NEXRAD RANGE-VELOCITY MITIGATION PROGRESS at NCAR

NEXRAD TAC MEETING

30-31 March 2004

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National Center for Atmospheric Research, Boulder CO

Sponsored by The Radar Operations Center, Norman OK

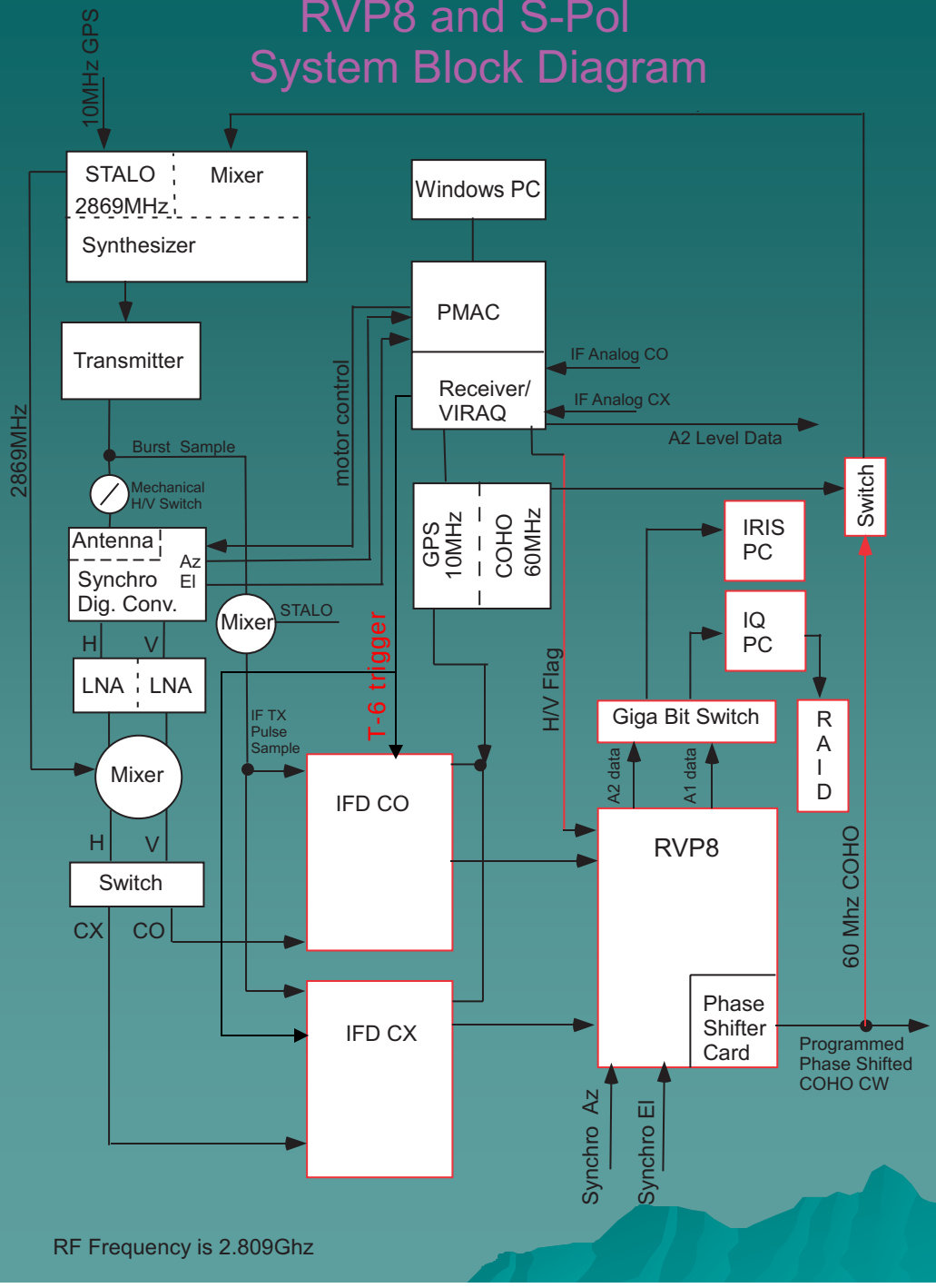
NCAR

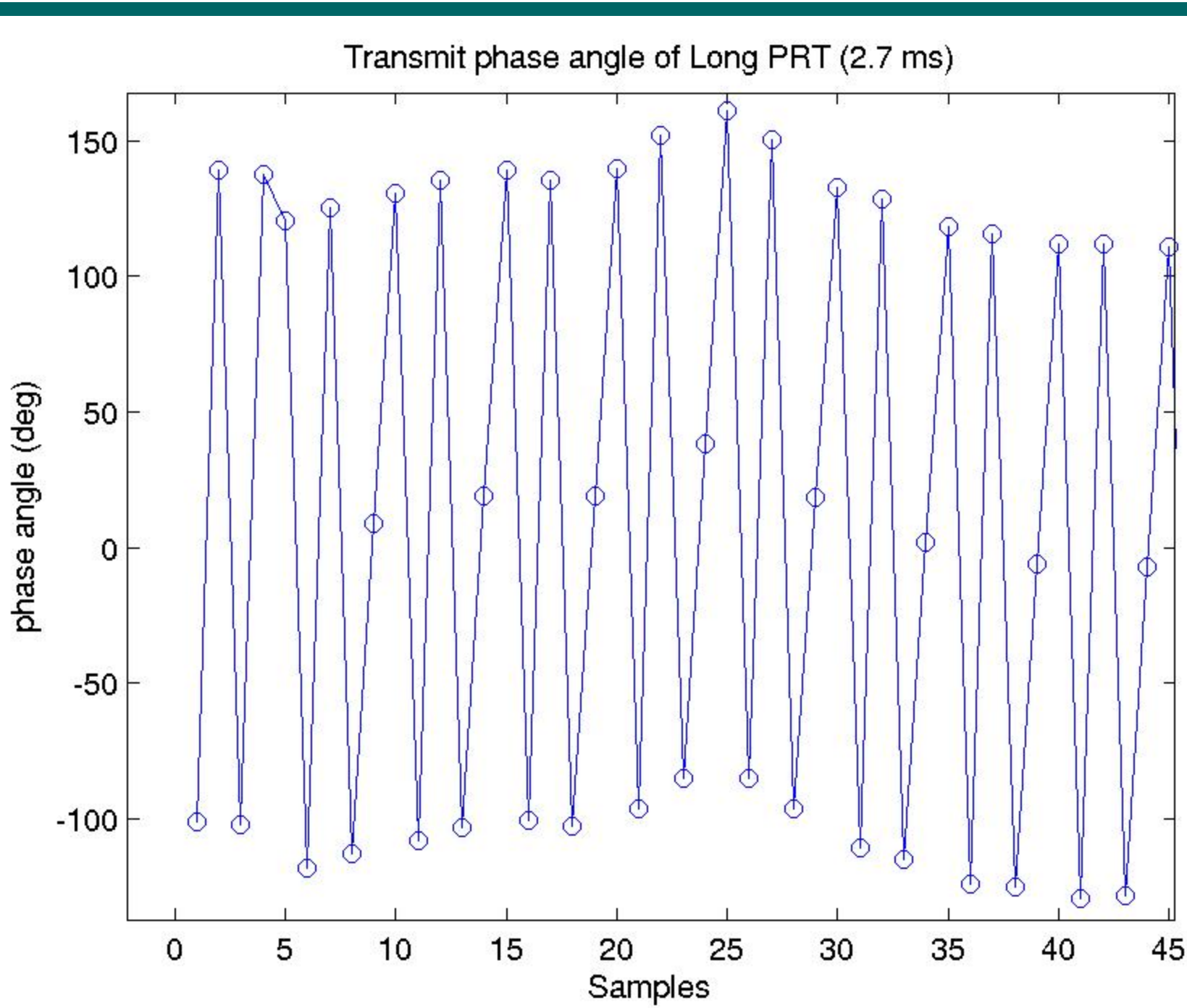
FY2004 Progress

- RVP8 is installed in parallel with the S-Pol VIRAQ receiver/processor.
  - Now can switch, at will, PRFs between 320Hz and 1250Hz. Both divisible by 10MHz (GPS) and 36MHz (RVP8 IFD sample) clocks.
  - Assisted SIGMET in identifying phase locking problem.

    RESULT: New clocks/freq. synthesis installed into RVP8 TX card. Available next month!

