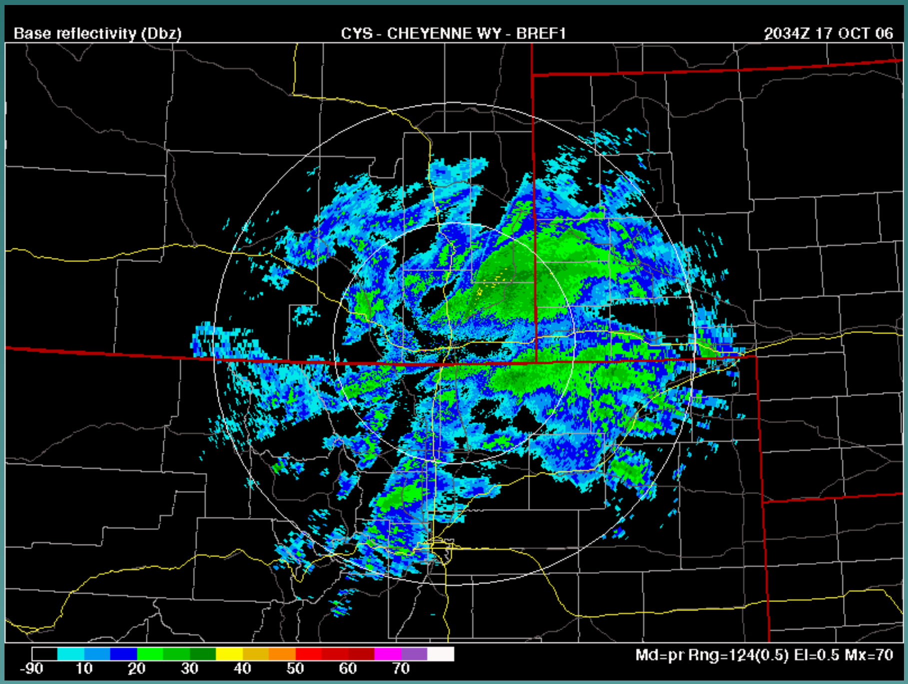
- In order to mitigate the problem, information other than that used by the filters must be used to determine whether clutter exists at a gate.

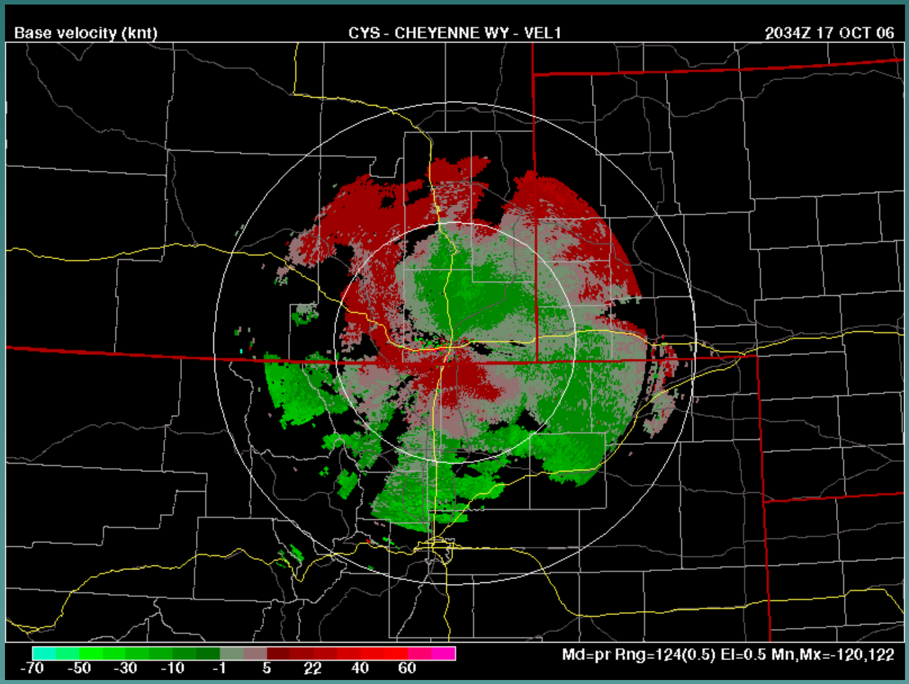
Little Rock, Arkansas



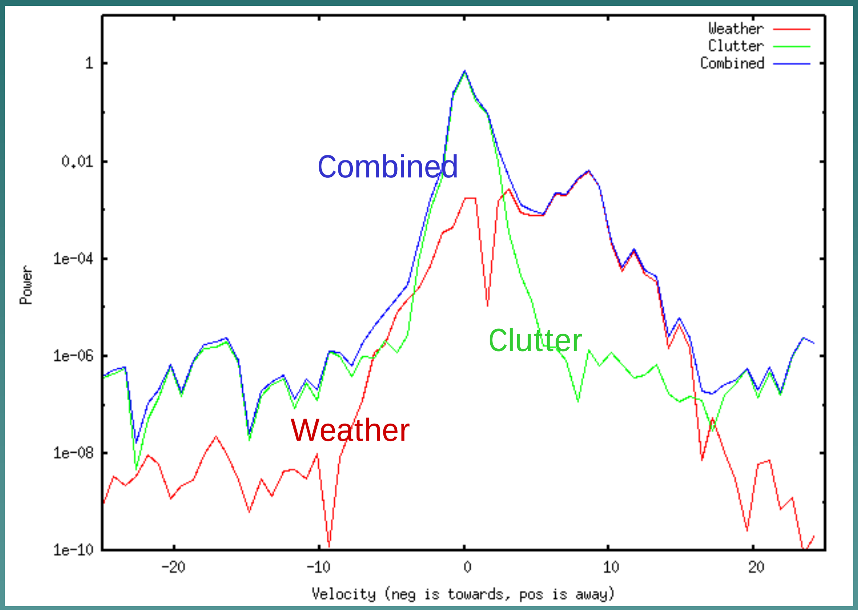


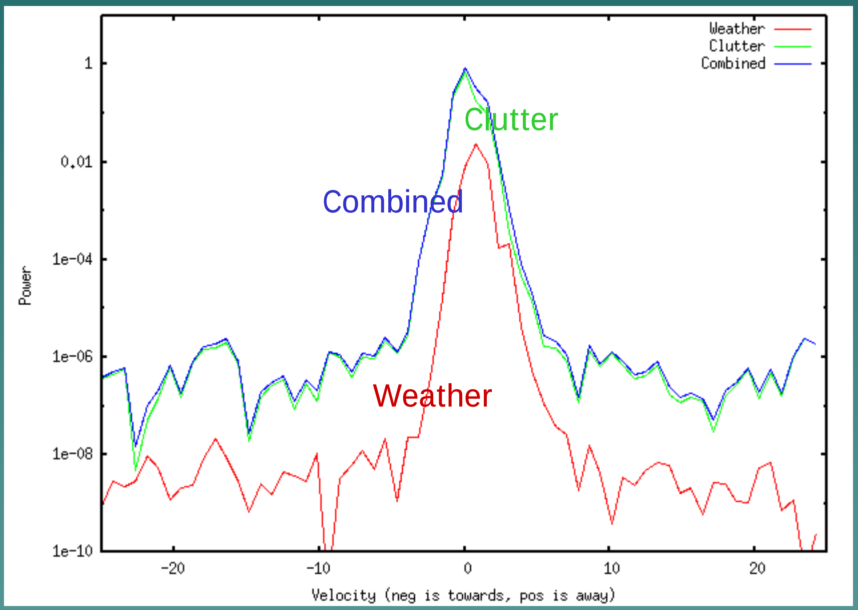
Cheyenne, Wyoming





Examples of clutter spectra mixed with weather





Weather has non-zero velocity and significant spectrum width. Signatures may be easily separated.

Weather has velocity close to 0 and narrow spectrum width. It 'hides' within the clutter and is it is difficult to separate the two signatures.

Feature fields

- In order to identify gates with clutter, we use a number of so-called feature fields. These contain information which is independent of that used by the clutter filter.

- The feature fields used in the latest CMD version are:

  – The TEXTURE of the reflectivity field – TDBZ.

  – The SPIN of the reflectivity field. This is a measure of how often the reflectivity gradient changes sign.

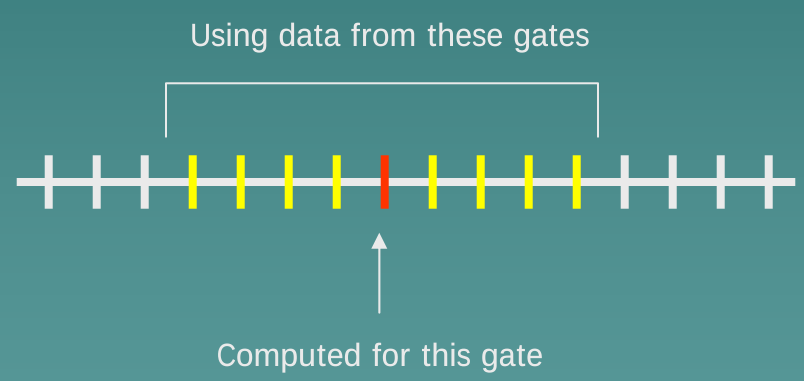
  – The Clutter Phase Alignment or CPA, which is a measure of the pulse-to-pulse stability of the returned signal.

TEXTURE of reflectivity - TDBZ

- TDBZ is computed as the mean of the squared reflectivity difference between adjacent gates.

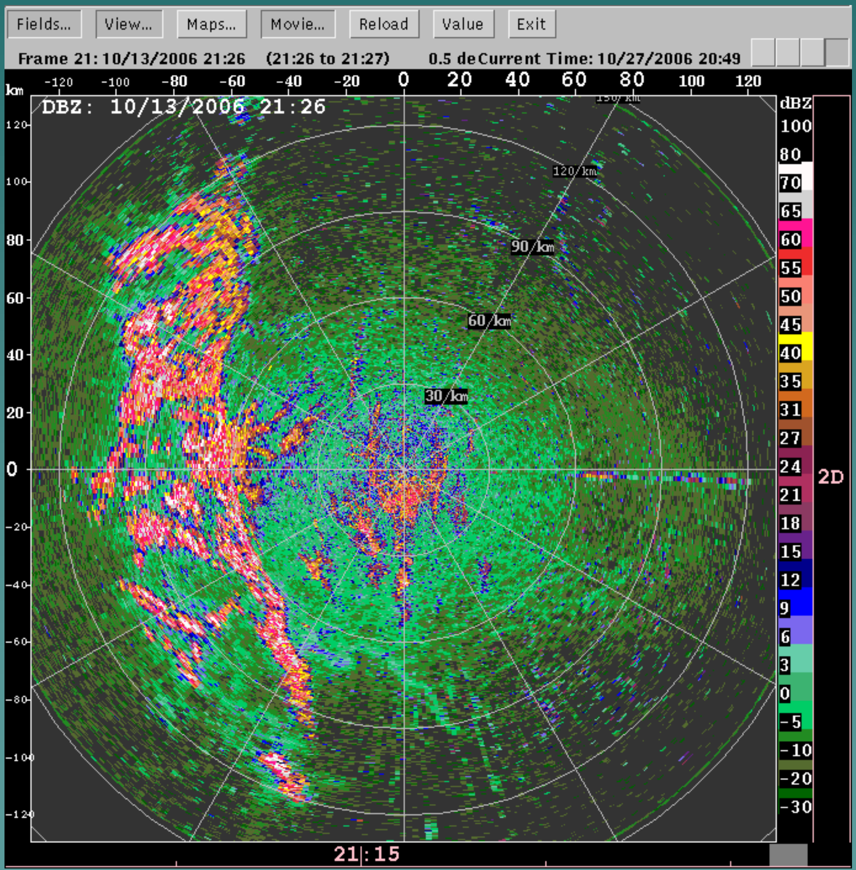
$$TDBZ = \left(\sum_{j}^{nbeams} \left(\sum_{i}^{ngates} (dBZ_{i,j} - dBZ_{i-1,j})^2 \right) \right) / N$$

- TDBZ is computed at each gate along the radial, with the computation centered on the gate of interest.
- TDBZ at a gate is computed using the dBZ values for the 4 gates on either side of the gate of interest.

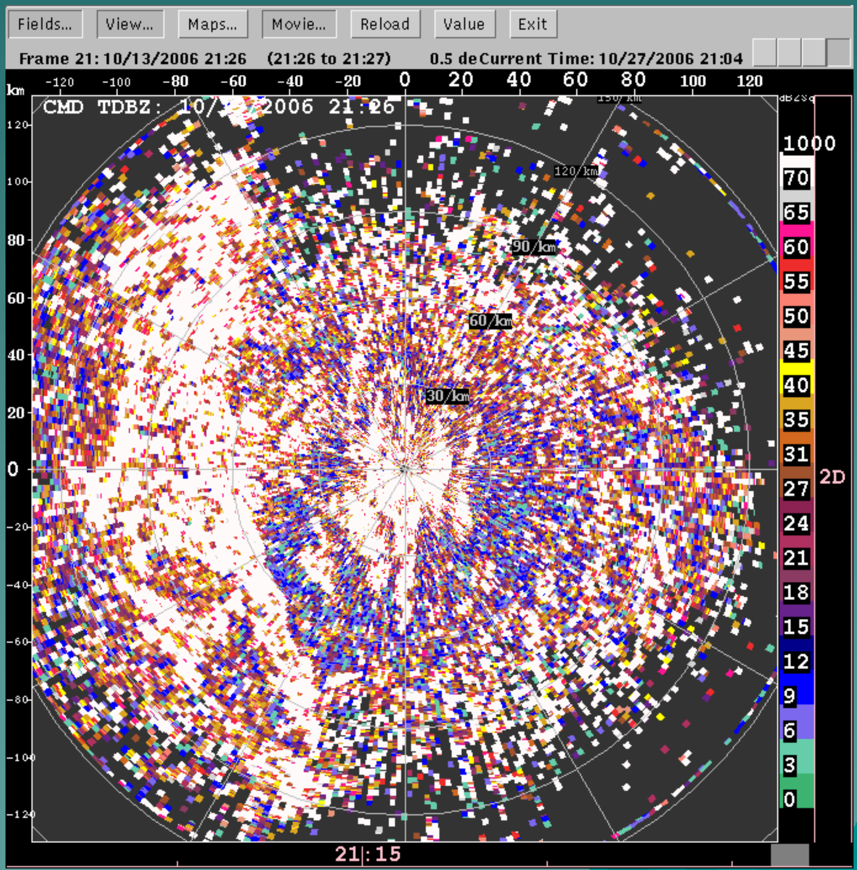


TDZB feature field

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



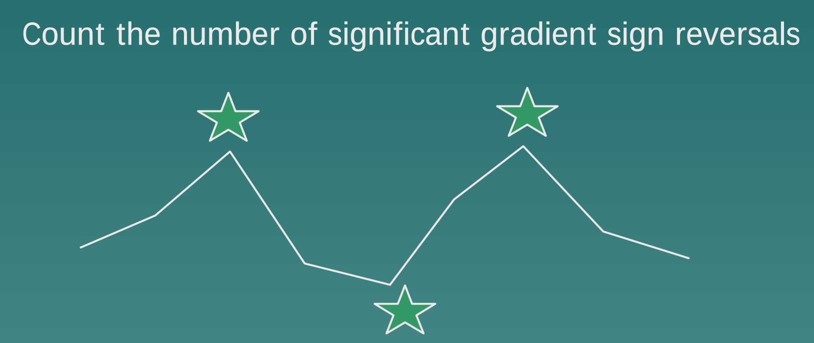
DBZ

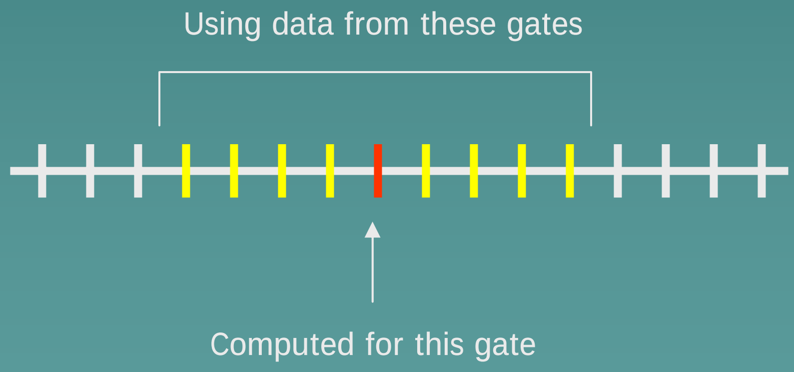


TDBZ

SPIN of reflectivity

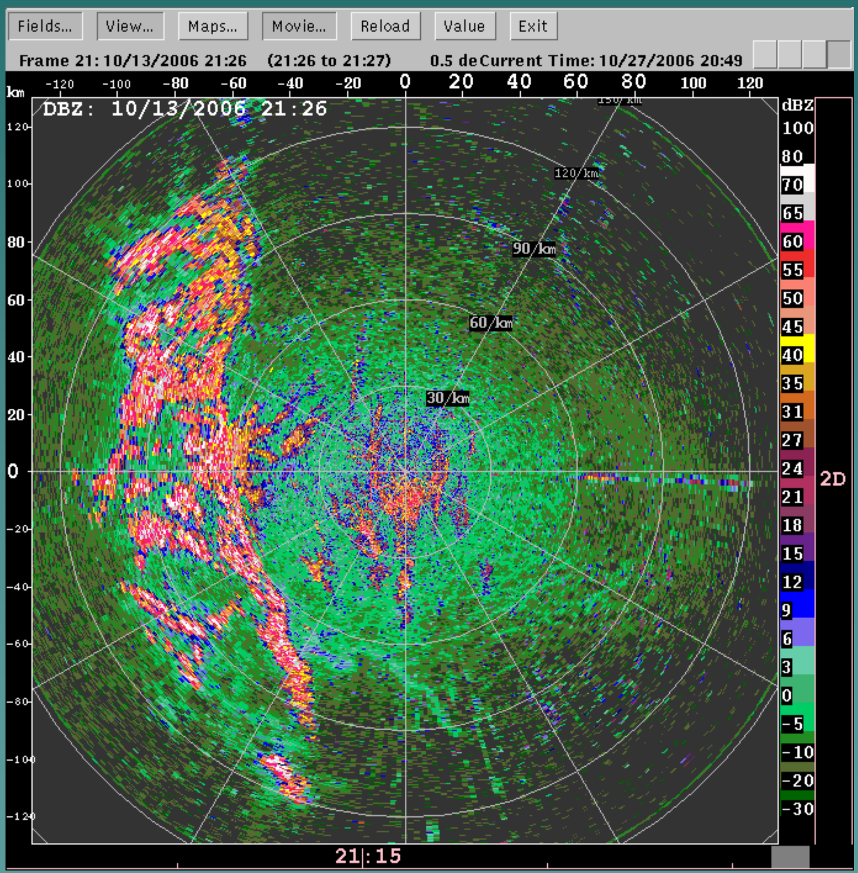
- The reflectivity SPIN is a measure of how often the gradient of reflectivity changes sign along the beam.
- The SPIN is computed at each gate along the radial, using 4 gates on either side, with the computation centered on the gate of interest.
- SPIN is normalized with respect to its maximum possible value, so that it ranges from 0 to 1.