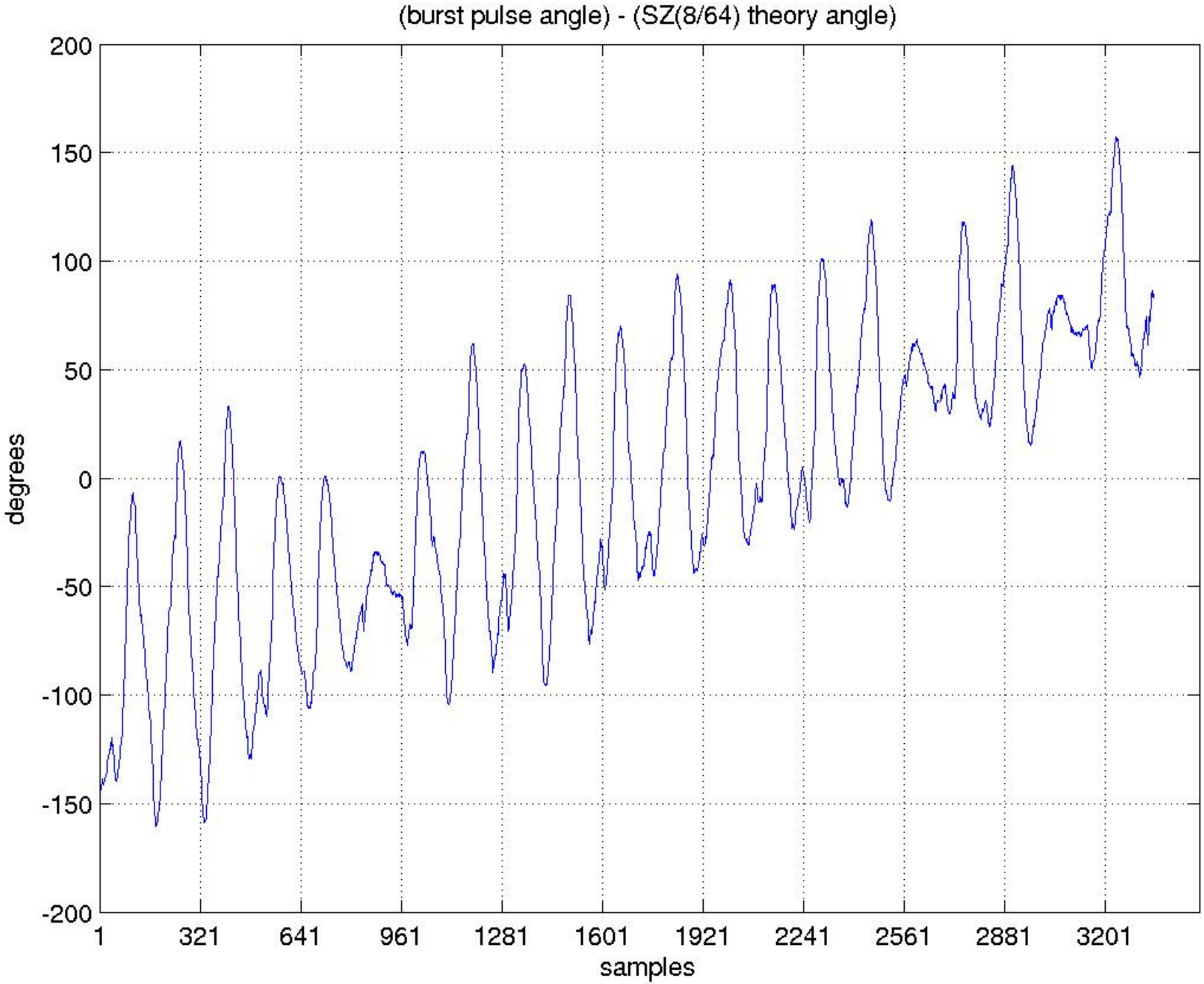
RVP8 and S-Pol System Block Diagram



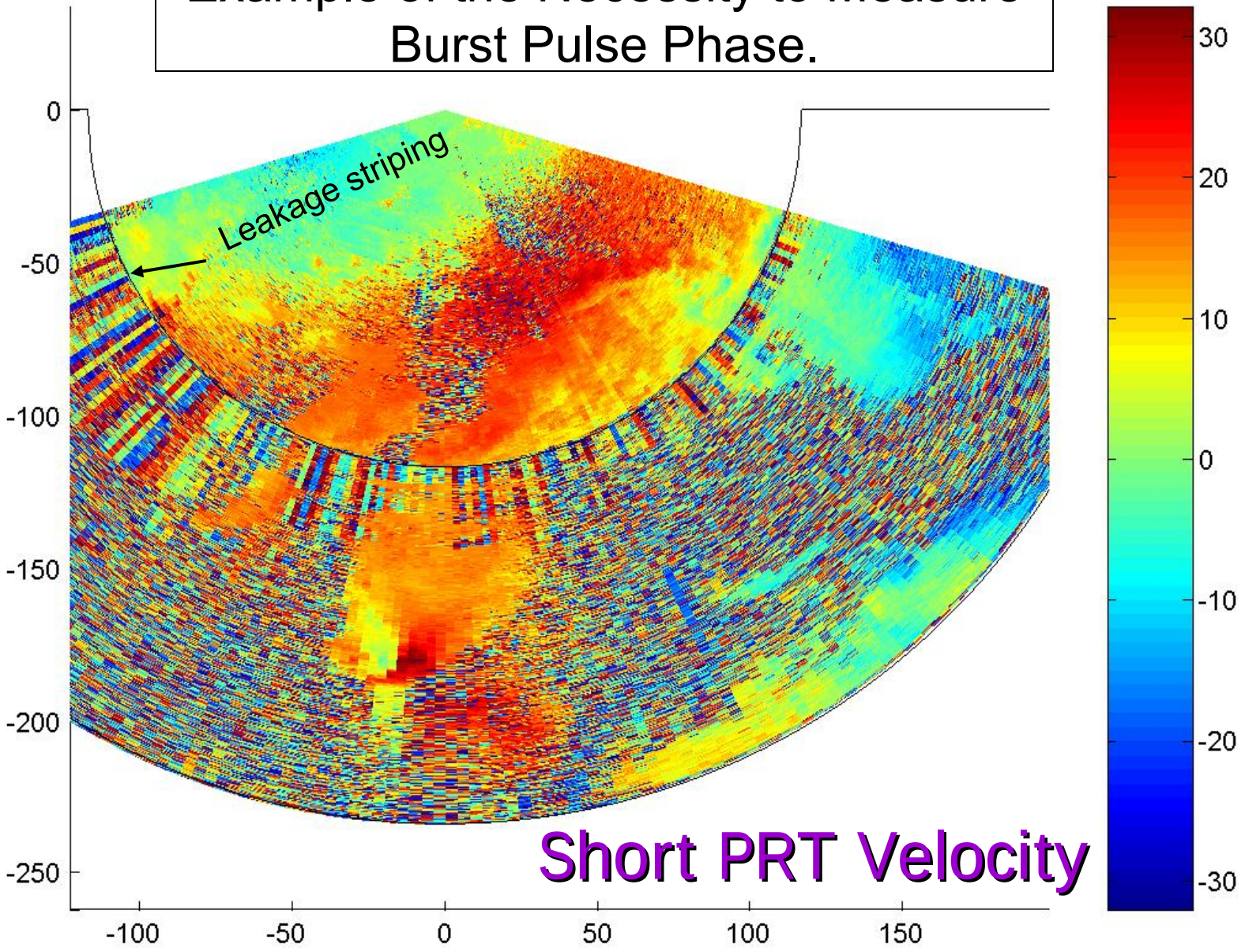

Transmit phase angle of Long PRT (2.7 ms)
phase angle (deg)
150
100
50
0
-50
-100
0
5
10
15
20
25
30
35
40
45
Samples

FY2003 Progress

- Collected and displayed RVP8 A2 data
- June, time series collected via A1 recorder
- Programmed and implemented SZ-1 Algo. on the IQ PC. Real Time!
- Censoring of SZ-1 and SZ-2 Data
  - Fuzzy logic with velocity texture inputs (Scott Ellis)
  - Weak trip spectral replica (Mike Dixon)
- Delivery of SZ-1 Algo. to ROC on 15 August
- In September ROC Programmed SZ-1 on RVP8
- Simulated time series and tested IQ SZ-1 algo.
- Investigated clutter filtering & SZ (Greg Meymaris)
- Modeled PPI velocity “stripes” (Greg Meymaris)
- SZ-2 logic flow diagram that allows for clutter in any trip and thus can accommodate AP clutter
- Attended API training TIM and have a general understanding of API programming


(burst pulse angle) - (SZ(8/64) theory angle)
200
150
100
50
0
-50
-100
-150
-200
degrees
1
321
641
961
1281
1601
1921
2241
2561
2881
3201
samples

Example of the Necessity to Measure Burst Pulse Phase.



OTHER FY2004 Progress

- Refined SZ-1 processing
- Programmed NCAR's SZ-2 in MAT Lab
- Refined SZ-2 censoring
- Modeled and quantified the incompatibility of SZ and legacy clutter filters

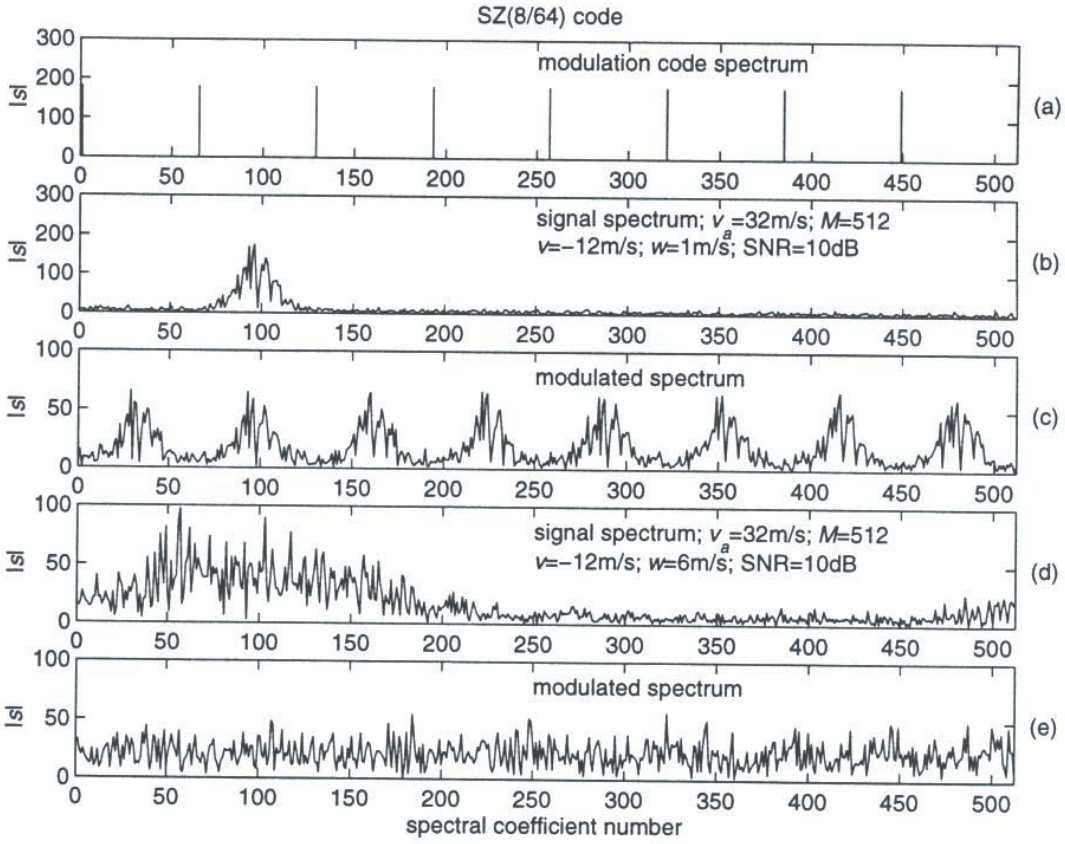
- Jeff Keeler Officially Retired 2 January

  (though, seems to be at NCAR more)