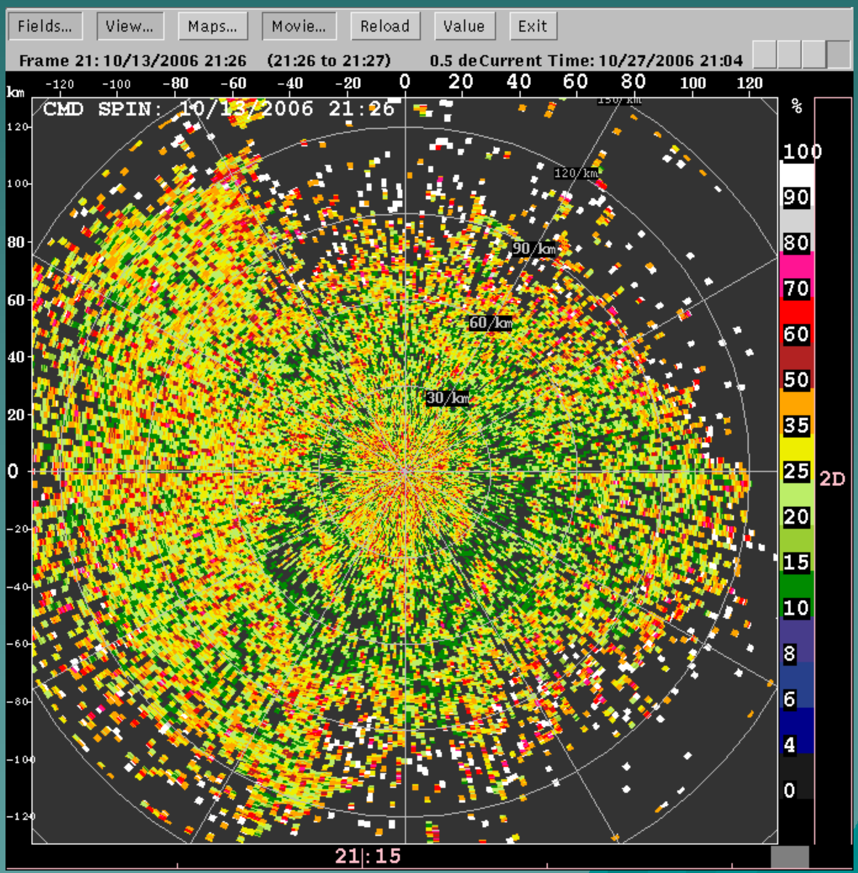


SPIN feature field

Example of SPIN on a clear day – Denver Front Range NEXRAD – KFTG
(SPIN is noisy in low SNR regions, it is less noisy when weather is present)



DBZ

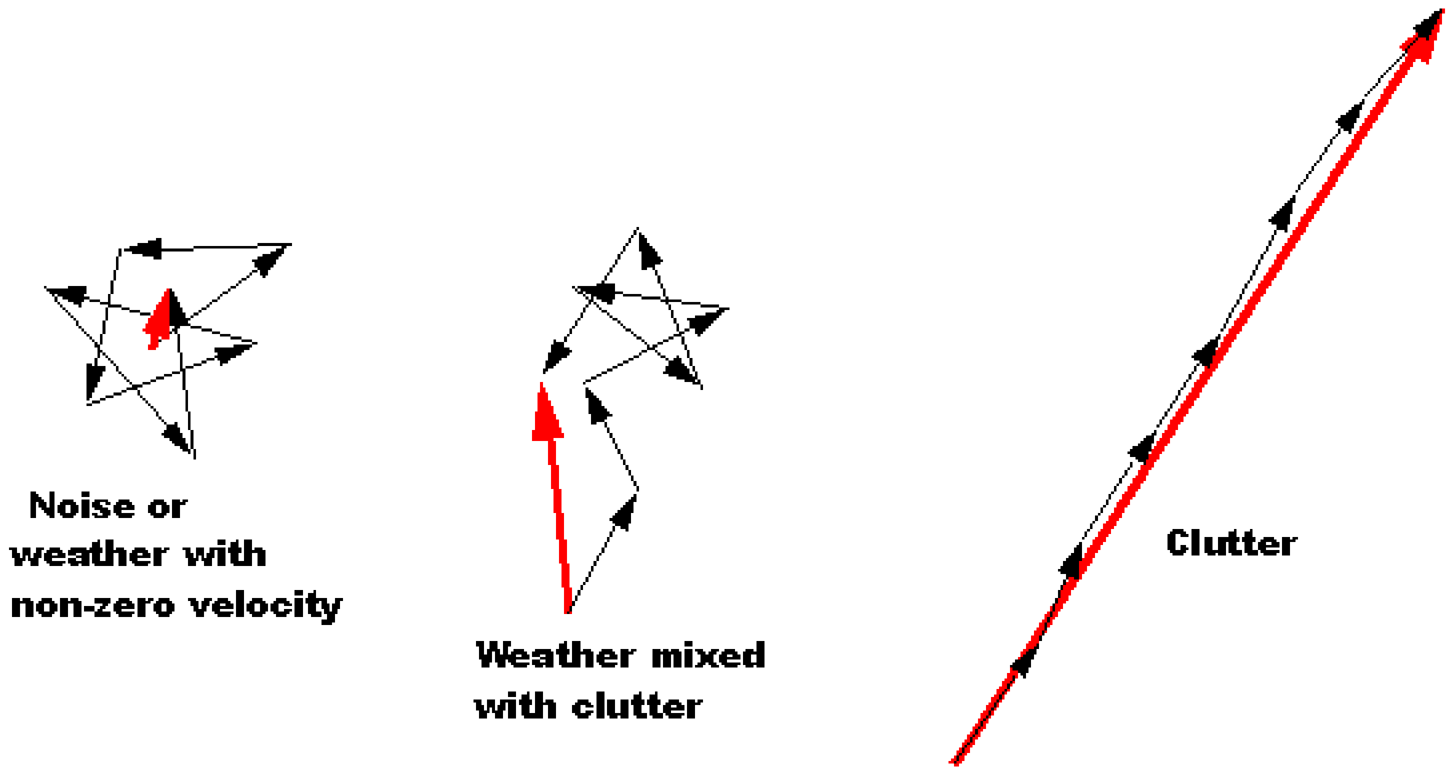


SPIN

Clutter Phase Alignment - CPA

- 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 for successive pulses



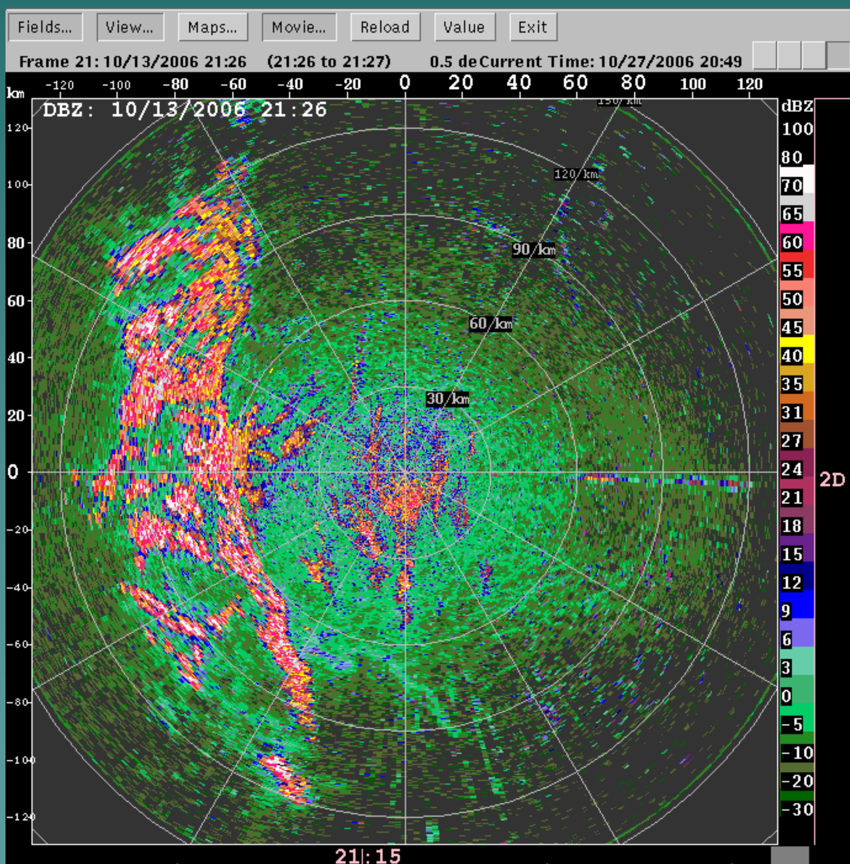
Adding I and Q for a gate in a phasor diagram

CPA feature field

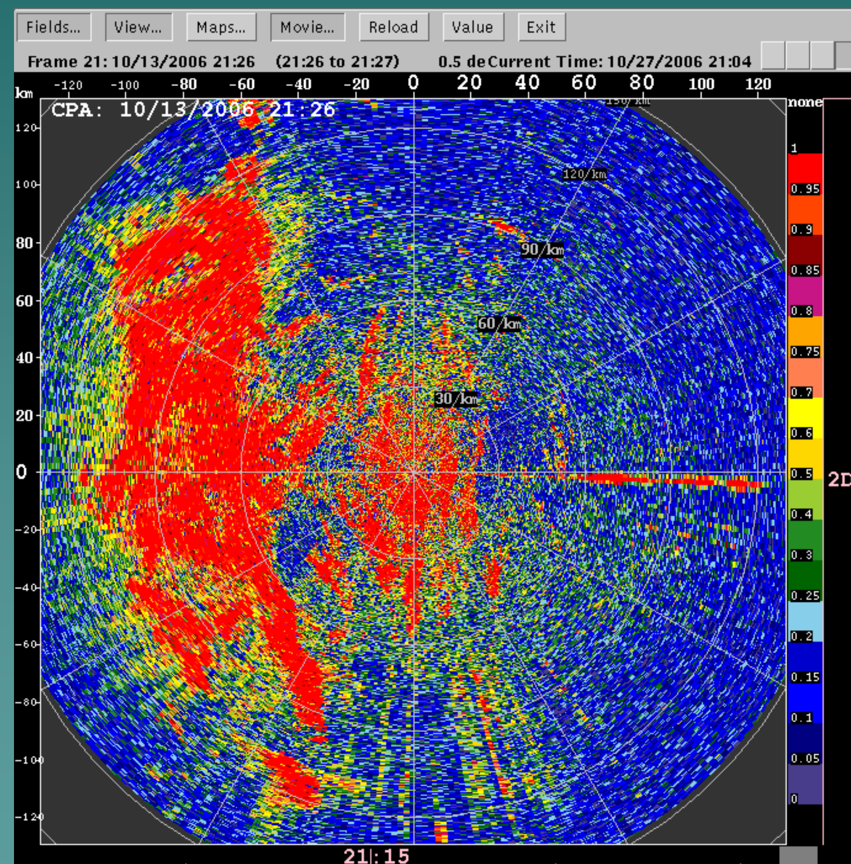
- CPA is computed as the length of the cumulative phaser vector, divided by the sum of the power for each pulse.
- CPA is computed at a single gate.
- It is a normalized value, ranging from 0 to 1.
- In clutter, CPA is typically above 0.95.
- In weather, CPA is often close to 0, but increases in weather with a velocity close to 0 and a narrow spectrum width.
- In noise, CPA is typically less than 0.05.
- CPA was originally developed as a quality control field for clutter targets used for refractivity measurements.

CPA feature field

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



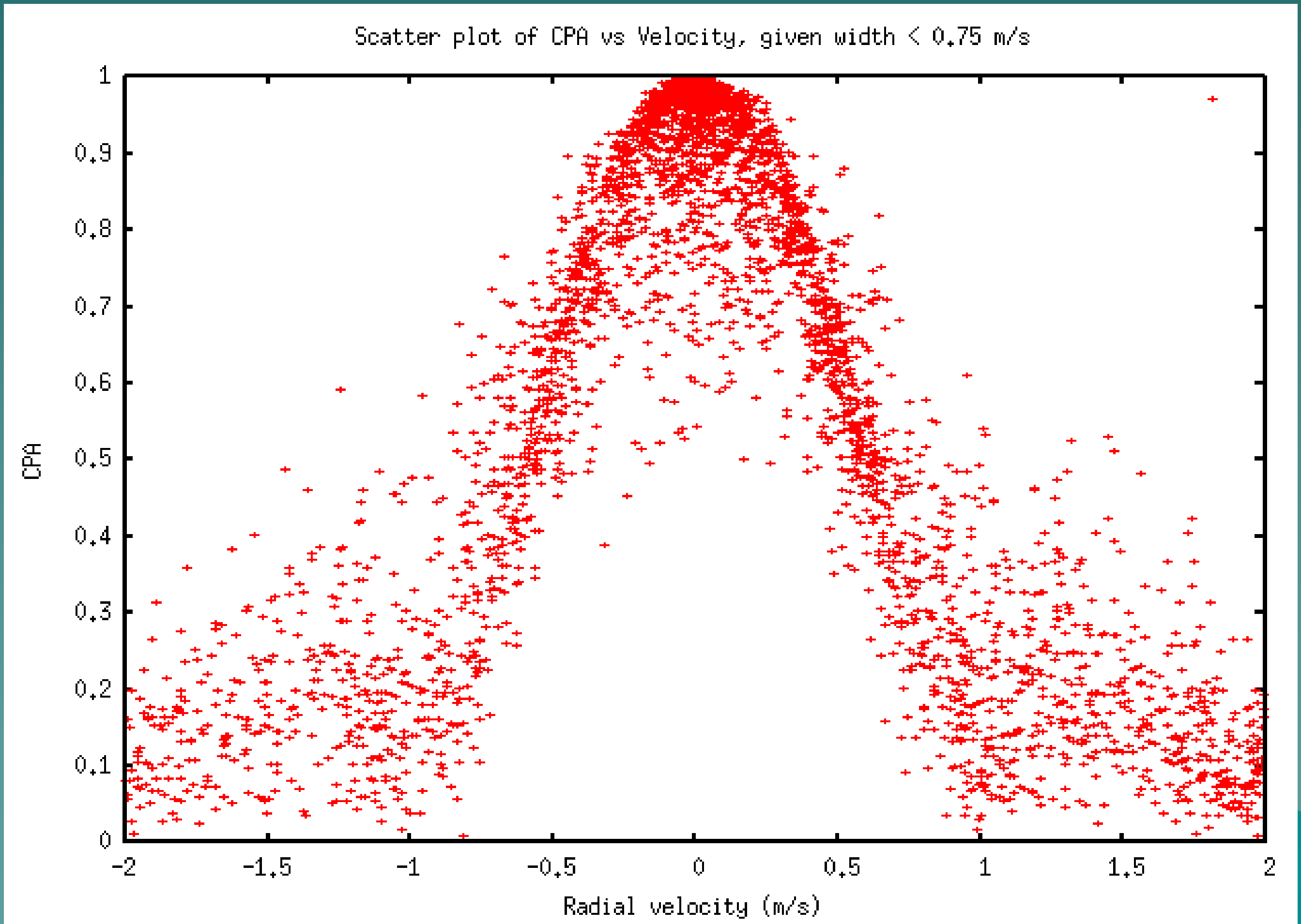
DBZ



CPA

CPA vs. Radial Velocity

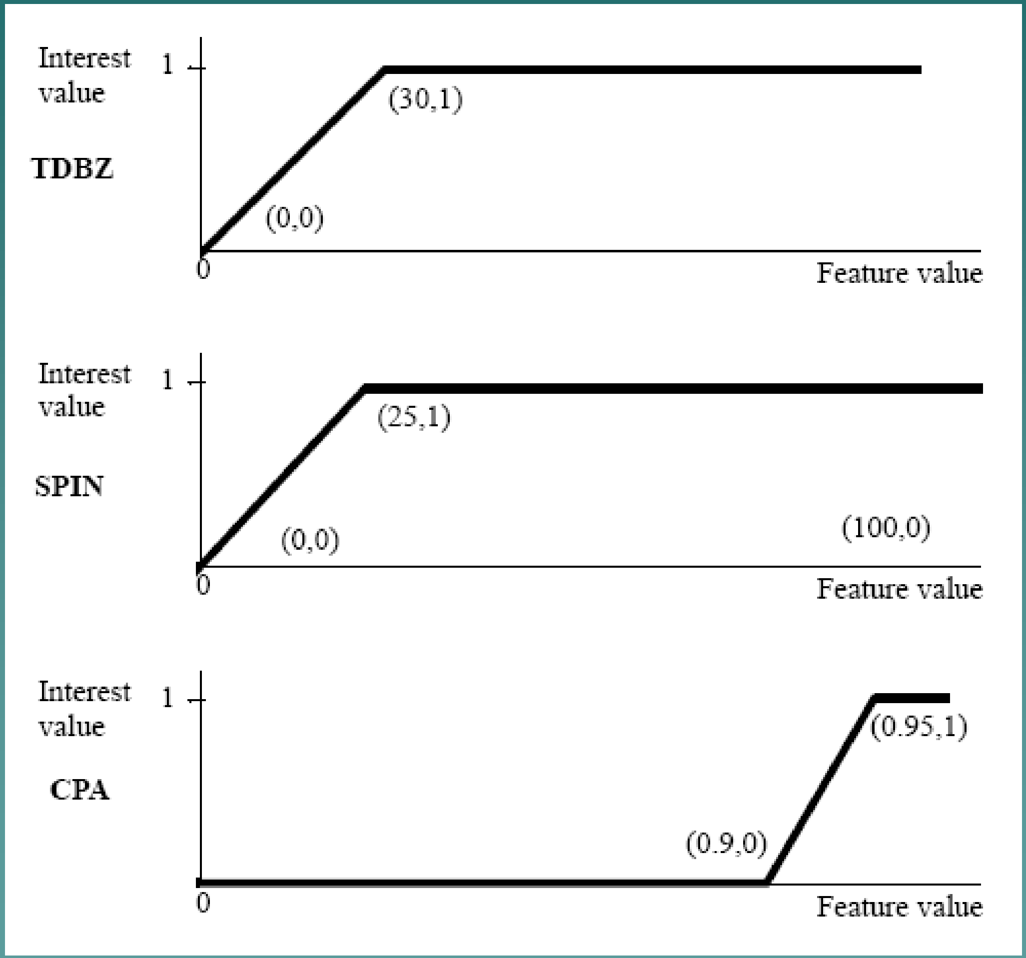
CPA appears to be a better discriminator of clutter than radial velocity



Combining TDBZ, SPIN and CPA

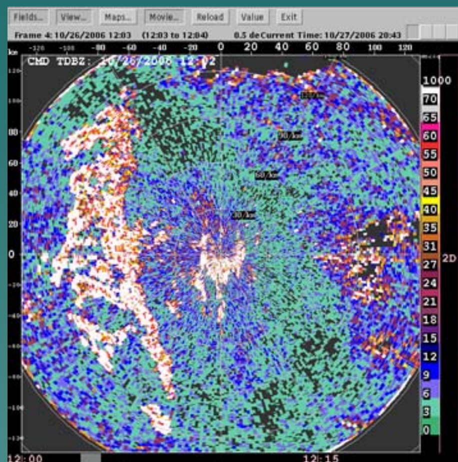
- The individual feature fields, TDBZ, SPIN and CPA, are combined into a single interest field using fuzzy logic.
- First, each feature field is converted into an interest field, using a membership transfer function.
- Interest fields have a range from 0.0 to 1.0.
- The interest fields are assigned a weight.
- The combined interest field is computed as a weighted mean of the individual interest fields.

Membership functions

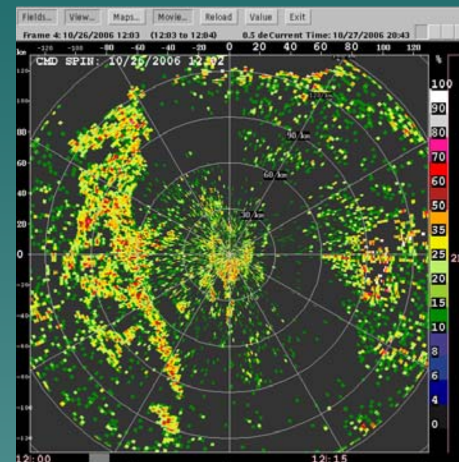


Creating combined interest field - CMD

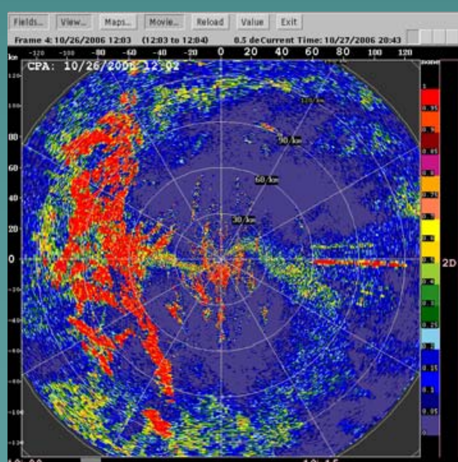
TDBZ



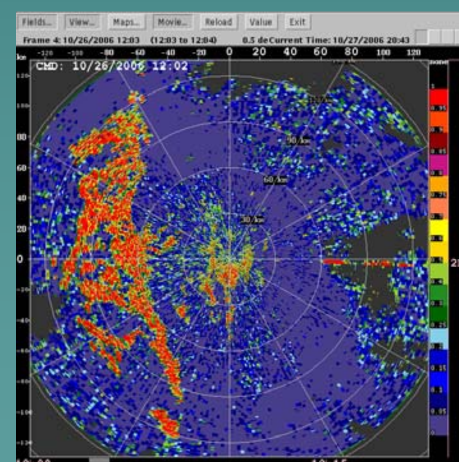
SPIN



CPA



CMD

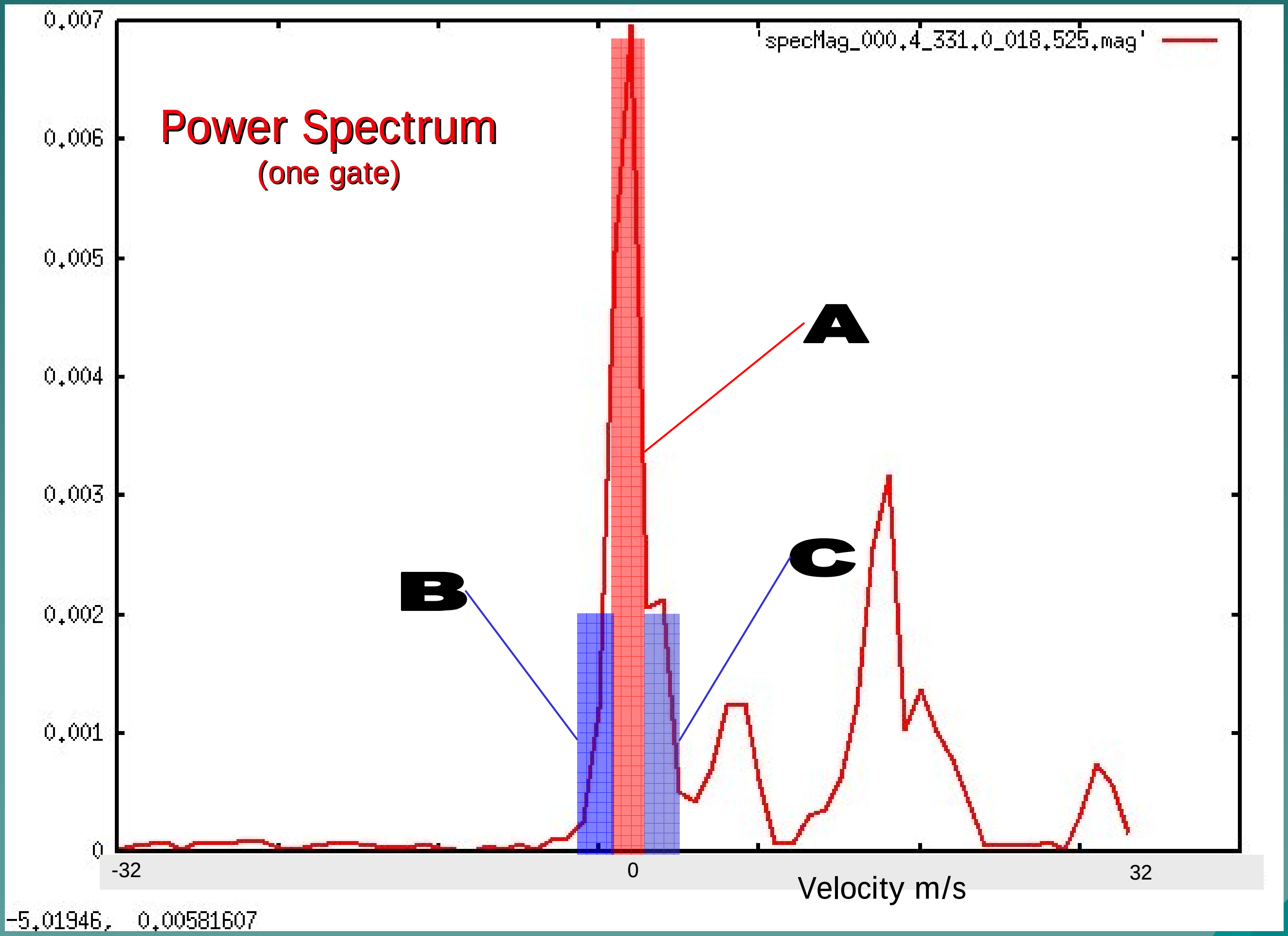


Clutter Ratio Narrow

- An additional field is computed from the spectrum in order to limit use of the clutter filter to only those gates which have a possibility of clutter.
- Clutter Ratio Narrow is defined as the power in the 3 spectral points at 0 velocity divided by the power in the surrounding 4 spectral points – i.e. 2 on either side.
- Ratio Narrow is not a good discriminator of clutter from weather, it is only used to identify which gates have the possibility of clutter.
- If the ratio is less than 6 dB, it is inferred that clutter is not present at that gate.

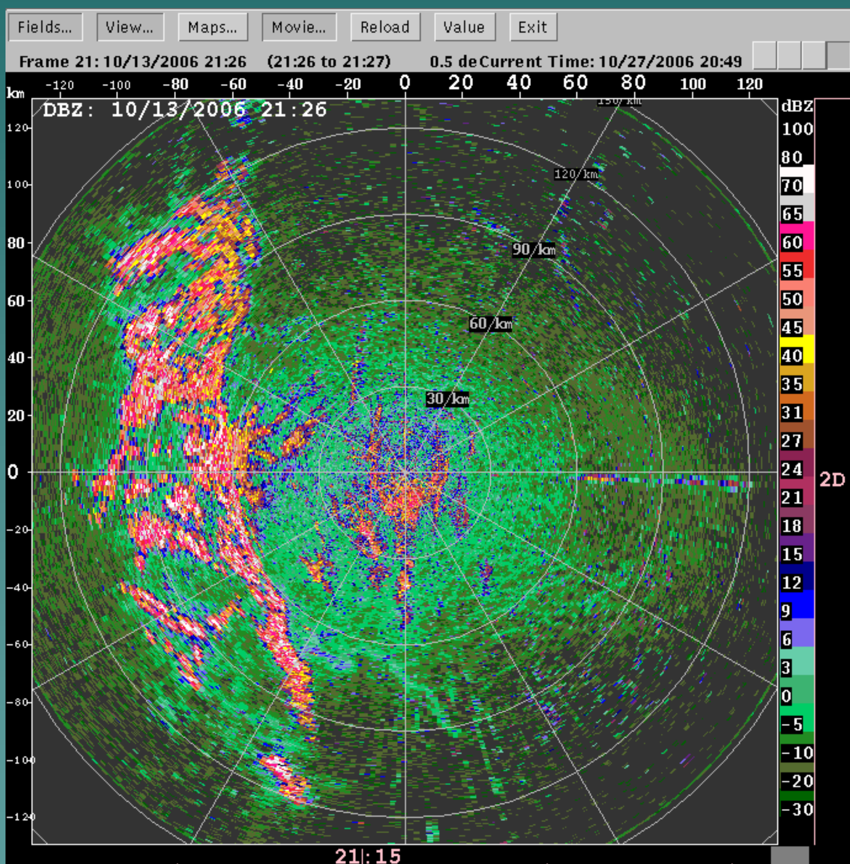
Clutter Ratio Narrow

RatioNarrow = Power in A / (Power in B + Power in C), expressed in dB

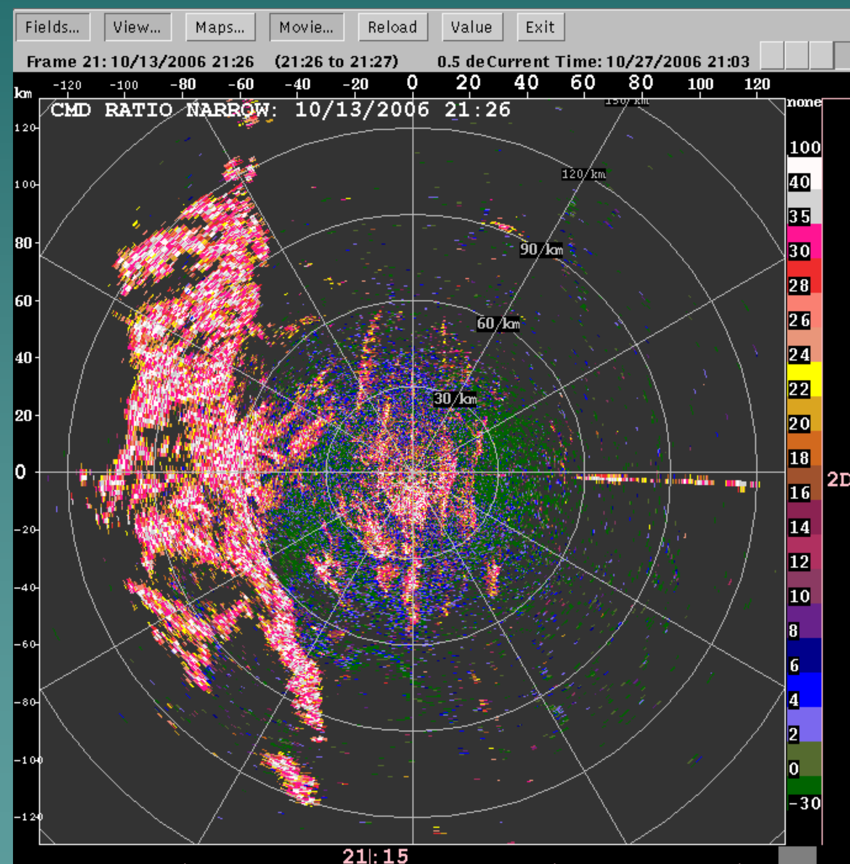


Clutter Ratio Narrow

Clutter Ratio Narrow on a clear day – Denver Front Range NEXRAD - KFTG



DBZ



Clutter ratio narrow

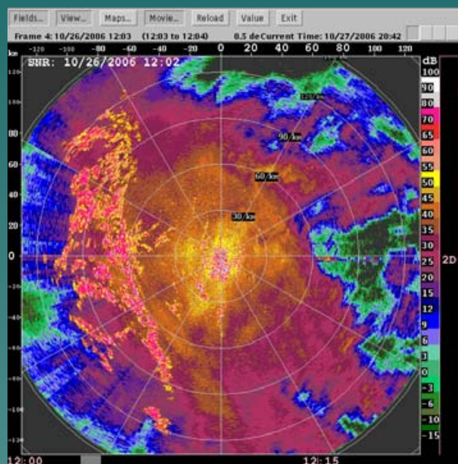
Setting the clutter flag

To compute the clutter flag at each gate, we proceed through the gates as follows:

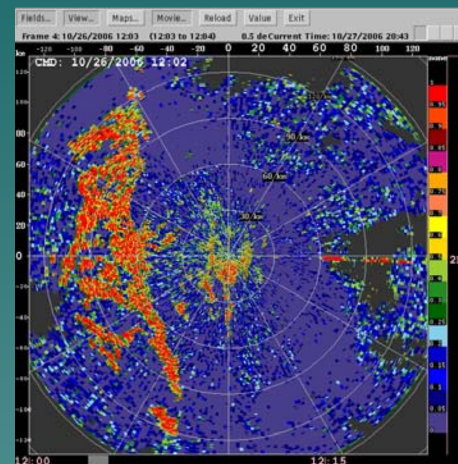
- If the Signal-to-Noise Ratio (SNR) < 3 dB, no clutter at this gate, skip to next gate.
- If Clutter Ratio Narrow < 6 dB, no clutter at this gate, skip to next gate.
- If CMD < 0.5, no clutter at this gate, skip to the next gate.
- Otherwise, apply clutter filter at this gate.

Logic for setting the clutter flag

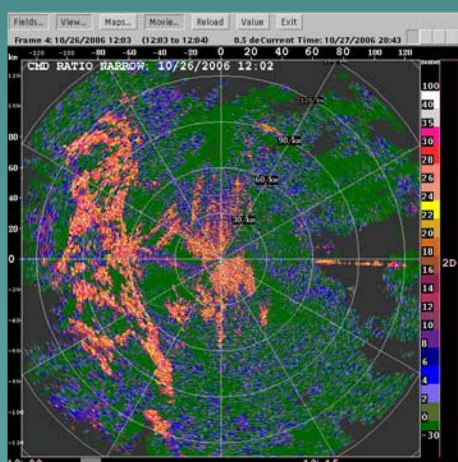
1.
SNR
> 3dB?



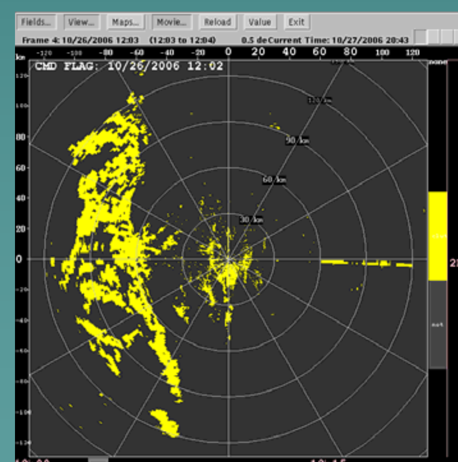
3.
CMD
> 0.5?



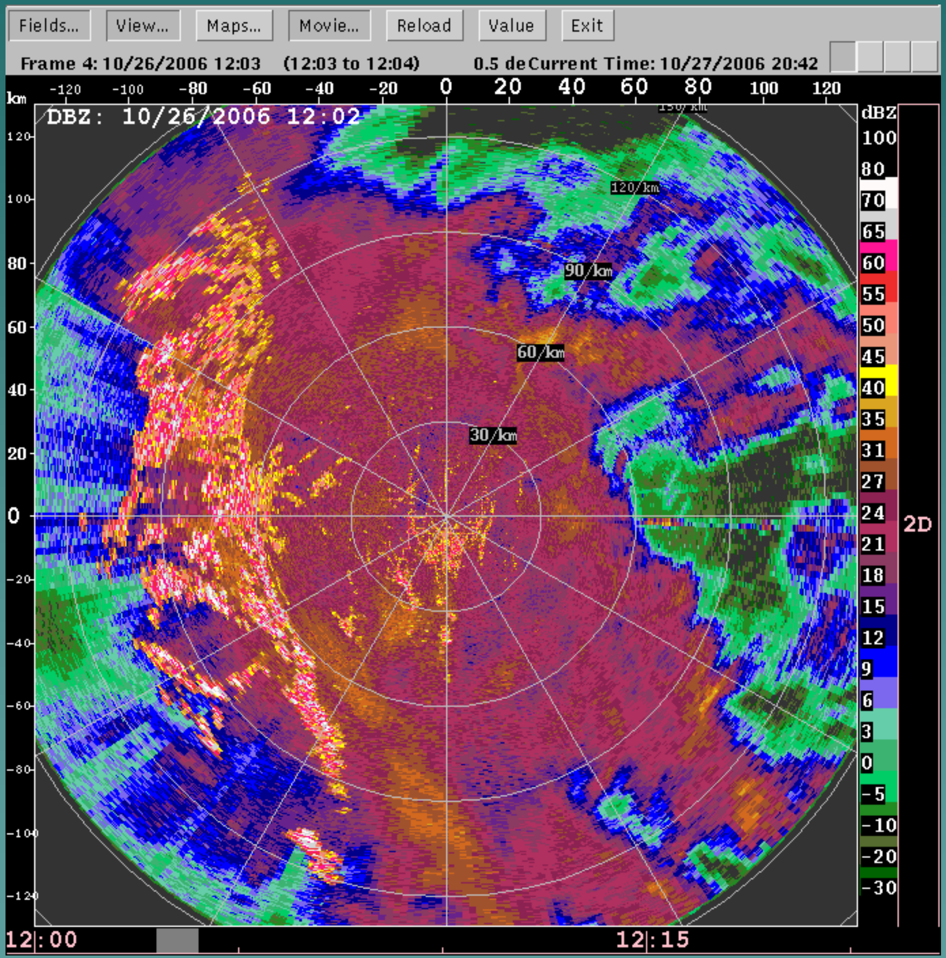
2.
Ratio
Narrow
> 6dB?