Phase Coding: SZ-1 versus SZ-2

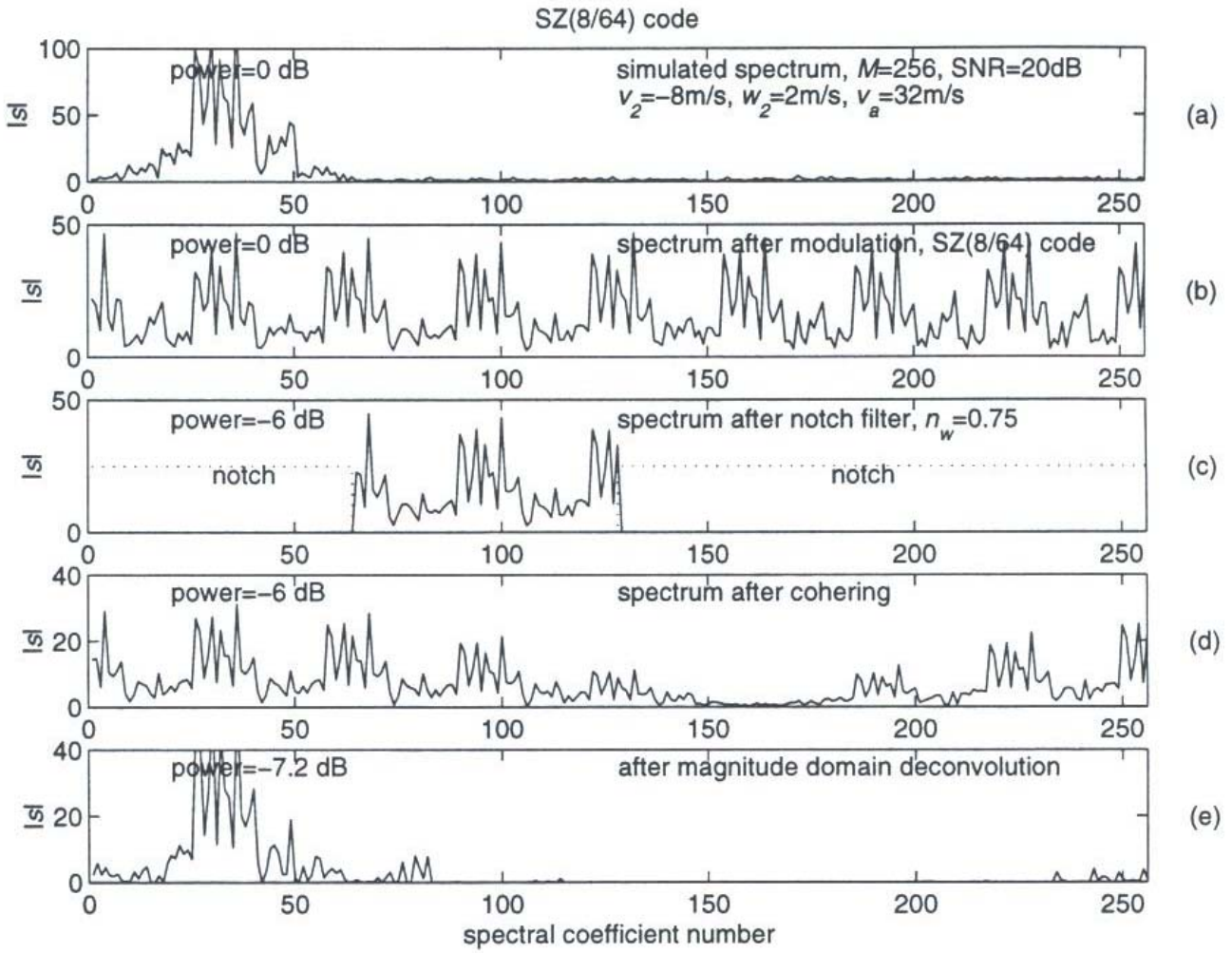
- SZ-2:
  - Long PRT (3.1ms) followed by a short PRT (0.78ms).
  - Long PRT provides reflectivities and widths. Also provides estimates of clutter power and weather power for short PRT decoding.
  - For elevations below 1.5 degrees.
- SZ-1:
  - “Stand alone mode”.
  - Choose smallest PRT such that only two trips are possible.

Example of Phase Coding of Simulated Spectra



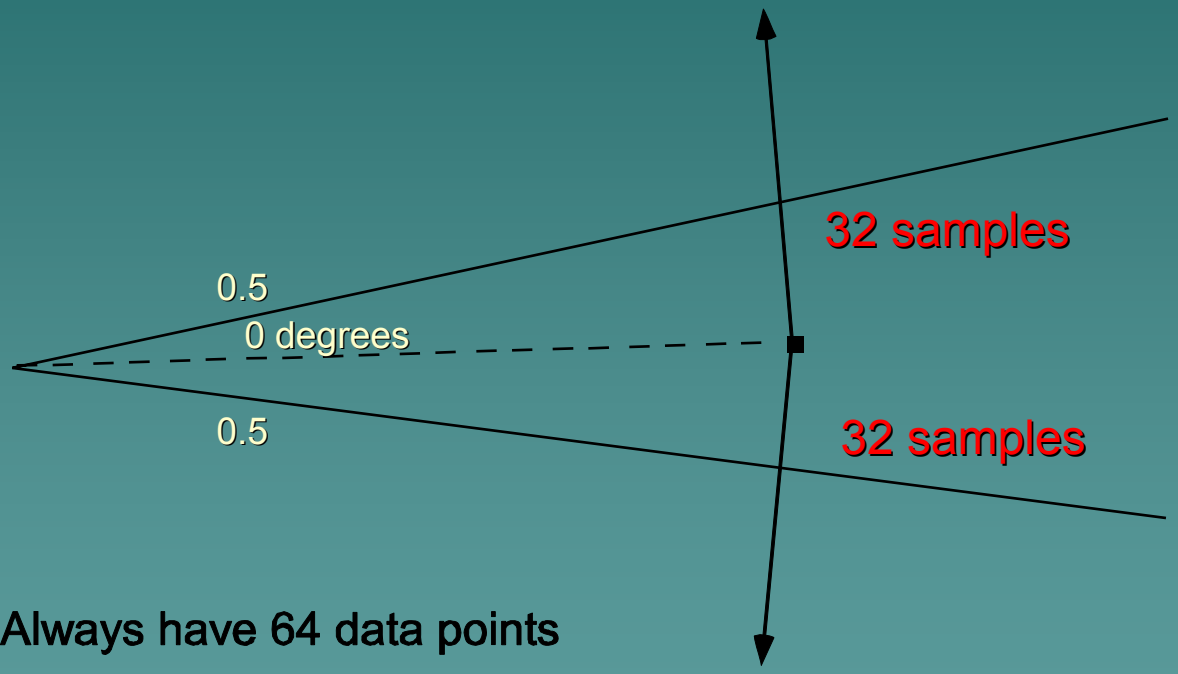
Each replica has a different phase “offset”