4.
Set
Flag.

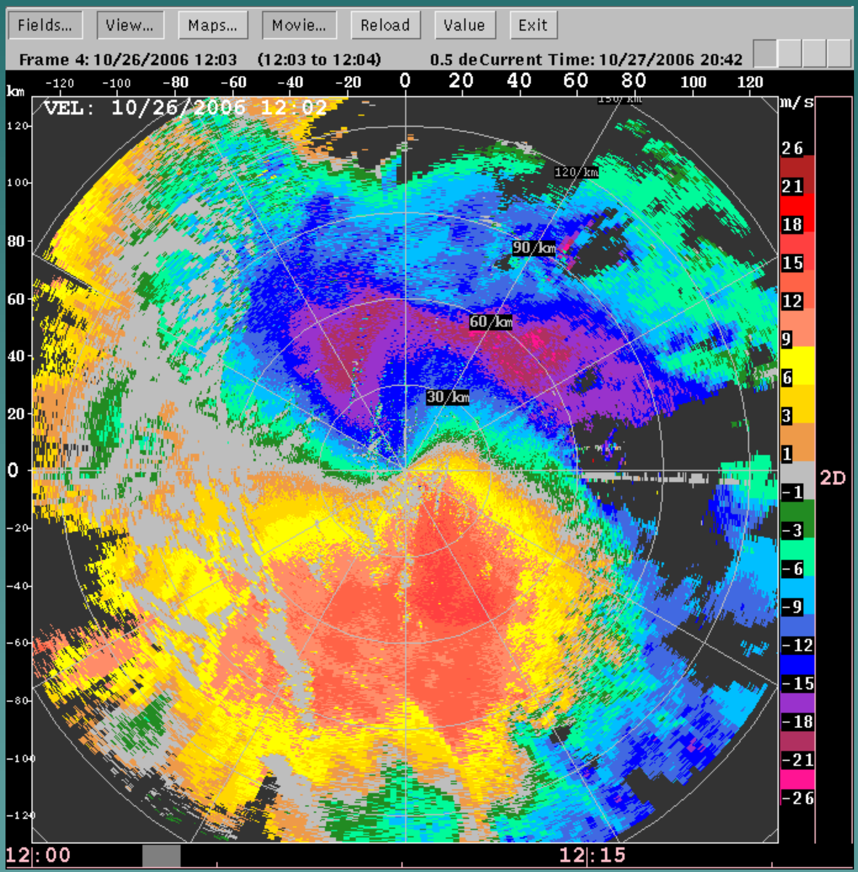


Example 1 : KFTG 2006/10/26, 1200 UTC

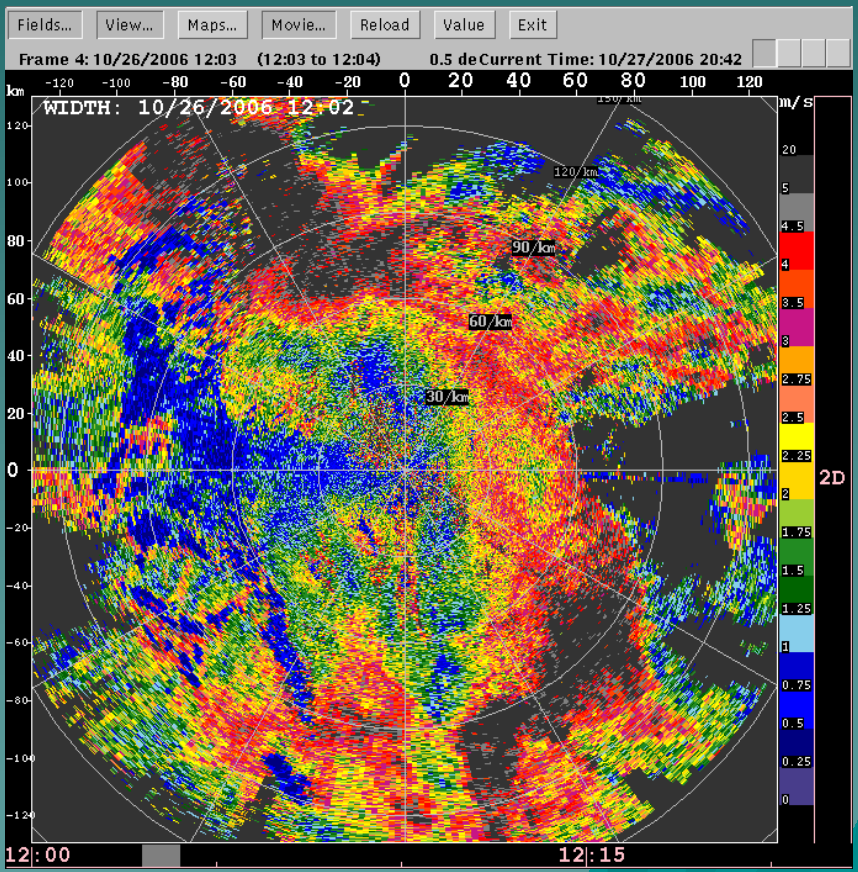


Reflectivity

Example 1 : KFTG 2006/10/26

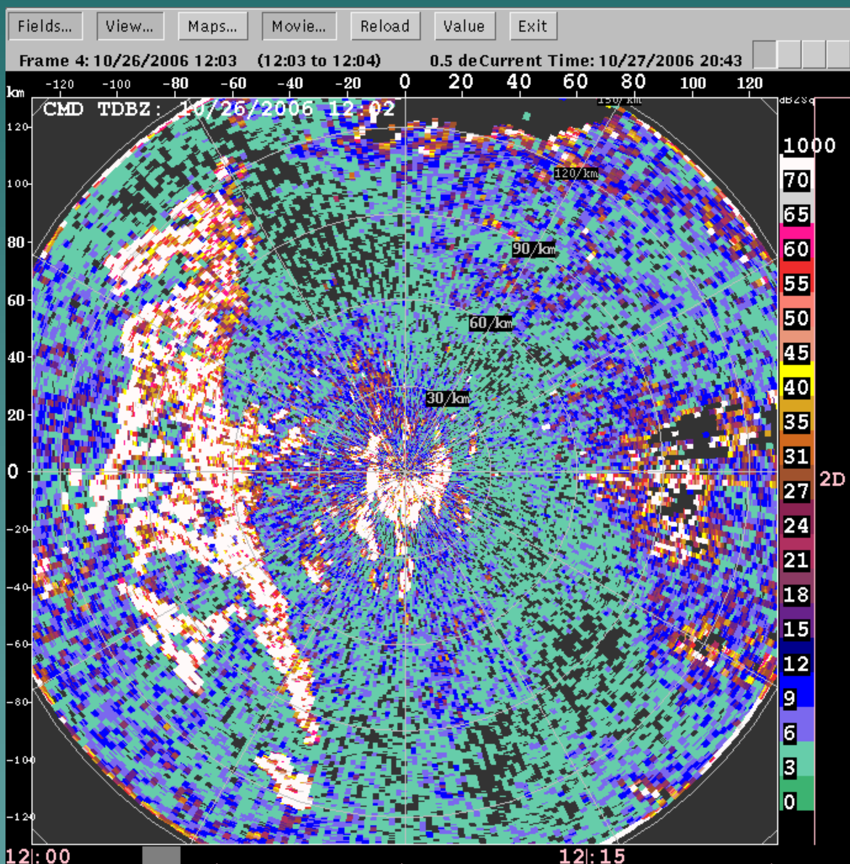


Radial velocity

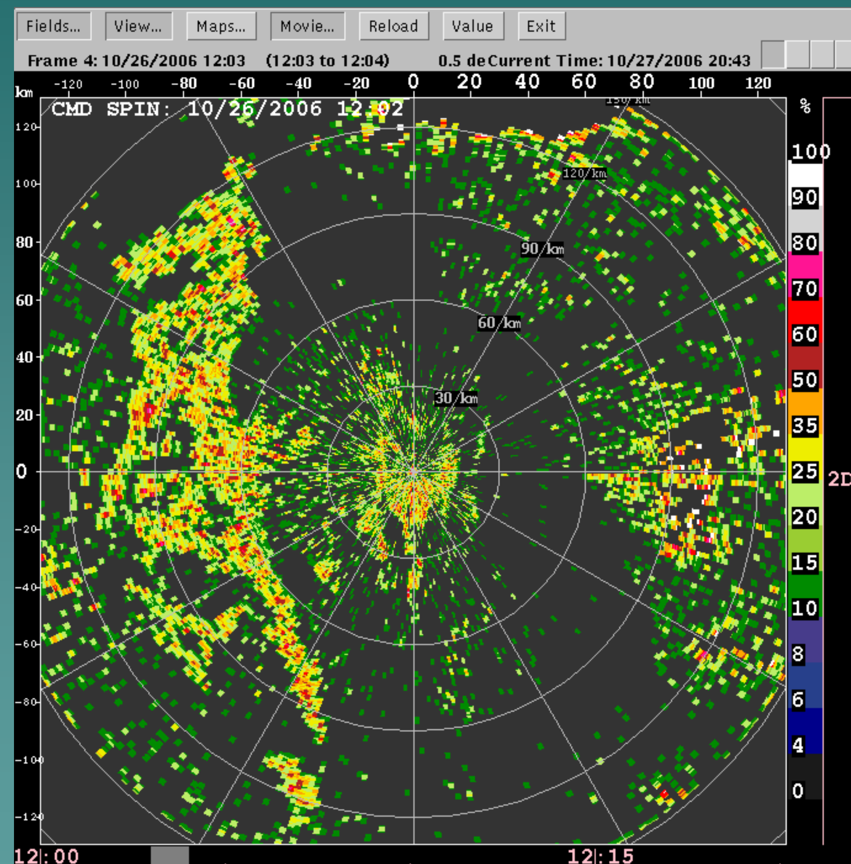


Spectrum width

Example 1 : KFTG 2006/10/26

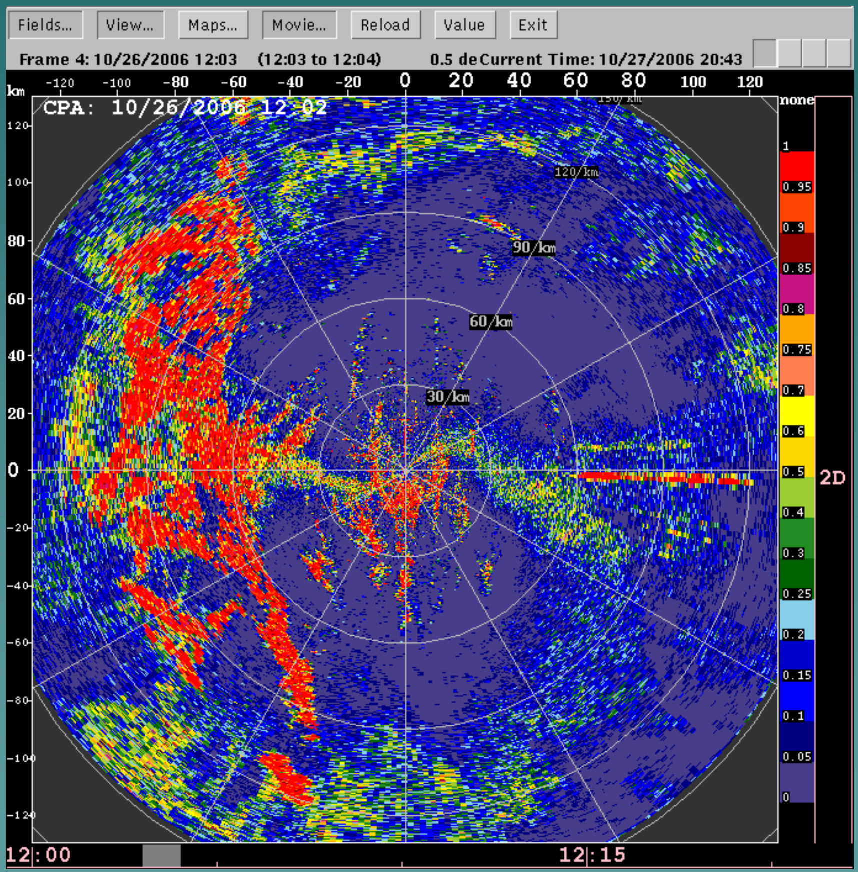


TDBZ

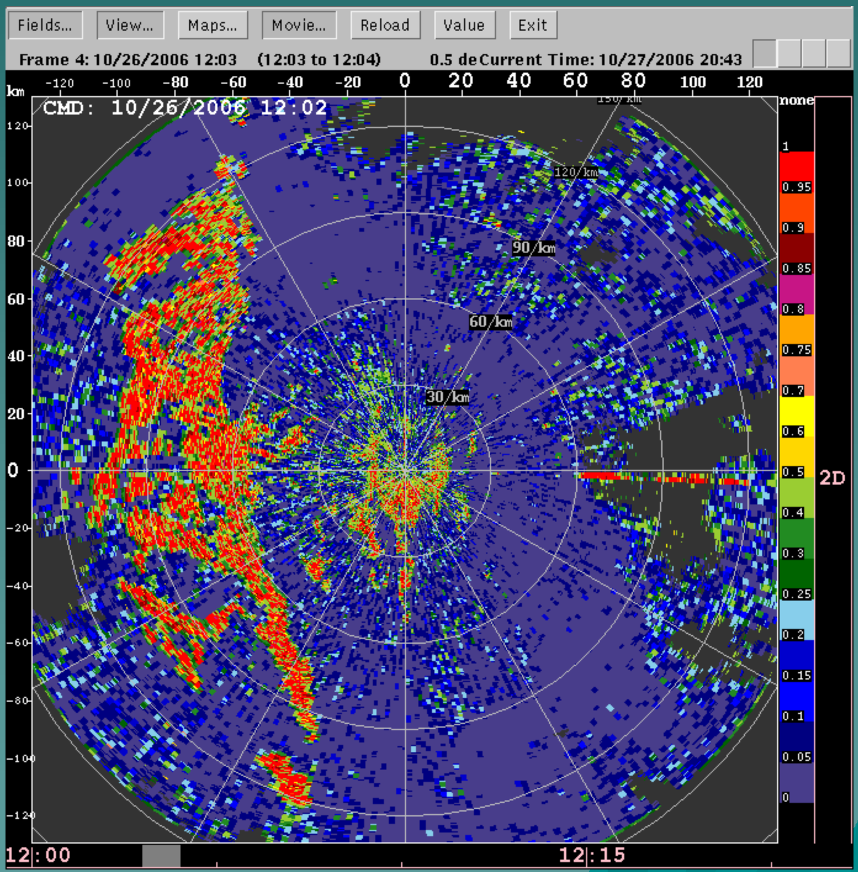


SPIN

Example 1 : KFTG 2006/10/26

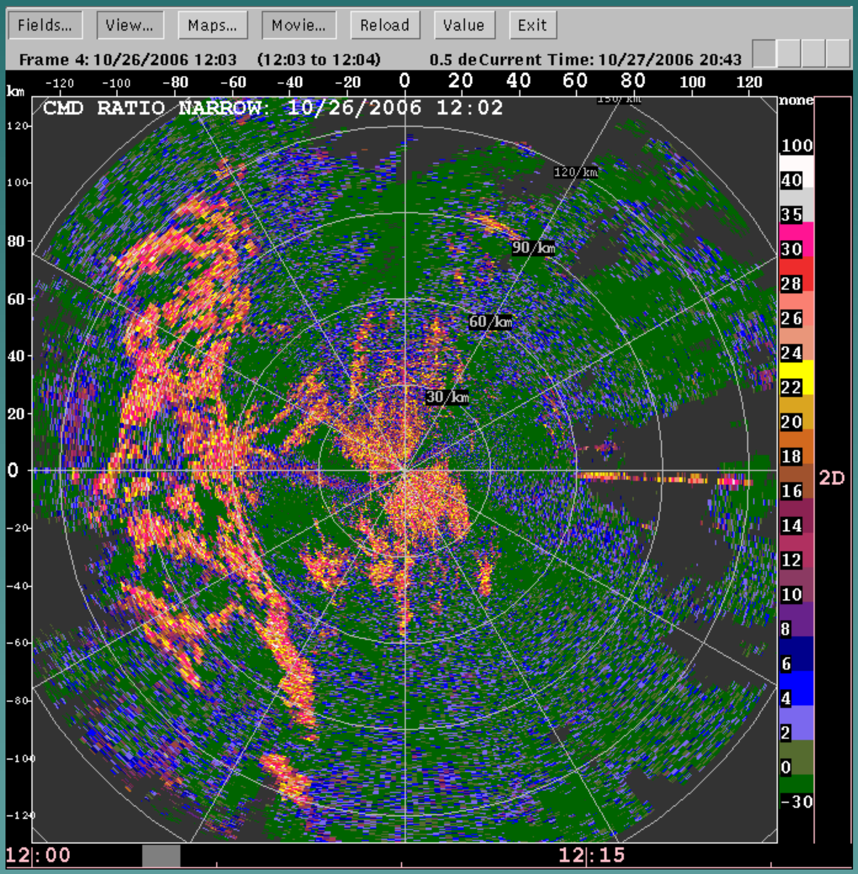


CPA

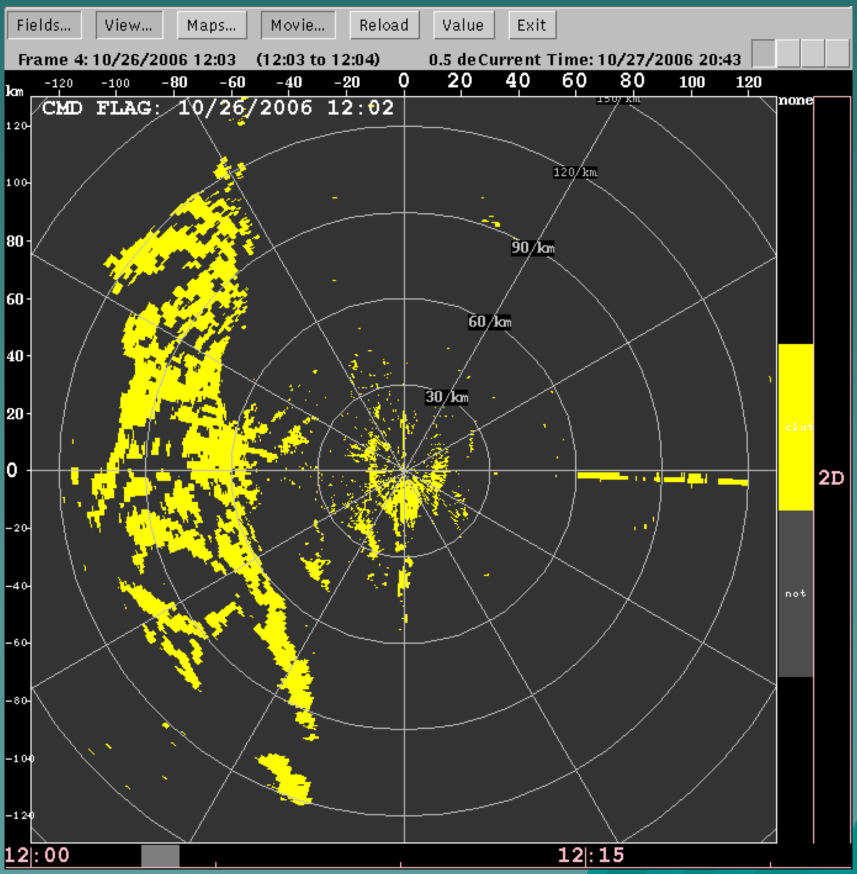


CMD

Example 1 : KFTG 2006/10/26

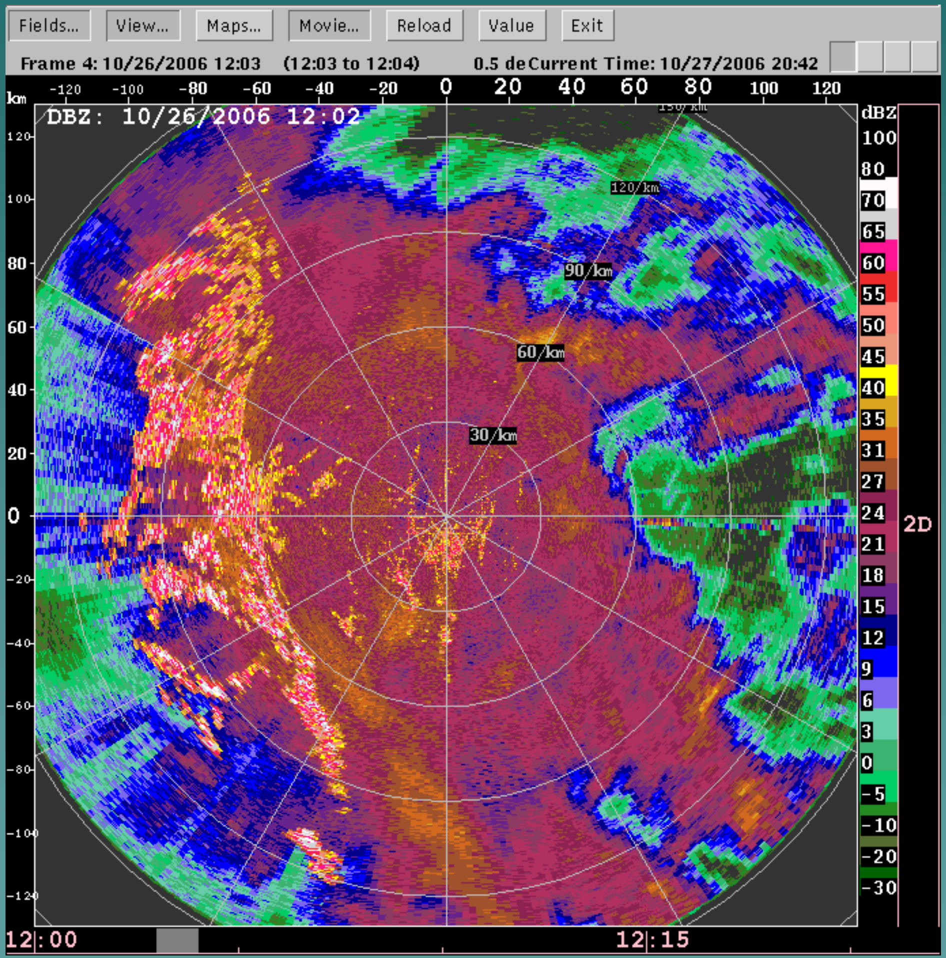


Ratio narrow



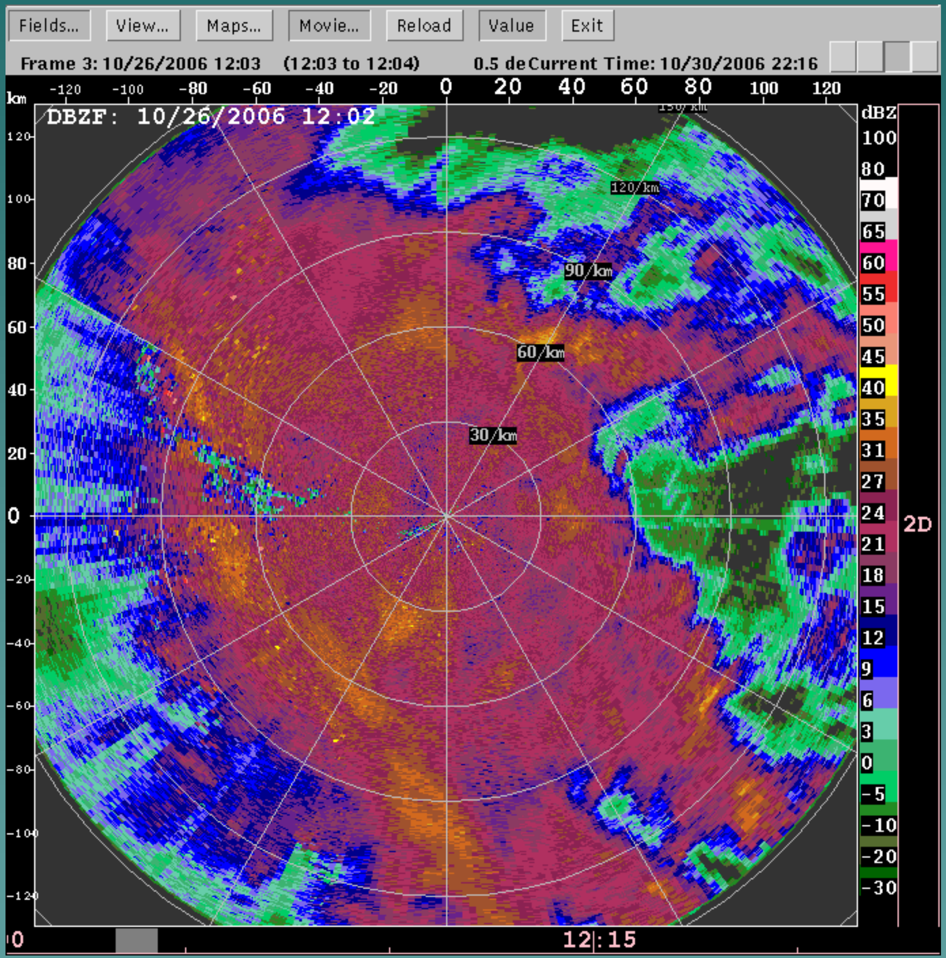
Clutter flag

Example 1 : KFTG 2006/10/26



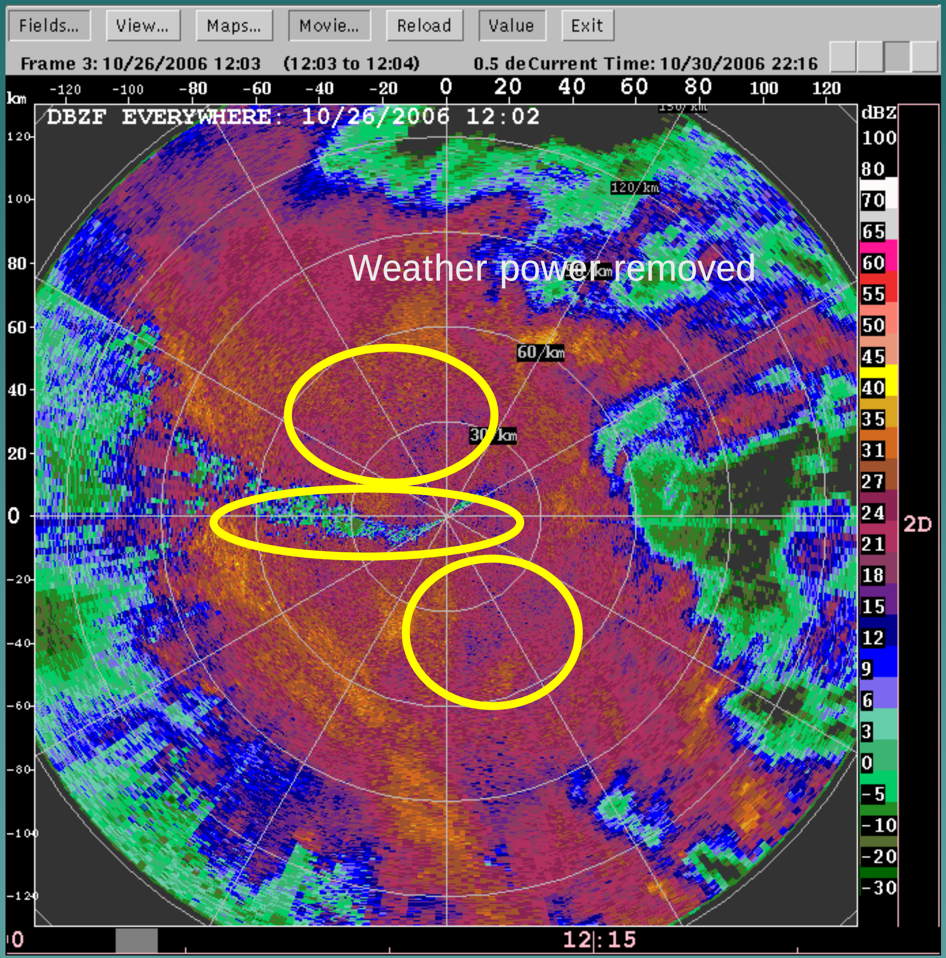
Reflectivity again

Example 1 : KFTG 2006/10/26



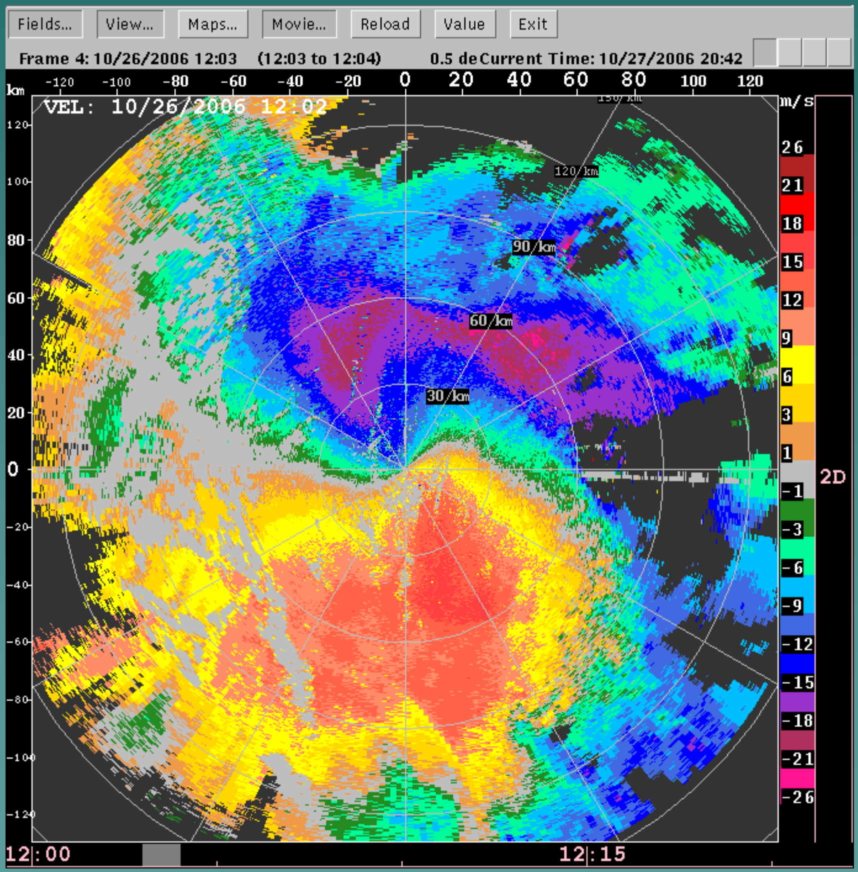
Filtered reflectivity using CMD

What happens if we filter everywhere?