Example of Weak Trip Recovery



Scan Strategy

Indexed Beams. 1Degree



Always have 64 data points

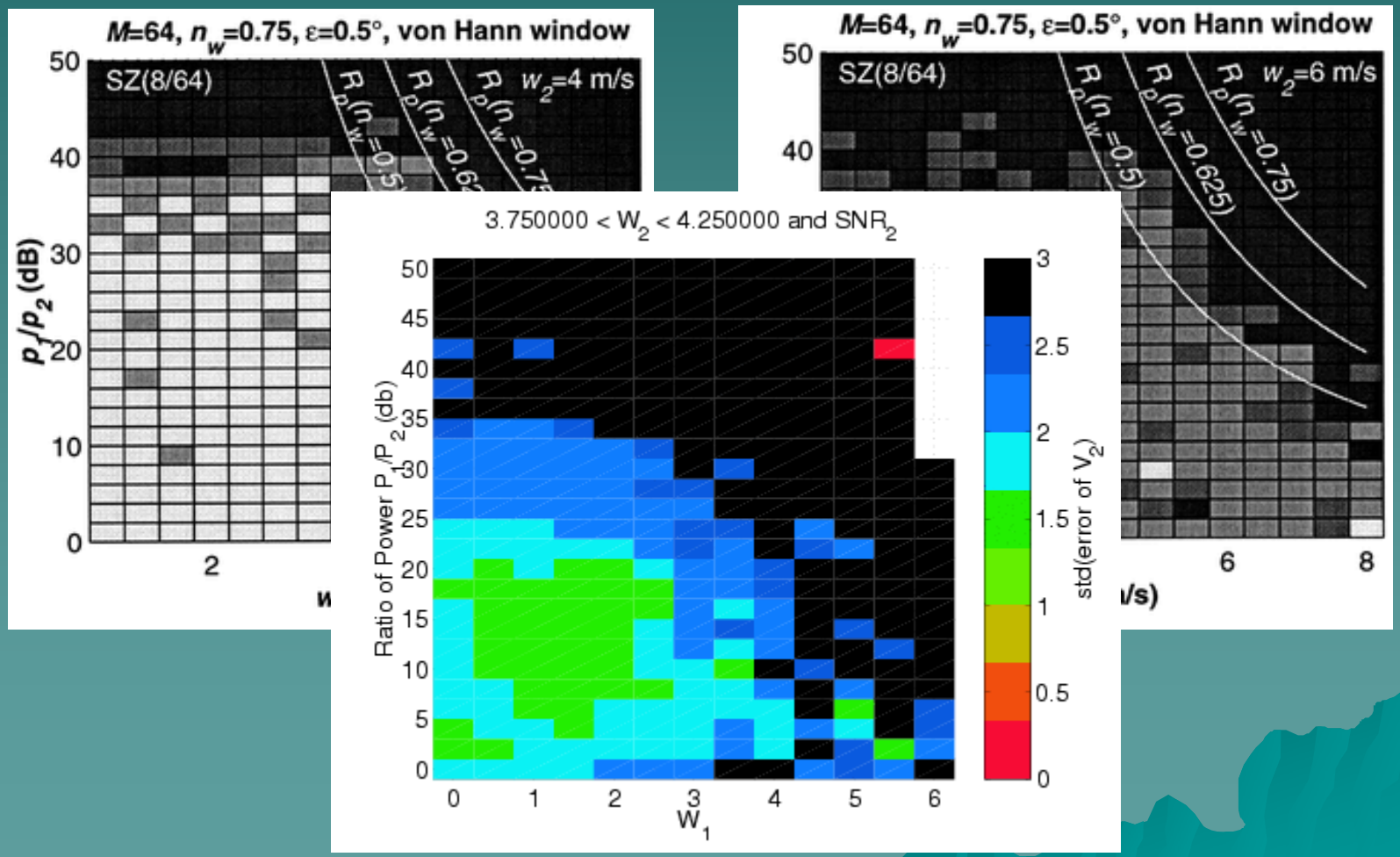
SZ-2 Censoring

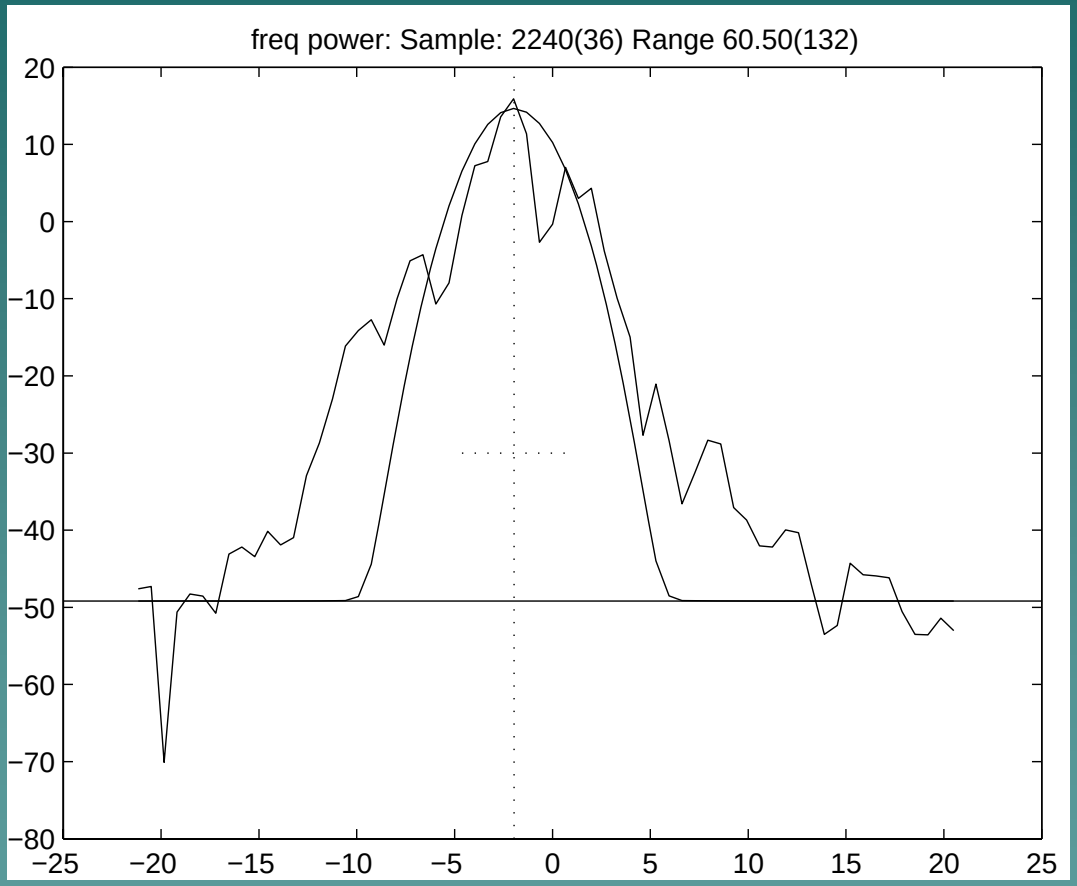
- Use long PRT scan to:
  - Compute the power ratio P_1/P_2
  - Compute the contaminating noise power
    - Trip 1 noise power = $N_{sys} + N_{trip2} + N_{trip3} + N_{trip4}$
    - Trip 2 noise power = $N_{sys} + N_{trip3} + N_{trip4}$
    - Threshold currently set to 3 dB above noise

SZ-2 Censoring

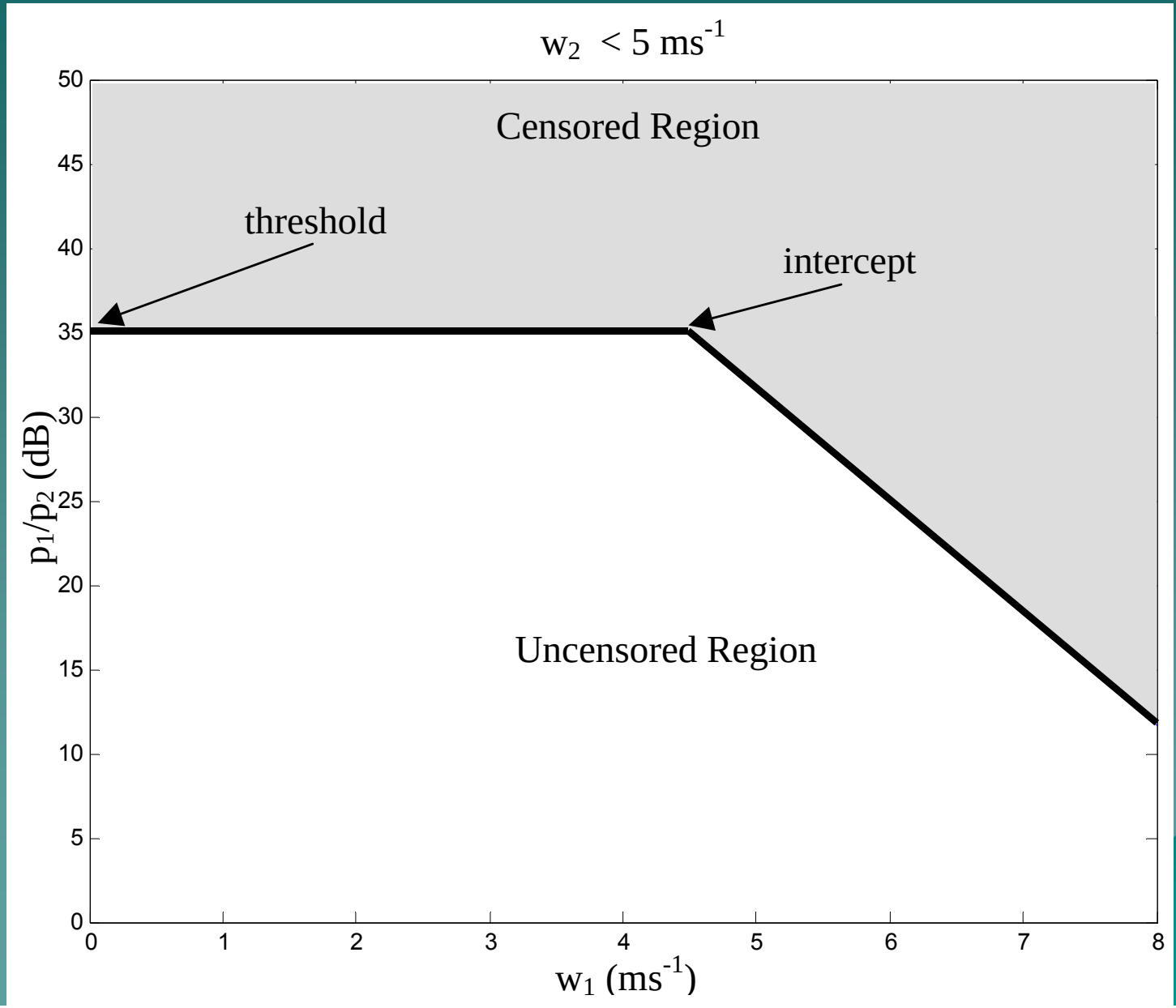
- Censor using strong to weak trip power ratio P_1/P_2 and spectrum widths, W_1 and W_2
- Censor data on SNR from long PRT
- Censor data on SNR from short PRT
  - Useful if echo in long PRT scan moves leaving void in short PRT scan