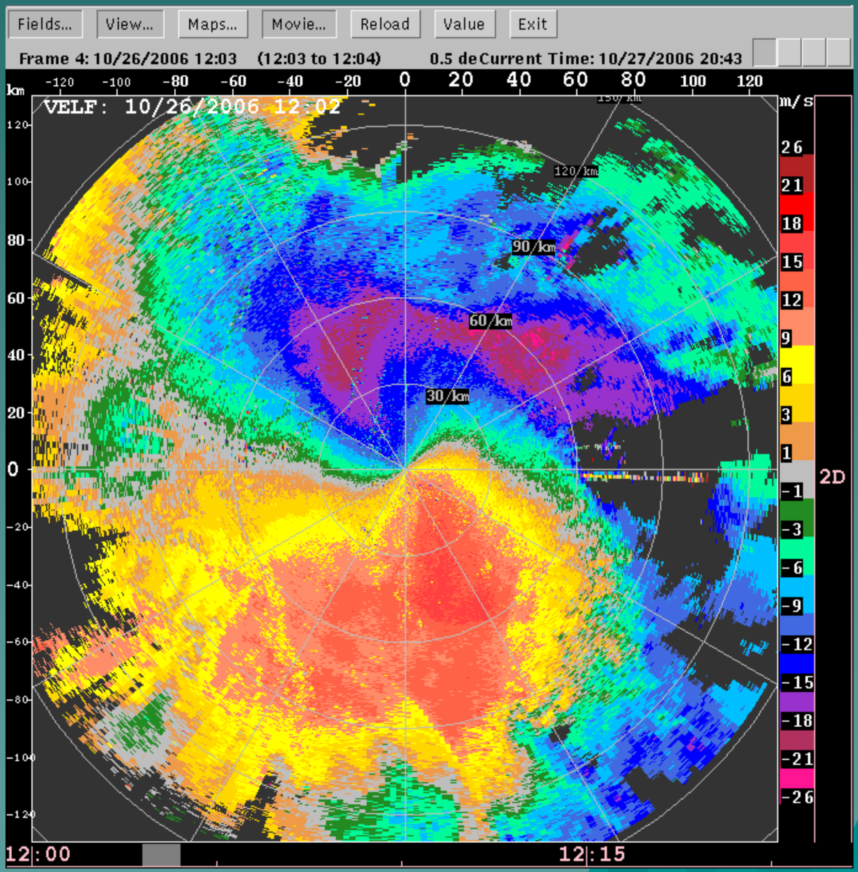


Filtered reflectivity – applying clutter filter everywhere

Example 1 : KFTG 2006/10/26

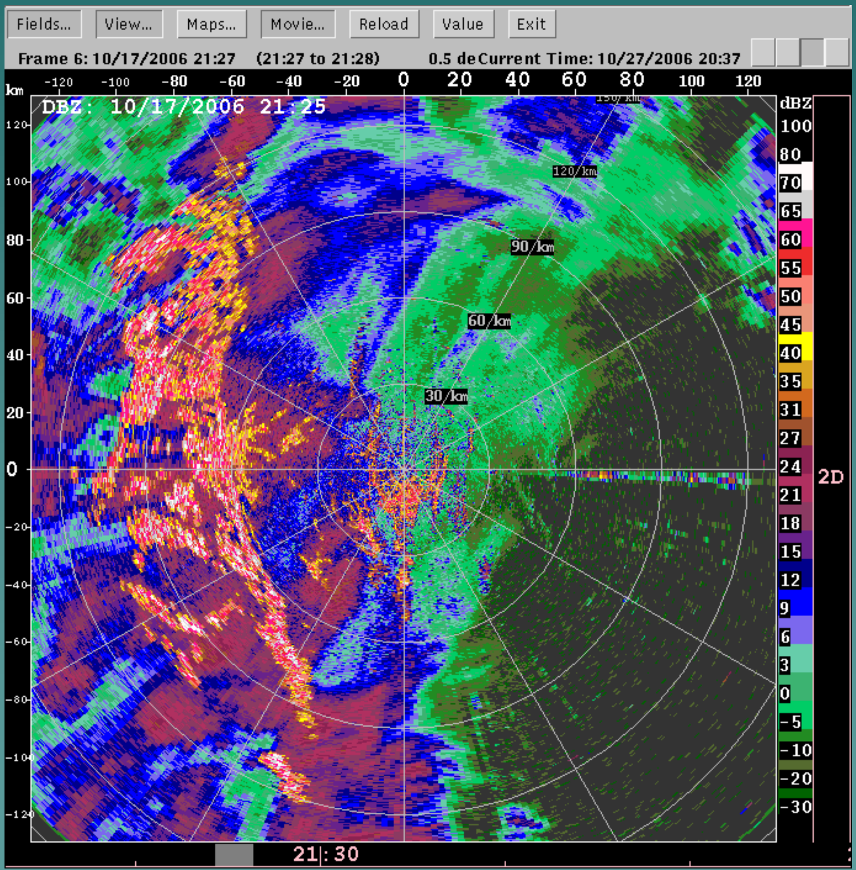


Velocity

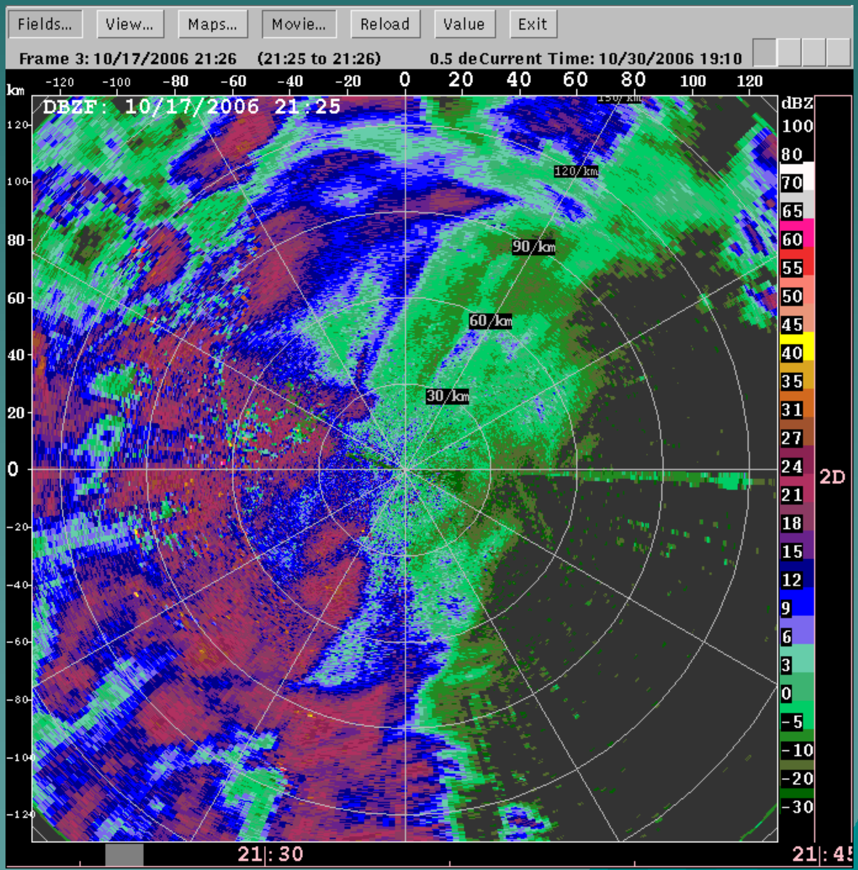


Filtered velocity

Example 2 : KFTG 2006/10/17, 2130 UTC

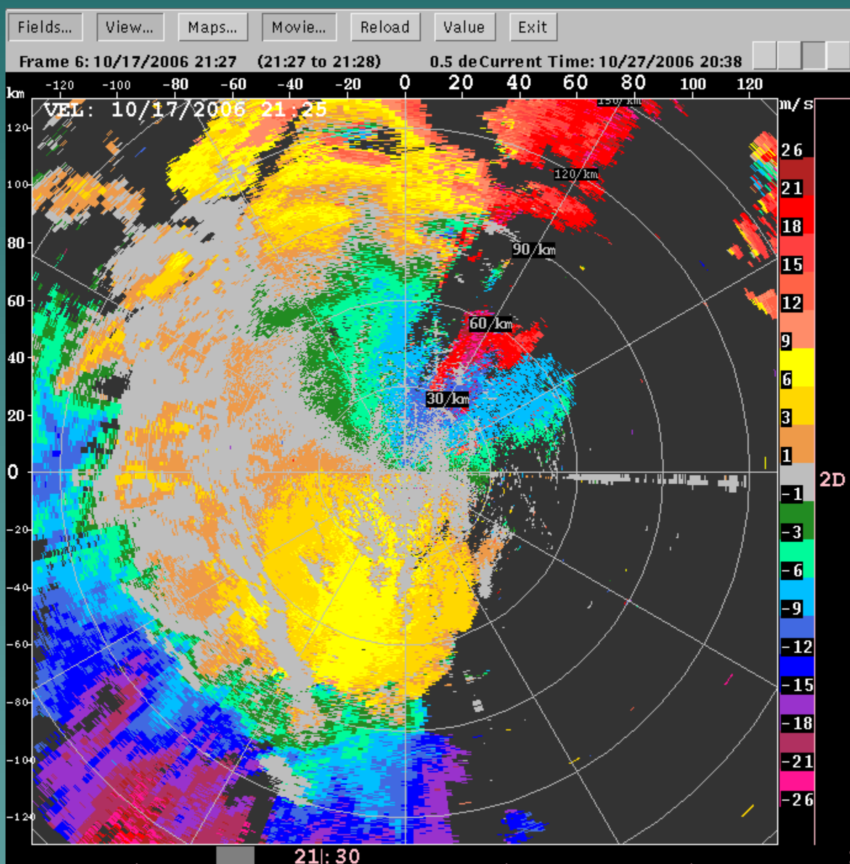


Reflectivity

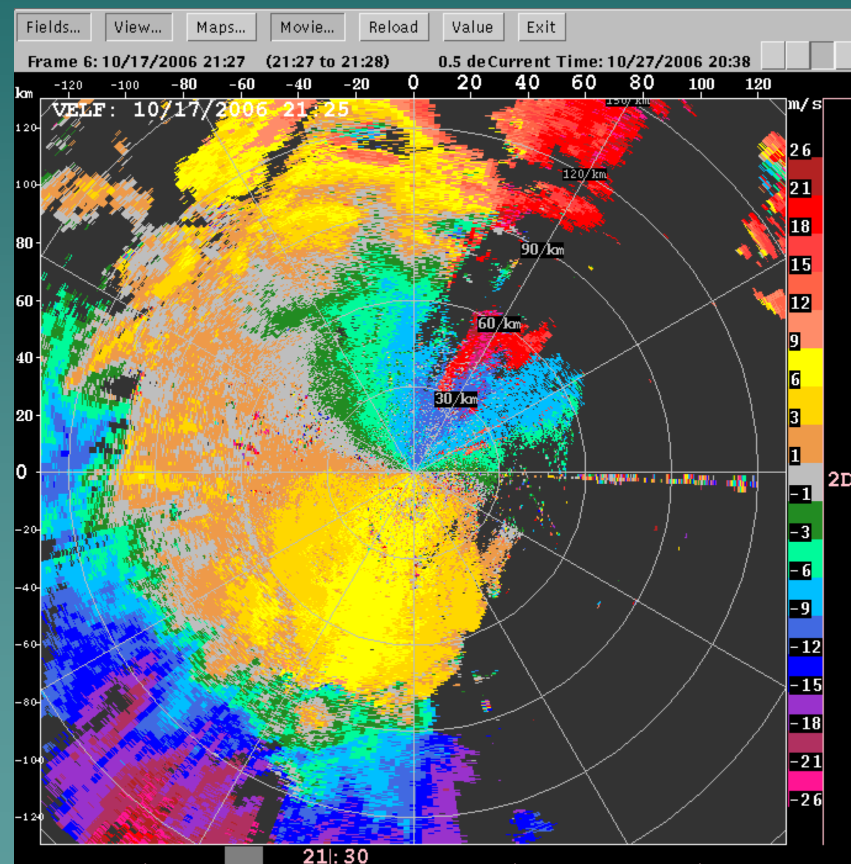


Filtered reflectivity

Example 2 : KFTG 2006/10/17

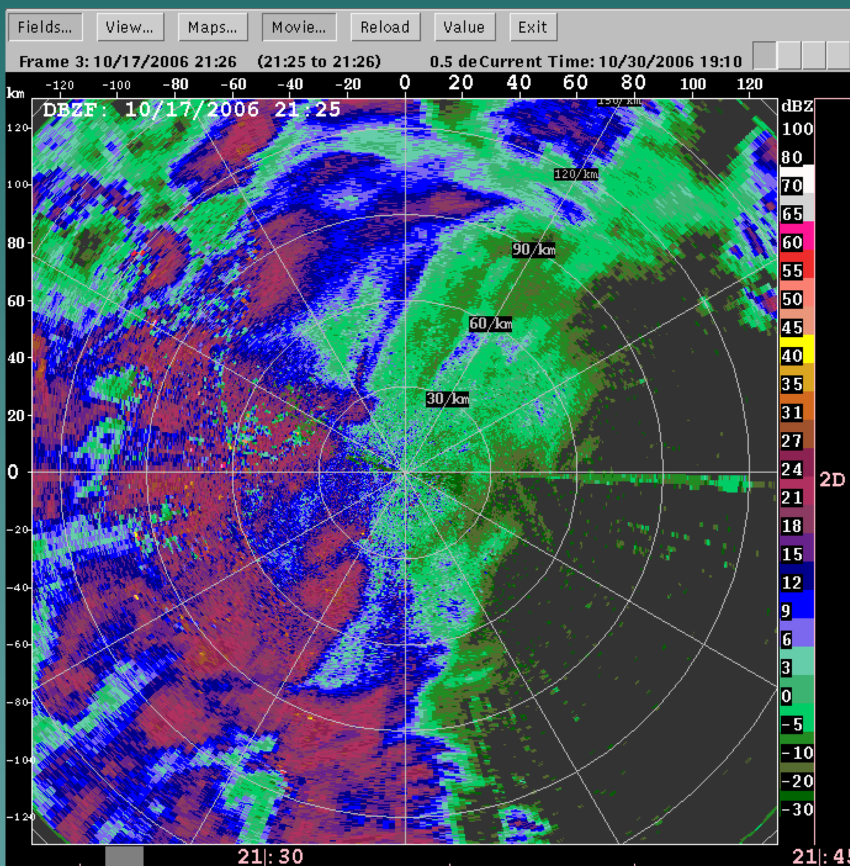


Velocity

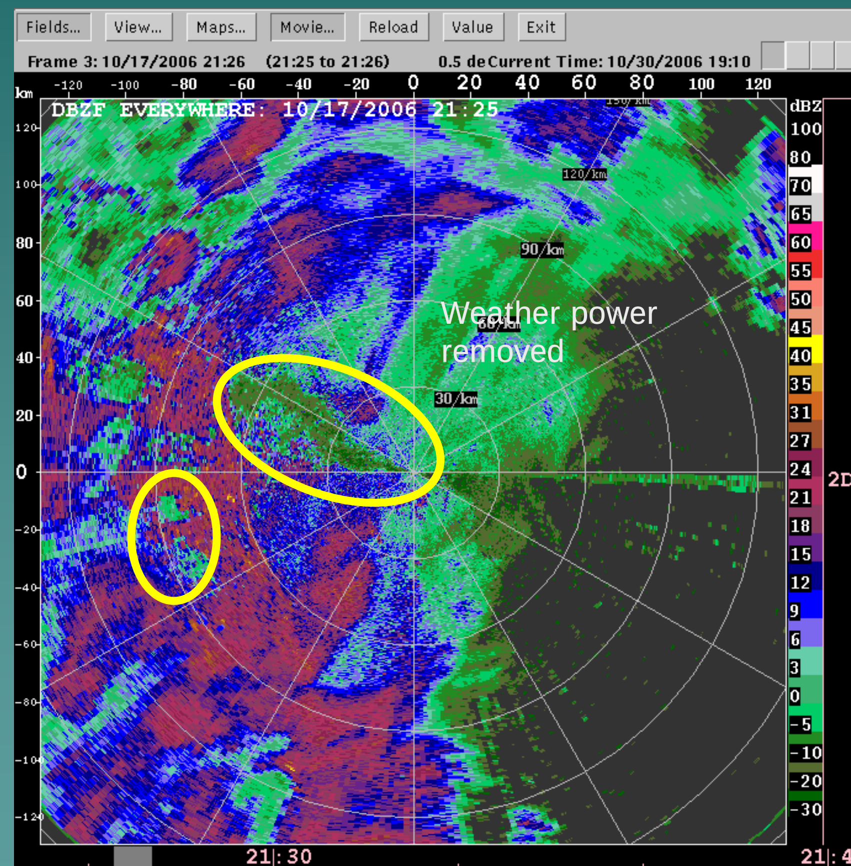


Filtered velocity

Example 2 : Filtering everywhere

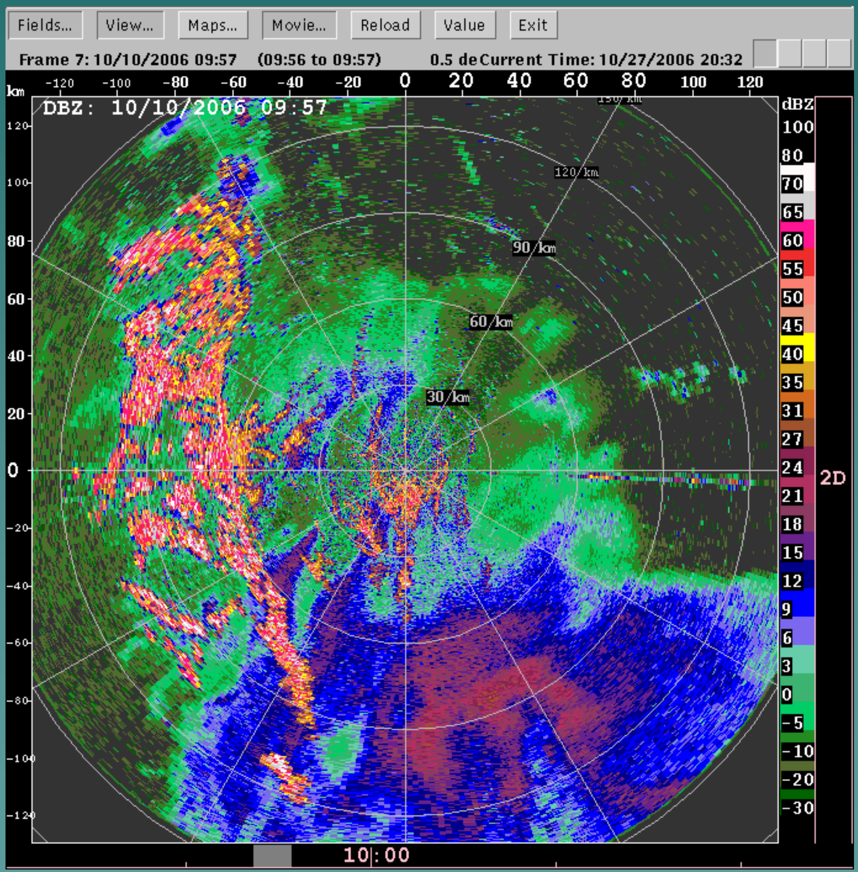


Filtered using CMD

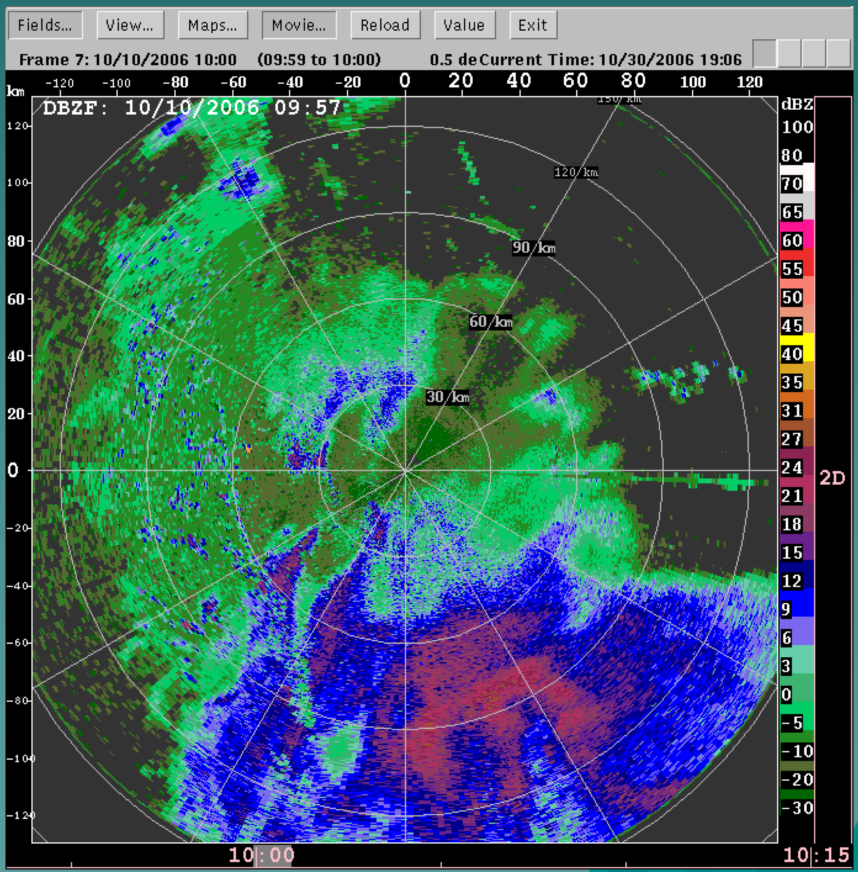


Filtered everywhere

Example 3 : KFTG 2006/10/10, 1000 UTC

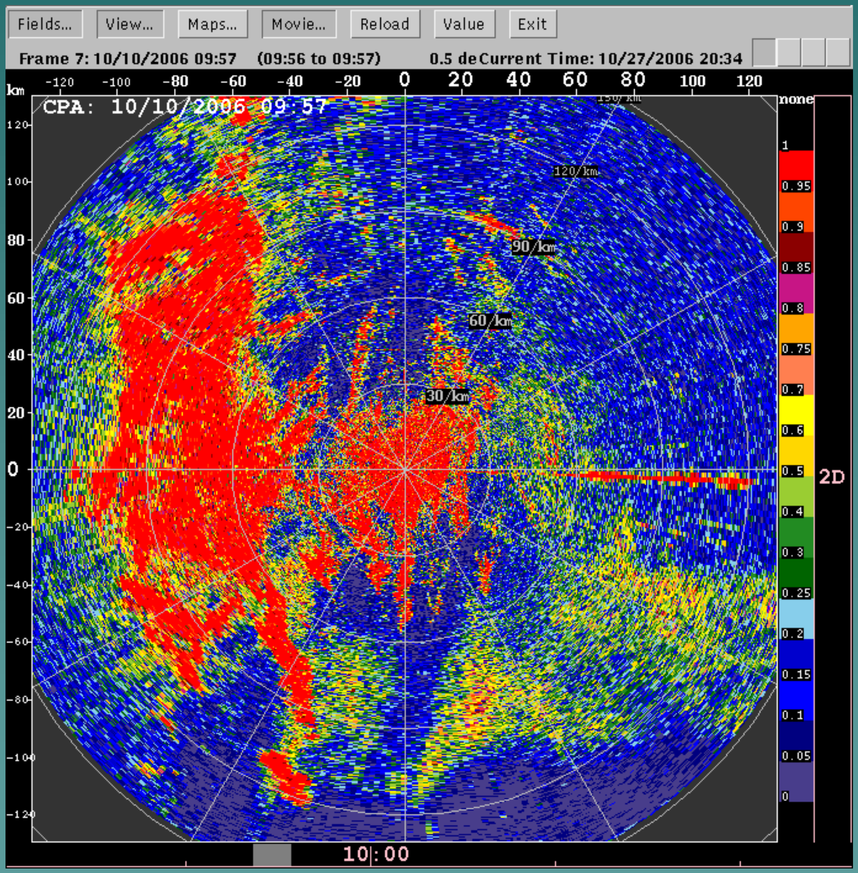


Reflectivity

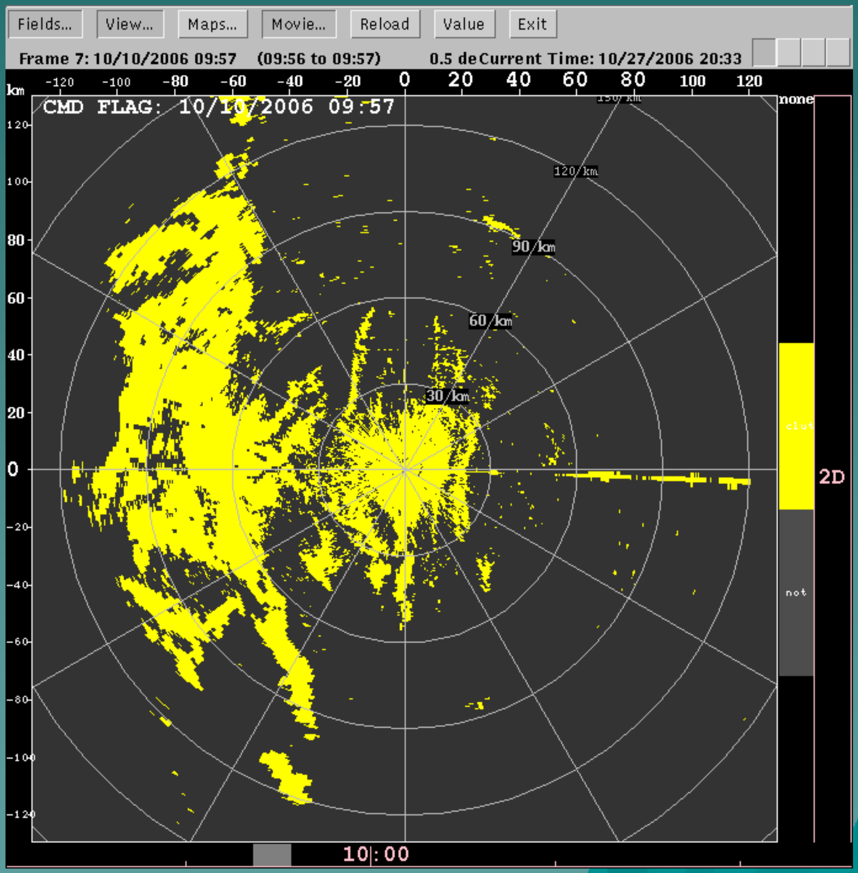


Filtered reflectivity

Example 3 : KFTG 2006/10/10, 1000 UTC

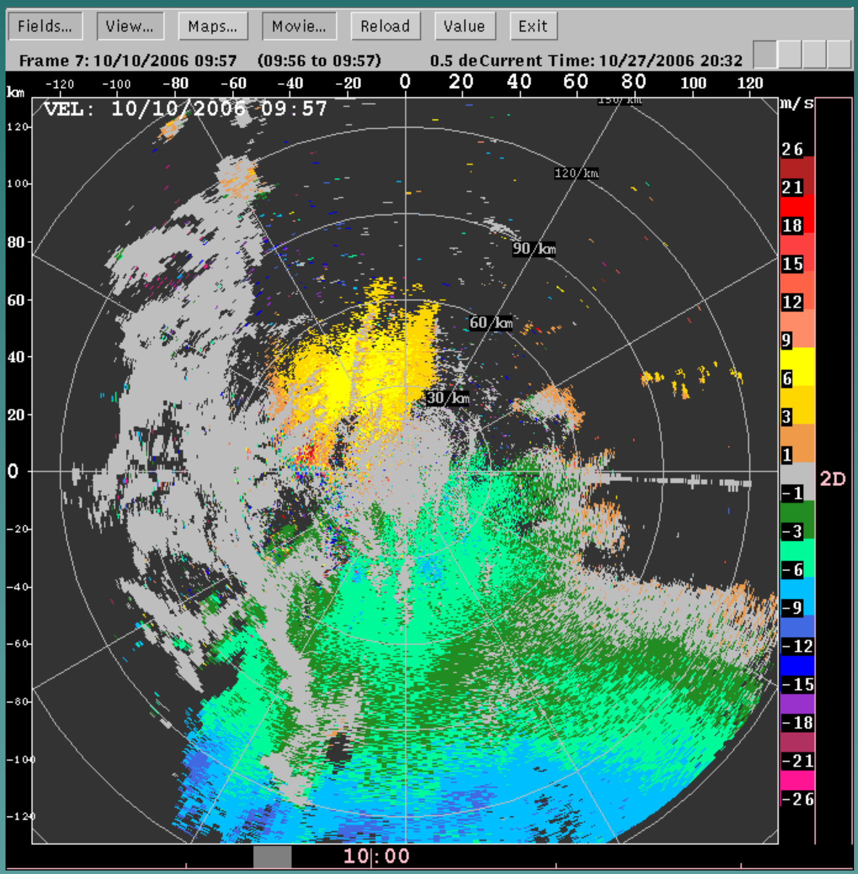


CPA

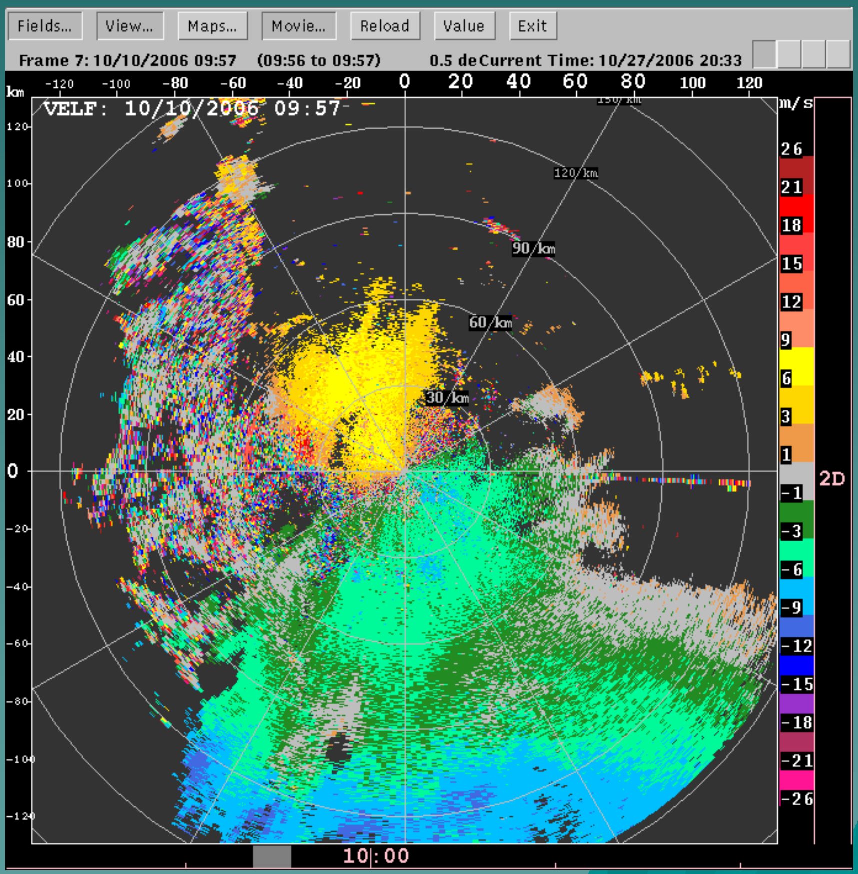


CMD flag

Example 3 : KFTG 2006/10/10, 1000 UTC

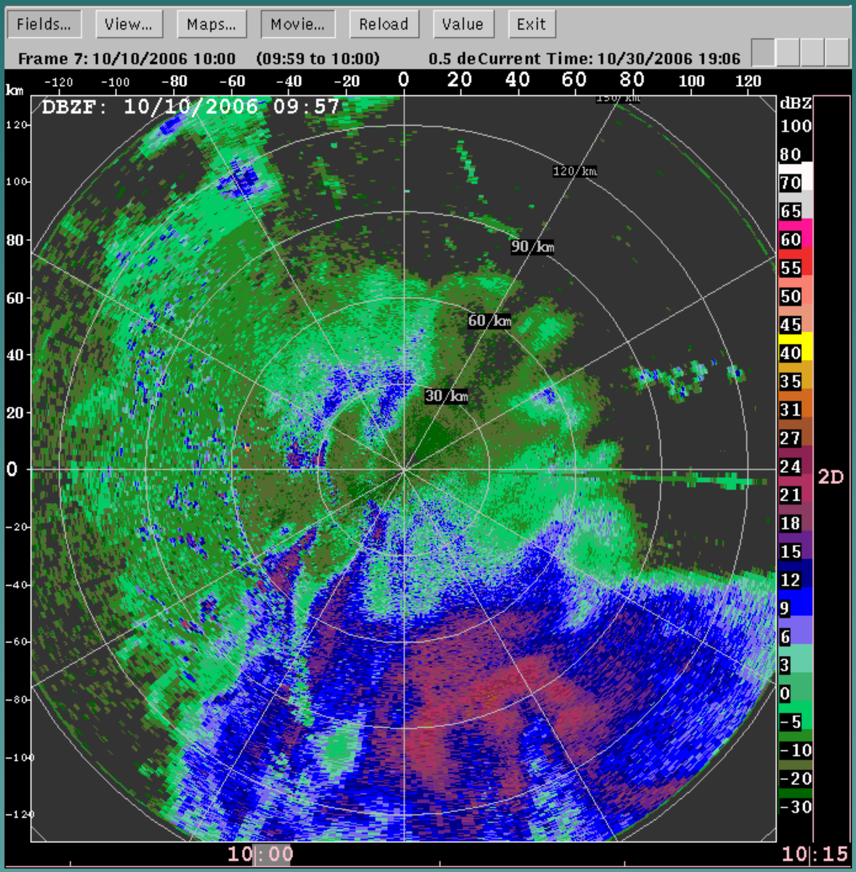


Velocity

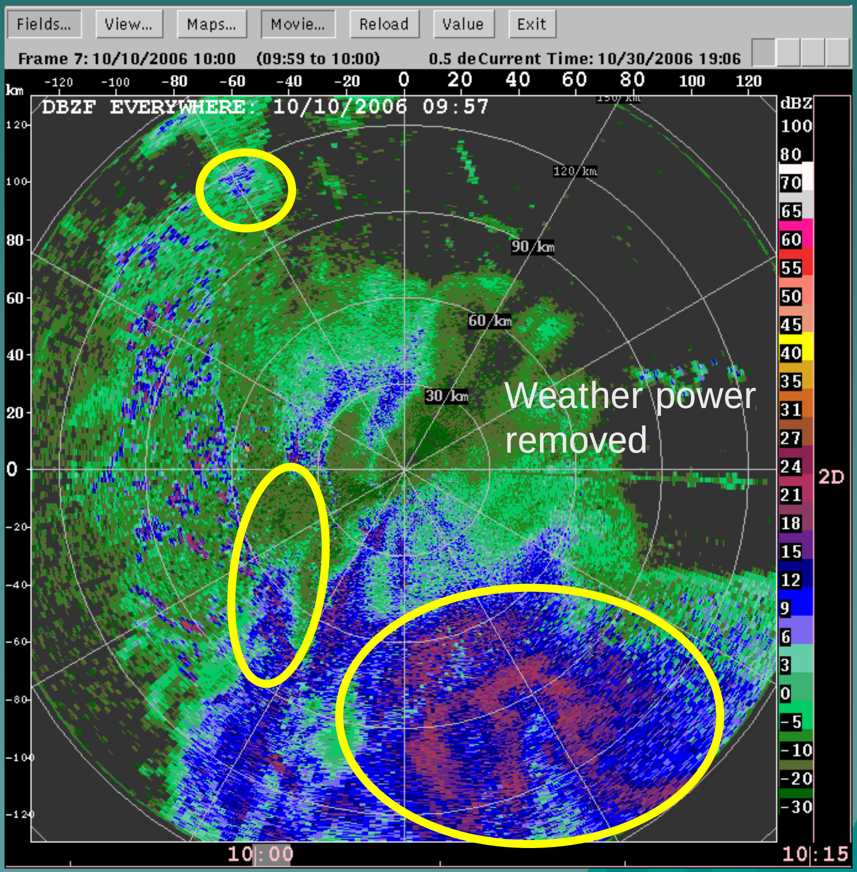


Filtered velocity

Example 3 : Filtering everywhere

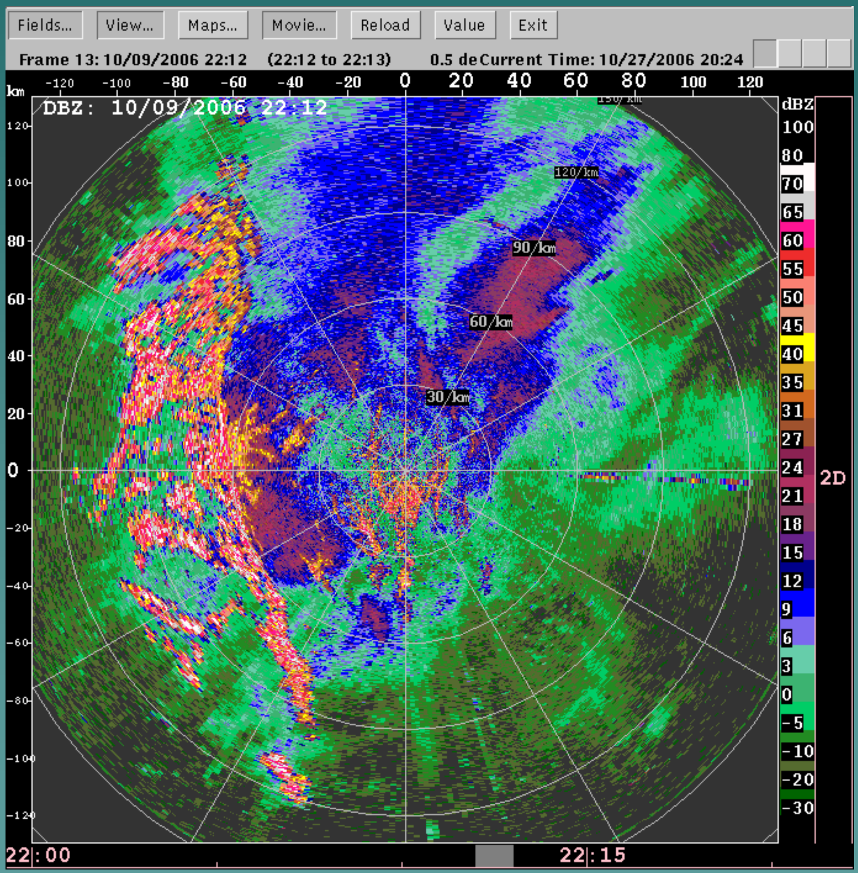


Filtered using CMD

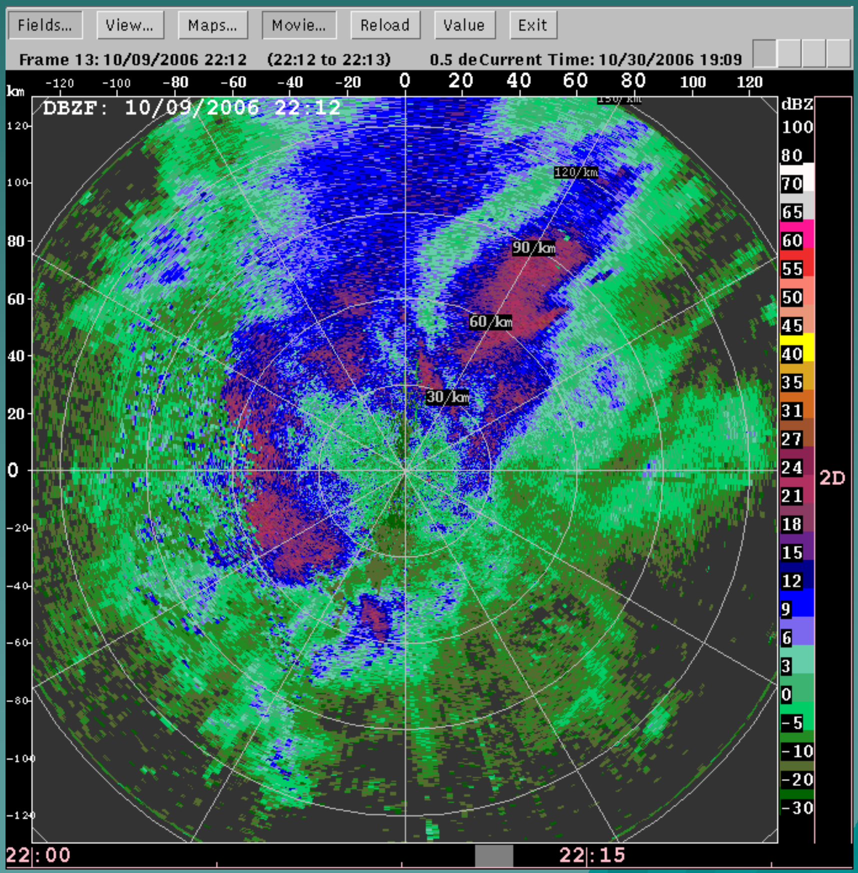


Filtered everywhere

Example 4 : KFTG 2006/10/09, 2200 UTC

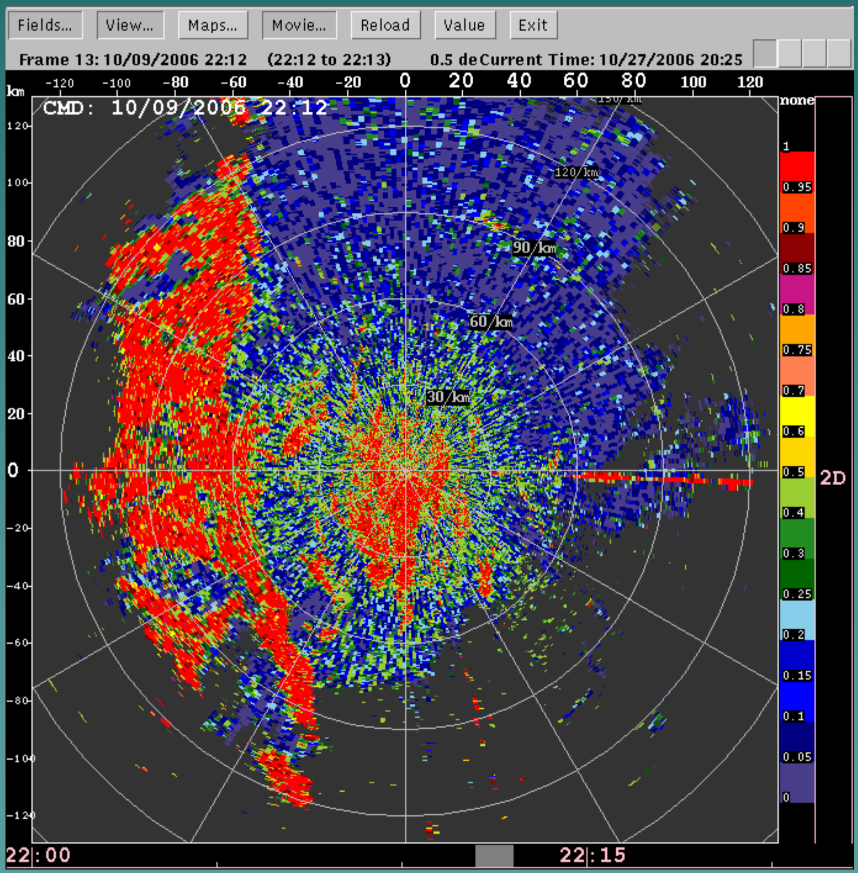


Reflectivity

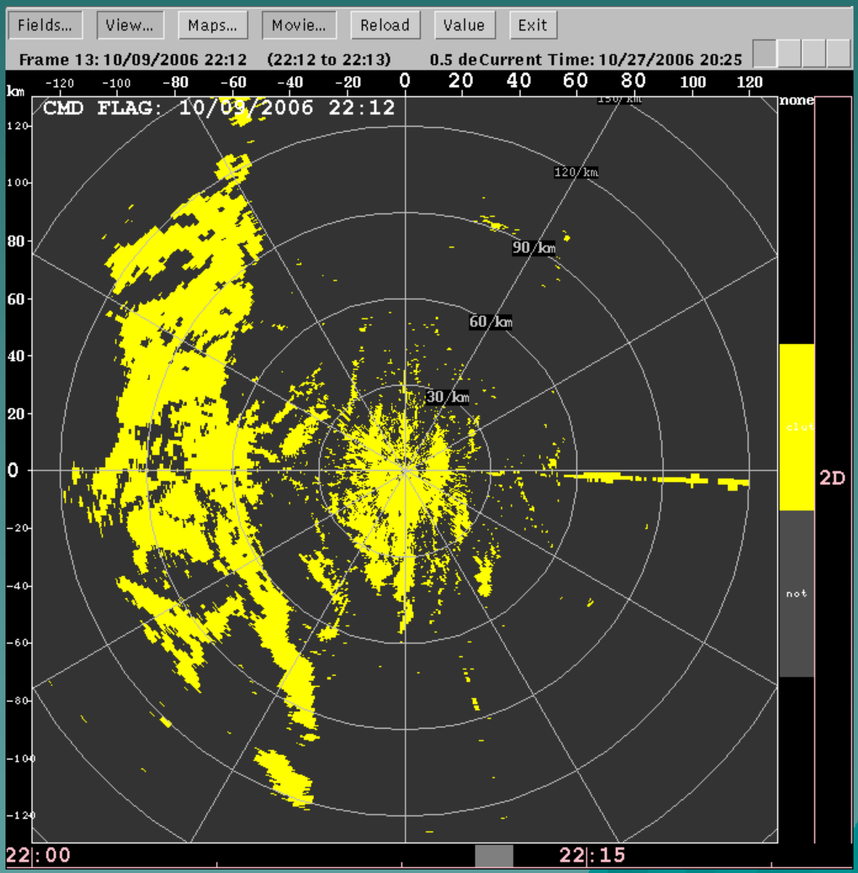


Filtered reflectivity

Example 4 : KFTG 2006/10/09, 2200 UTC

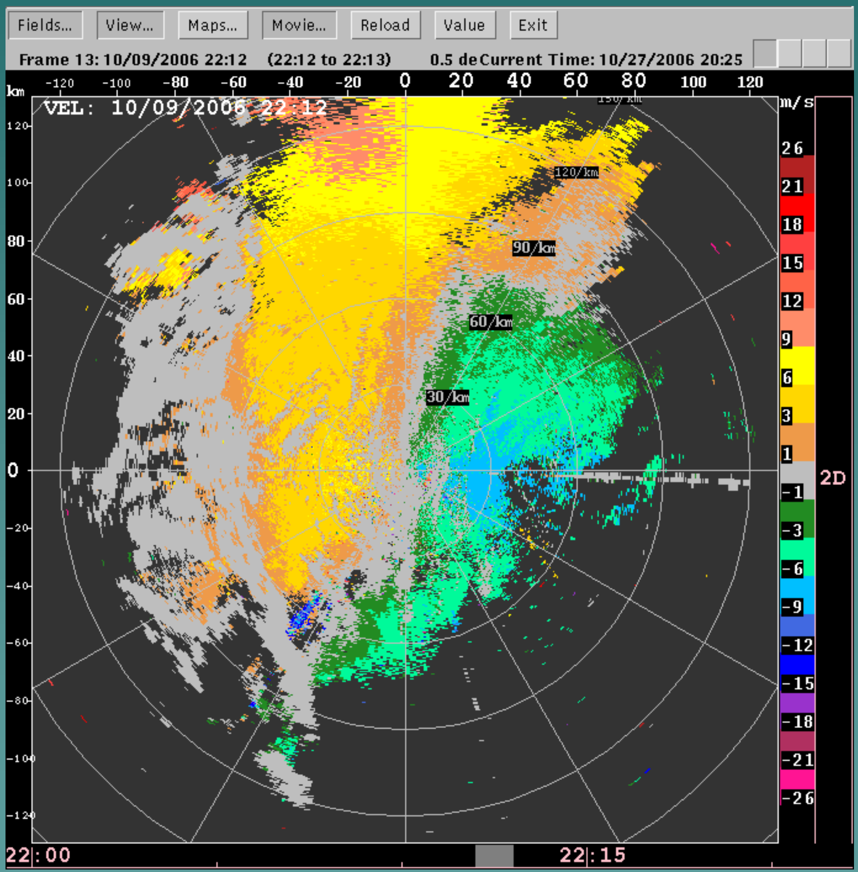


CMD

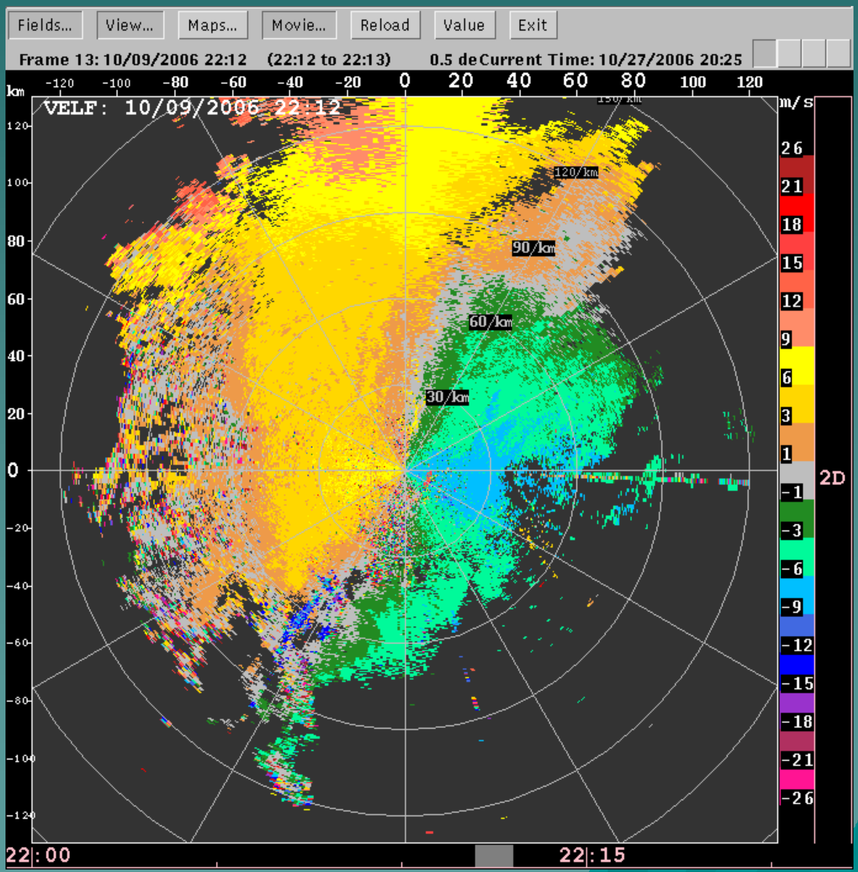


CMD flag

Example 4 : KFTG 2006/10/09, 2200 UTC

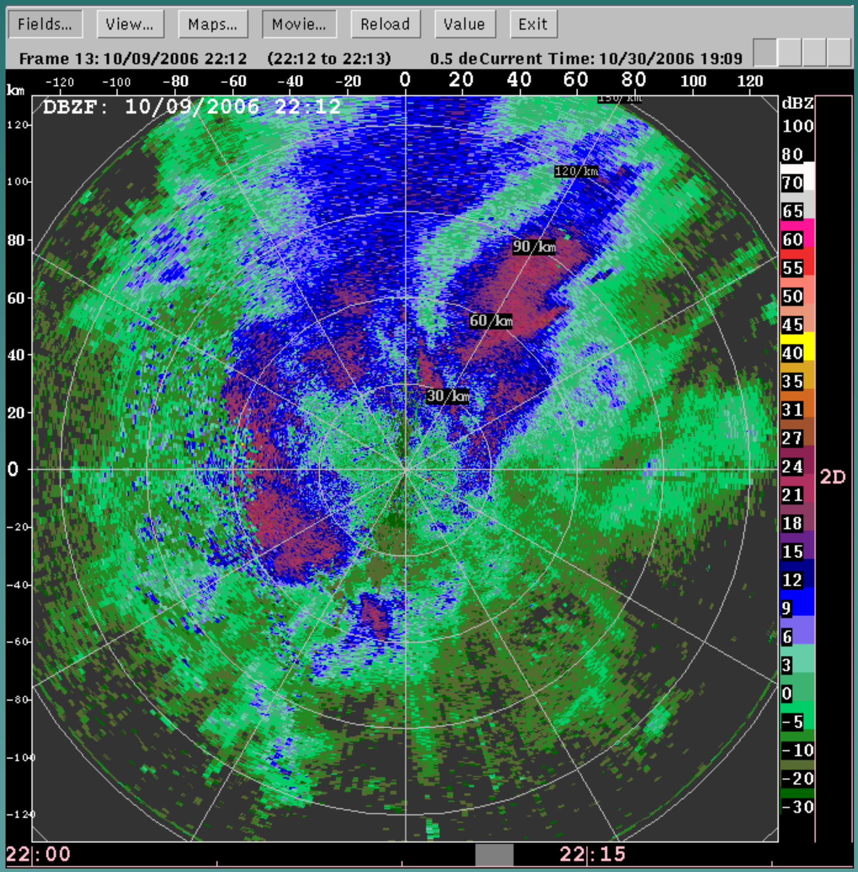


Velocity

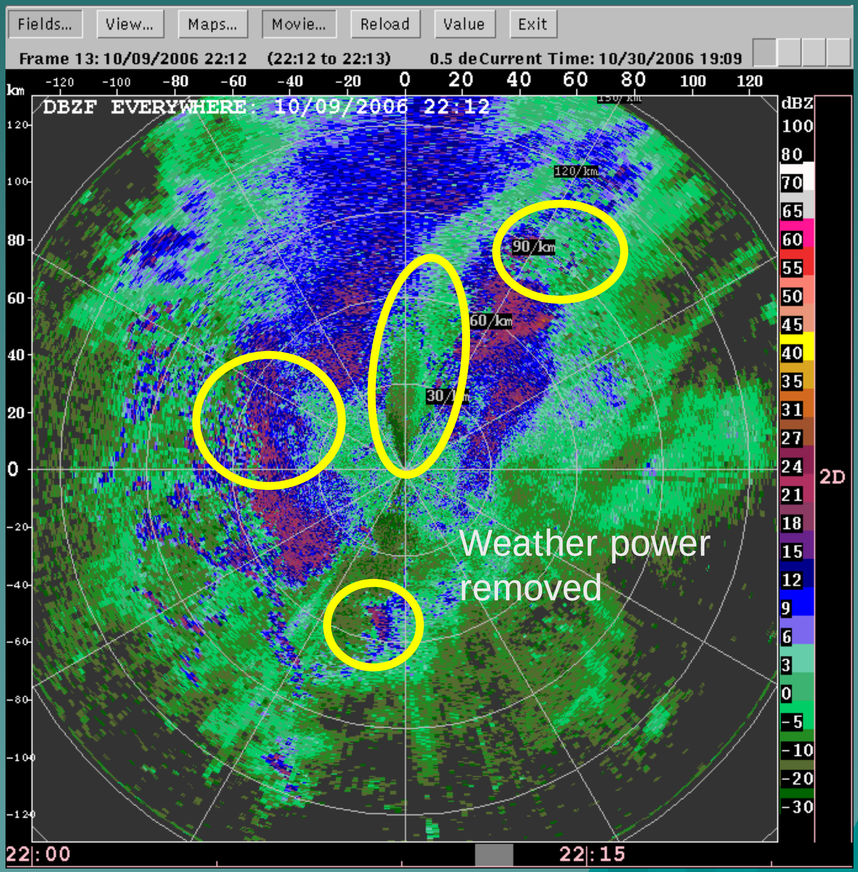


Filtered velocity

Example 4 : Filtering everywhere

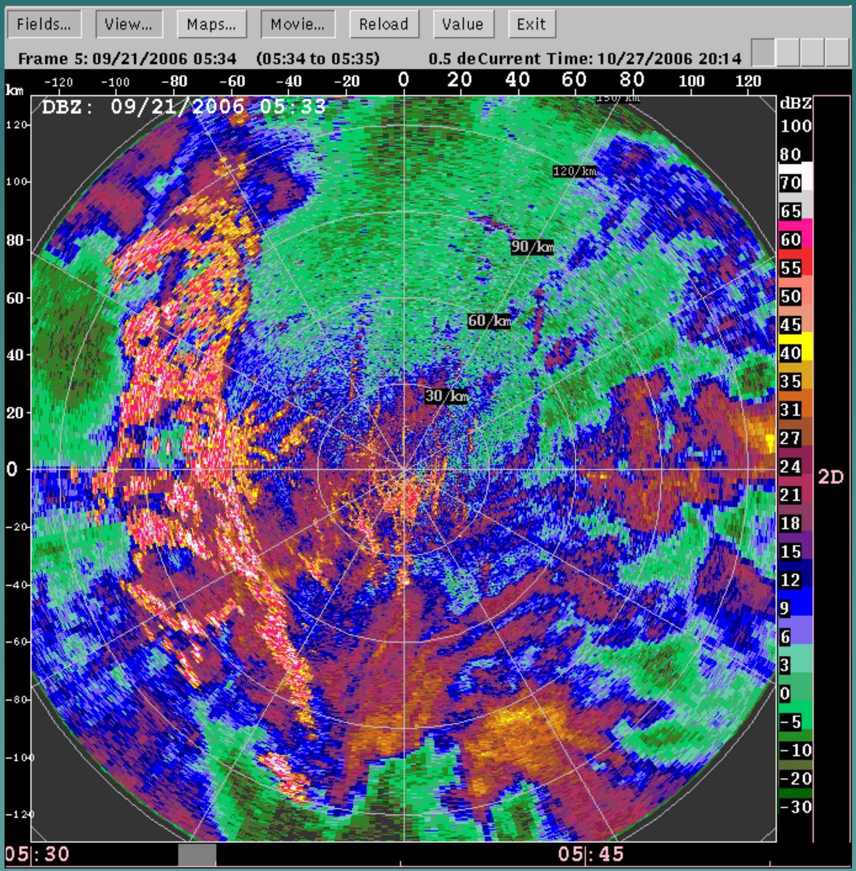


Filtered using CMD

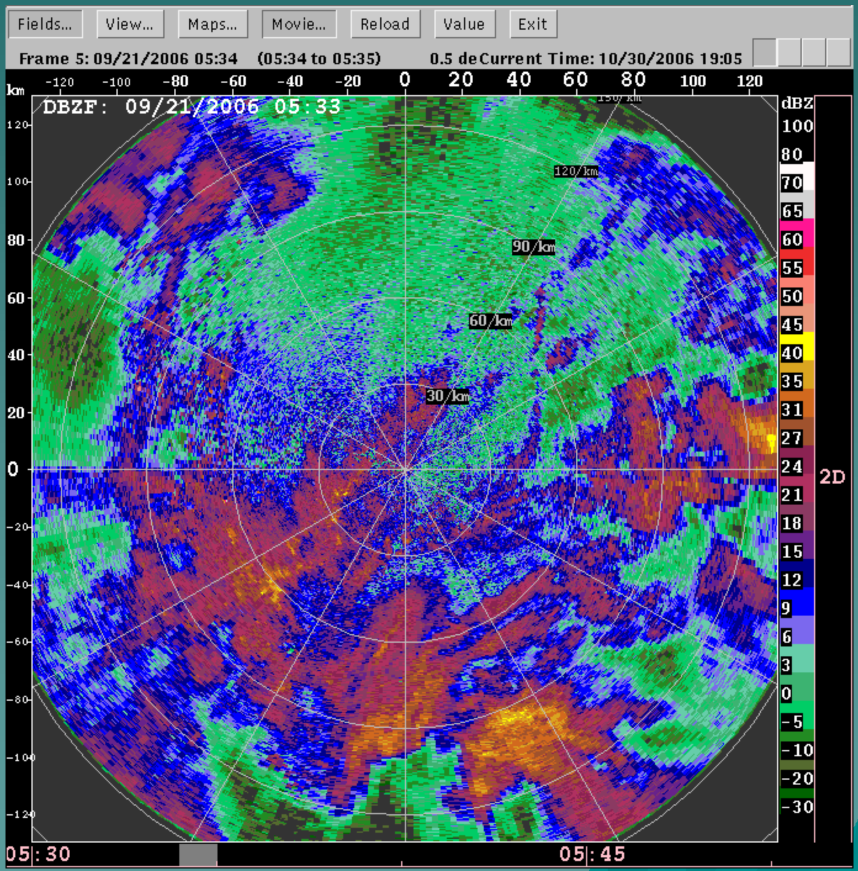


Filtered everywhere

Example 5 : KFTG 2006/09/21, 0530 UTC

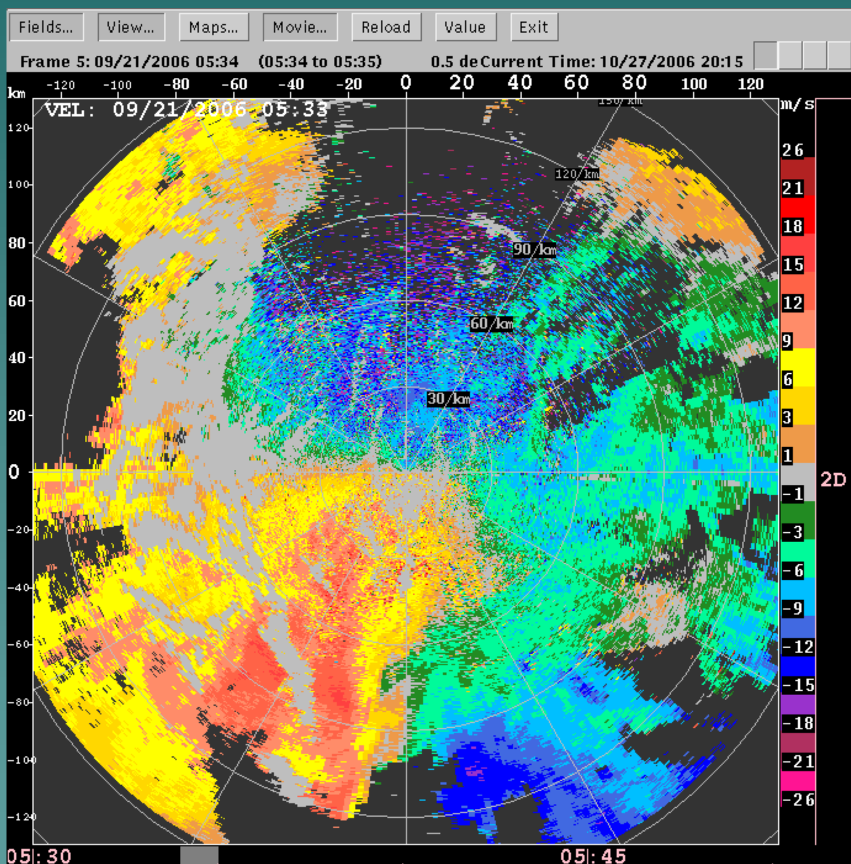


Reflectivity

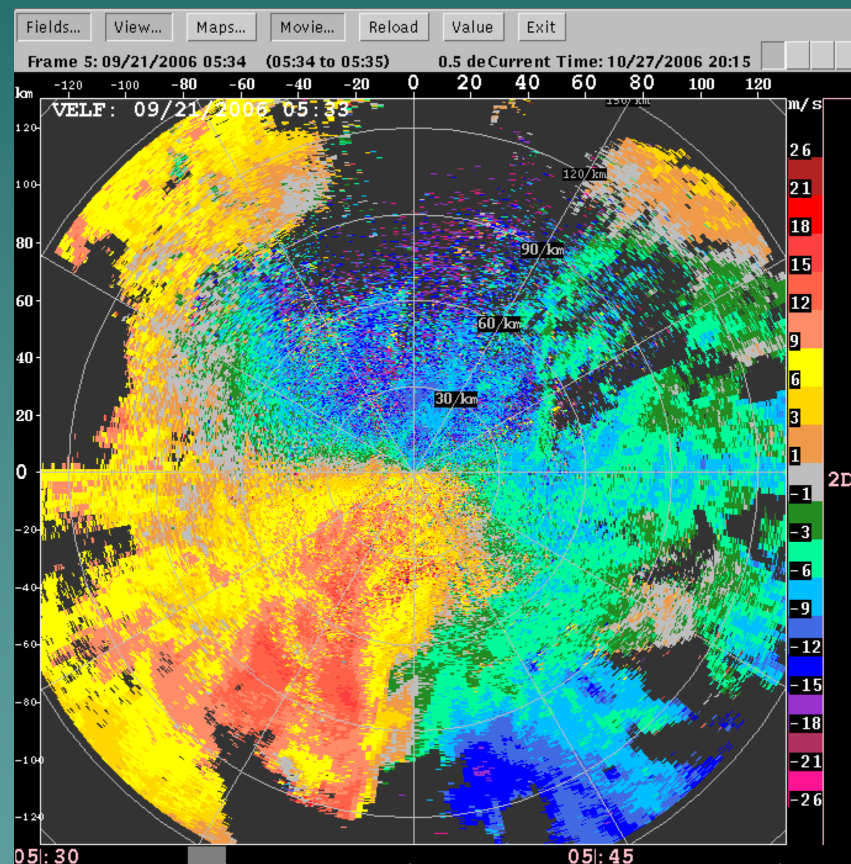


Filtered reflectivity

Example 5 : KFTG 2006/09/21, 0530 UTC

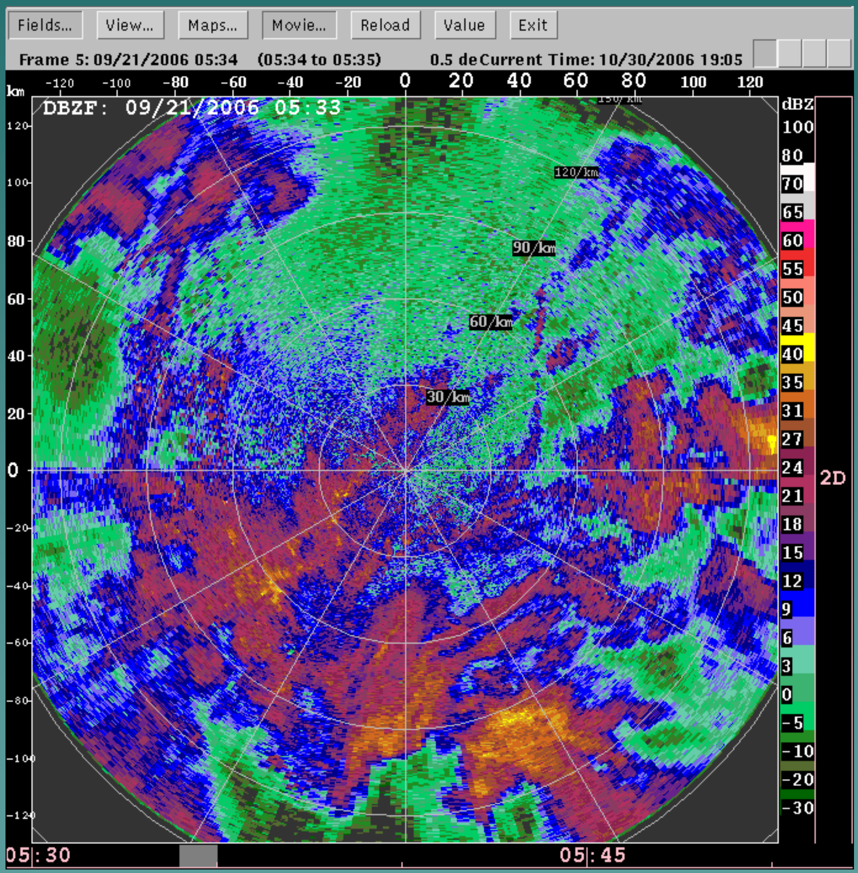


Velocity

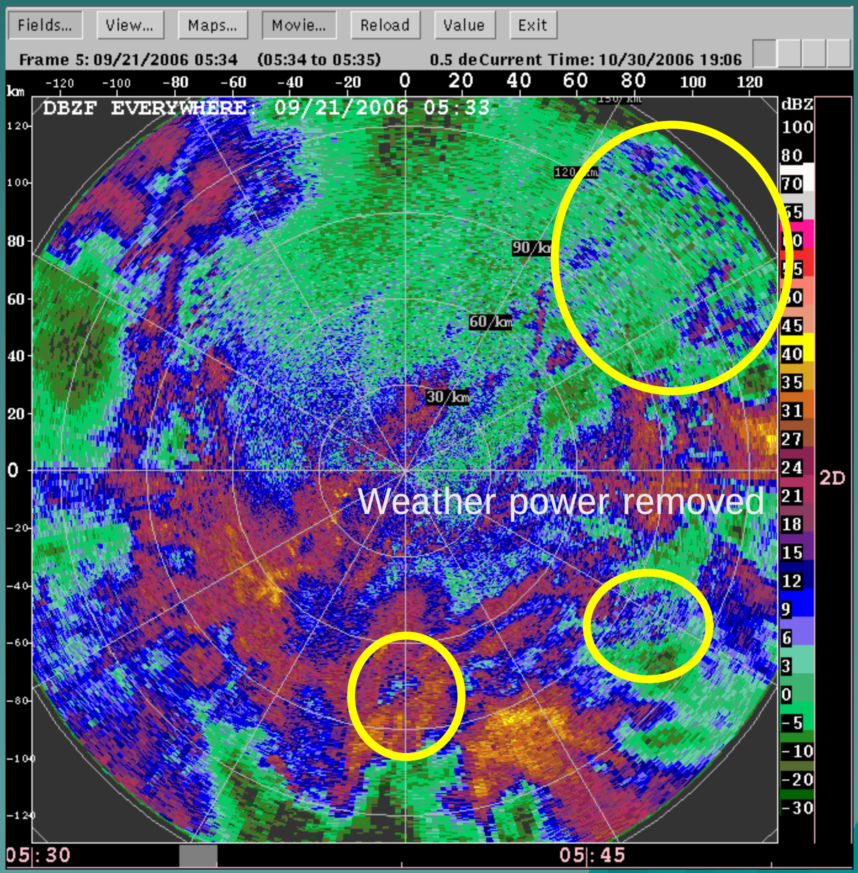


Filtered velocity

Example 5 : Filtering everywhere

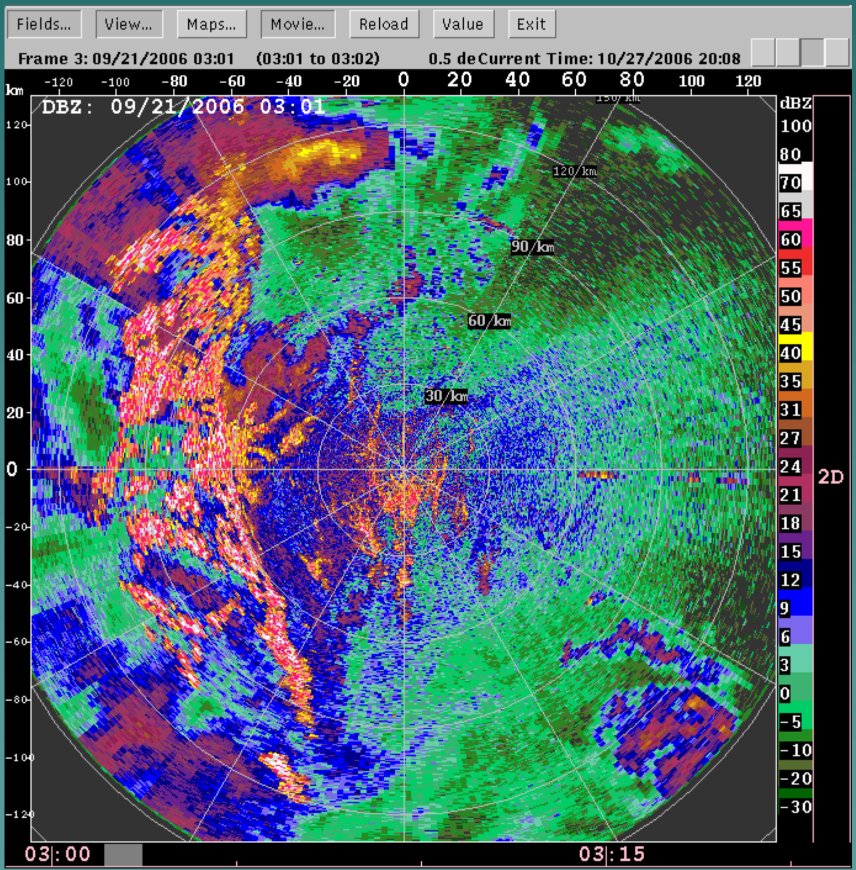


Filtered using CMD

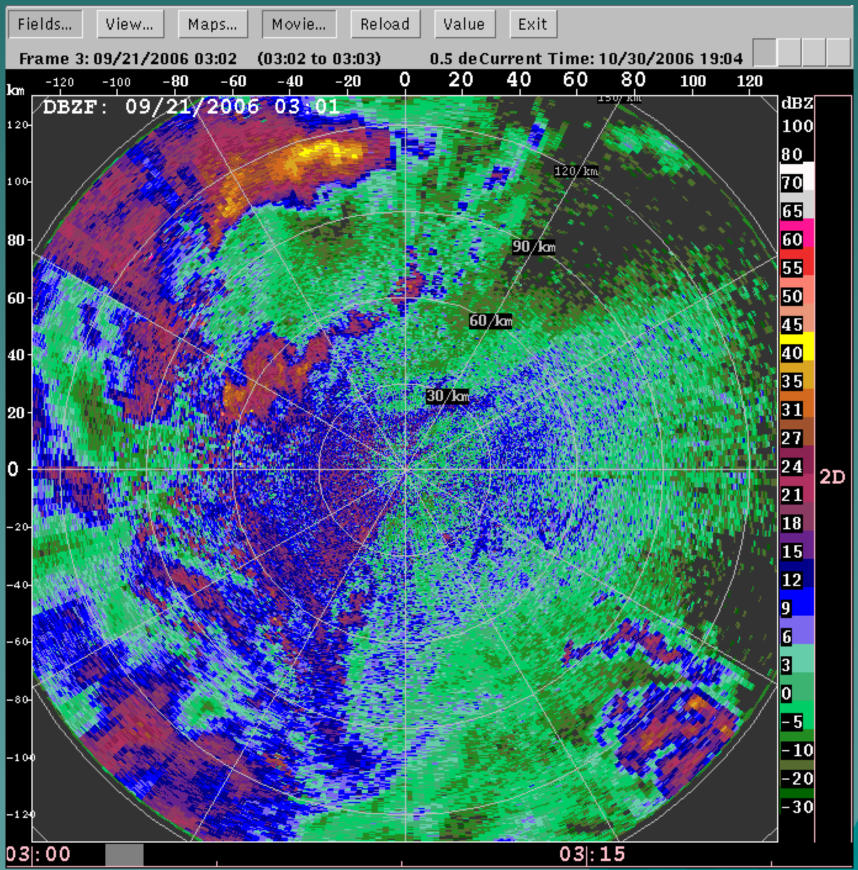


Filtered everywhere

Example 6 : KFTG 2006/09/21, 0300 UTC

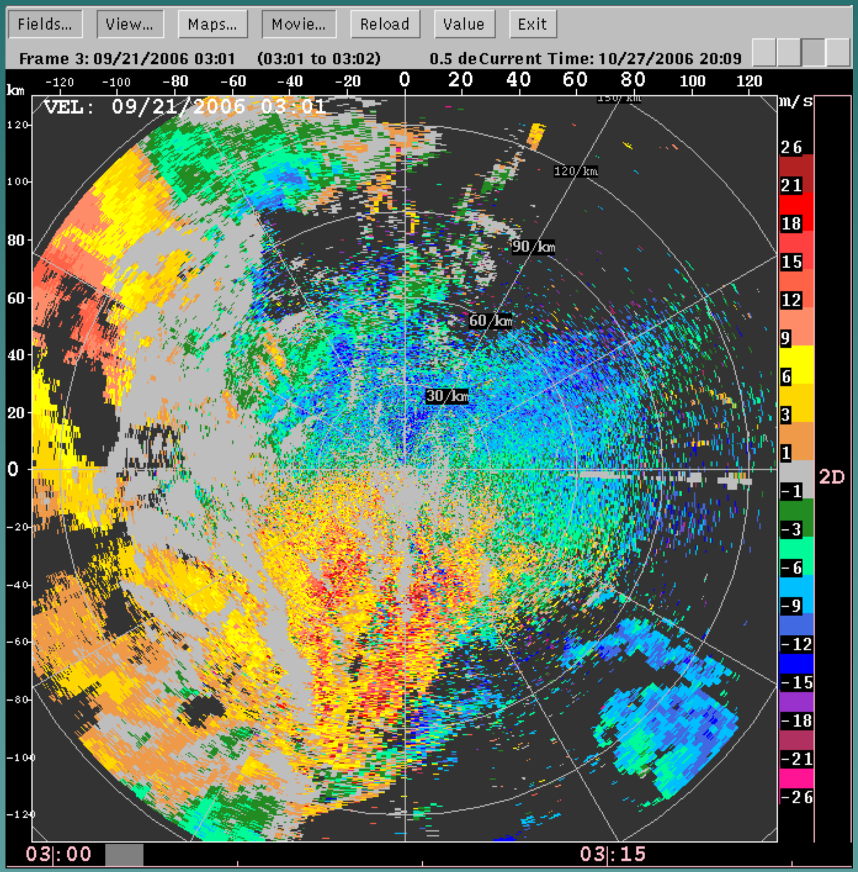


Reflectivity

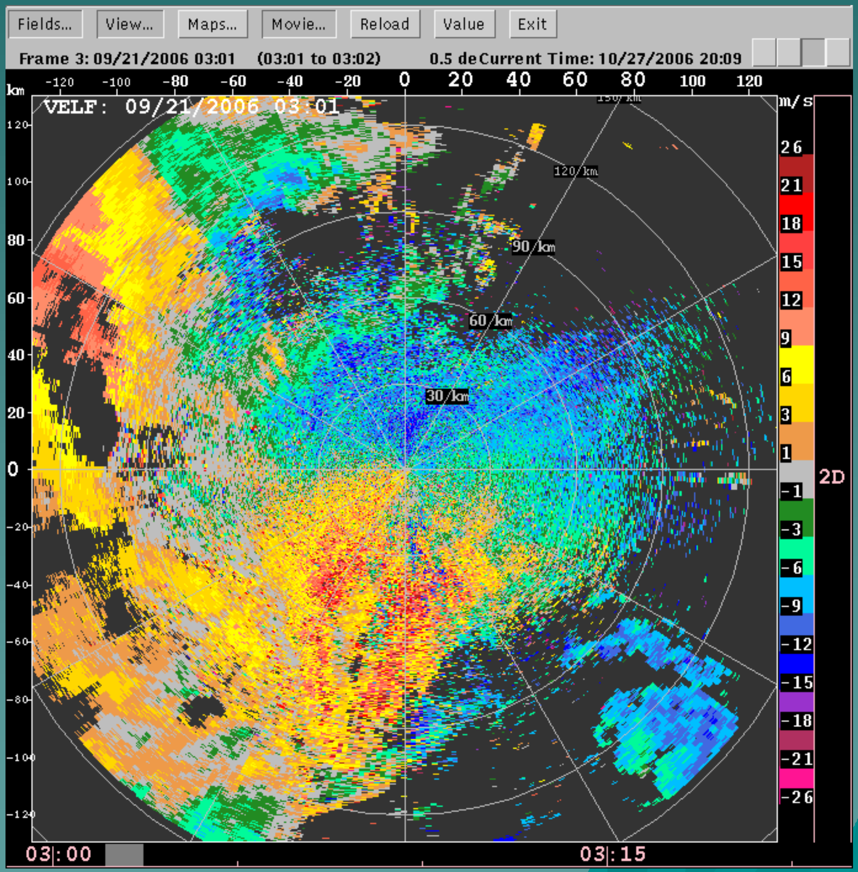


Filtered reflectivity

Example 6 : KFTG 2006/09/21, 0300 UTC

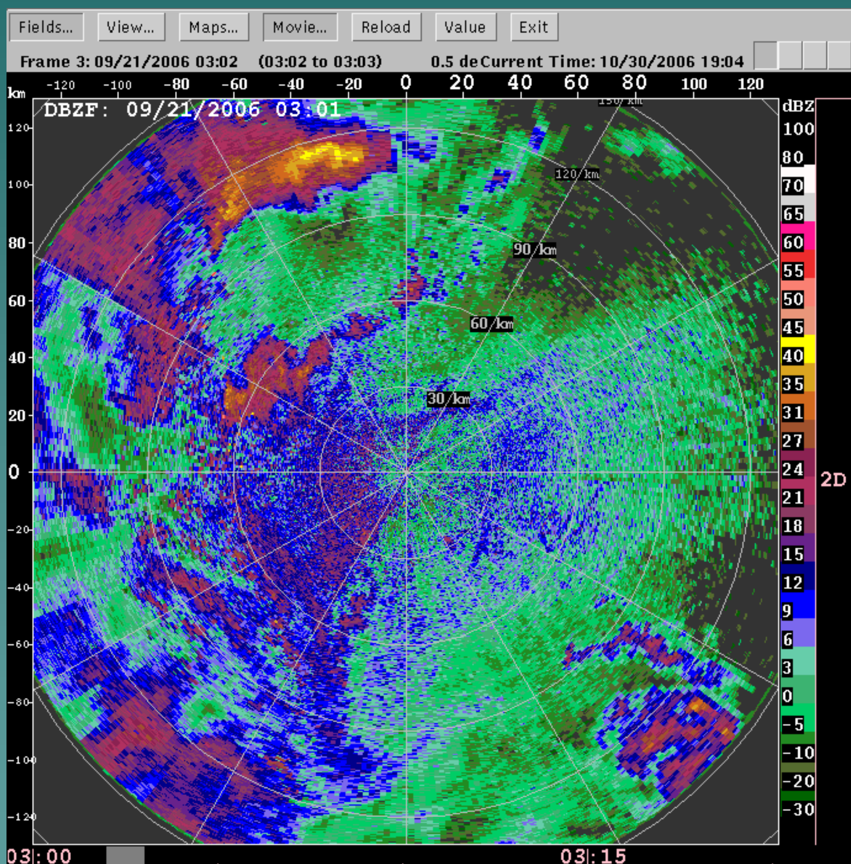


Velocity

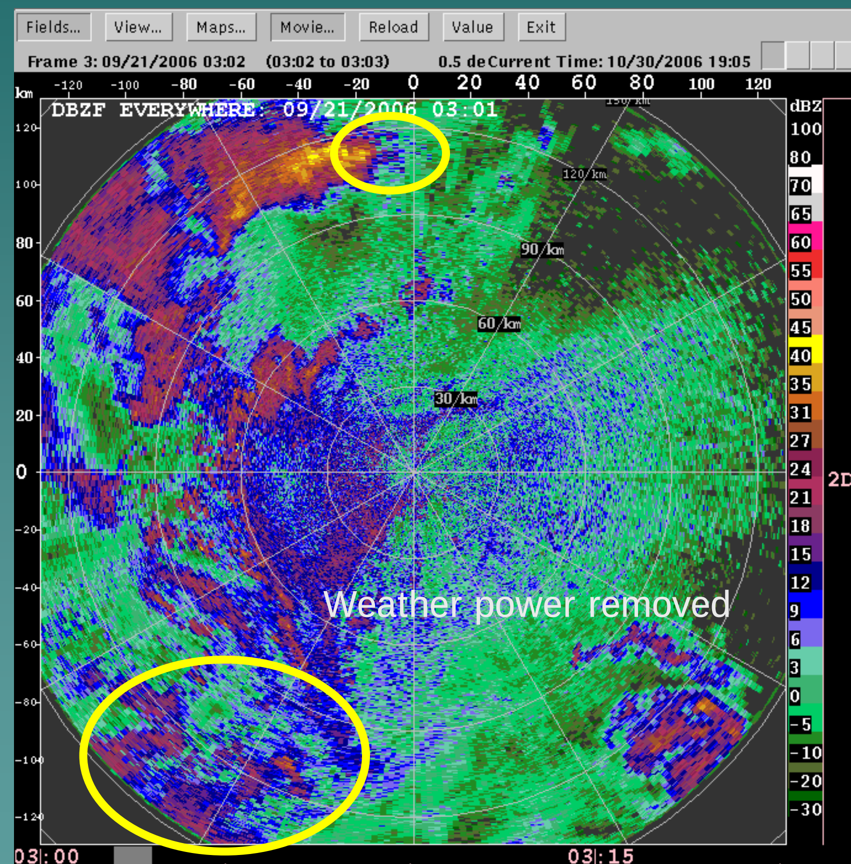


Filtered velocity

Example 6 : Filtering everywhere



Filtered using CMD



Filtered everywhere

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.

THANK YOU