Examples of theoretical and experimental P_1/P_2 recovery as a function of W_1 and W_2

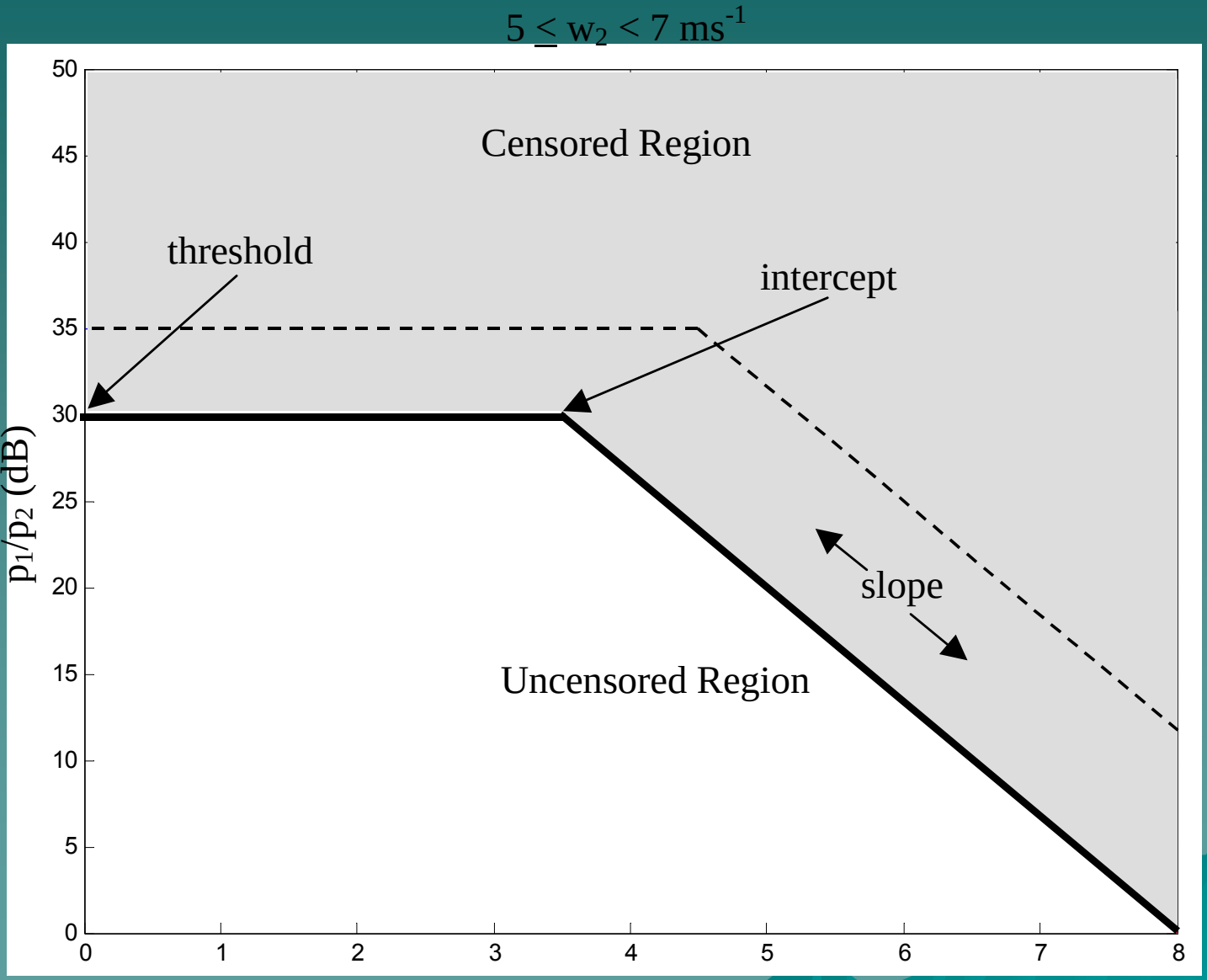



freq power: Sample: 2240(36) Range 60.50(132)
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−25
−20
−15
−10
−5
0
5
10
15
20
25

SZ-2 Censoring – Power ratio



SZ-2 Censoring – Power ratio

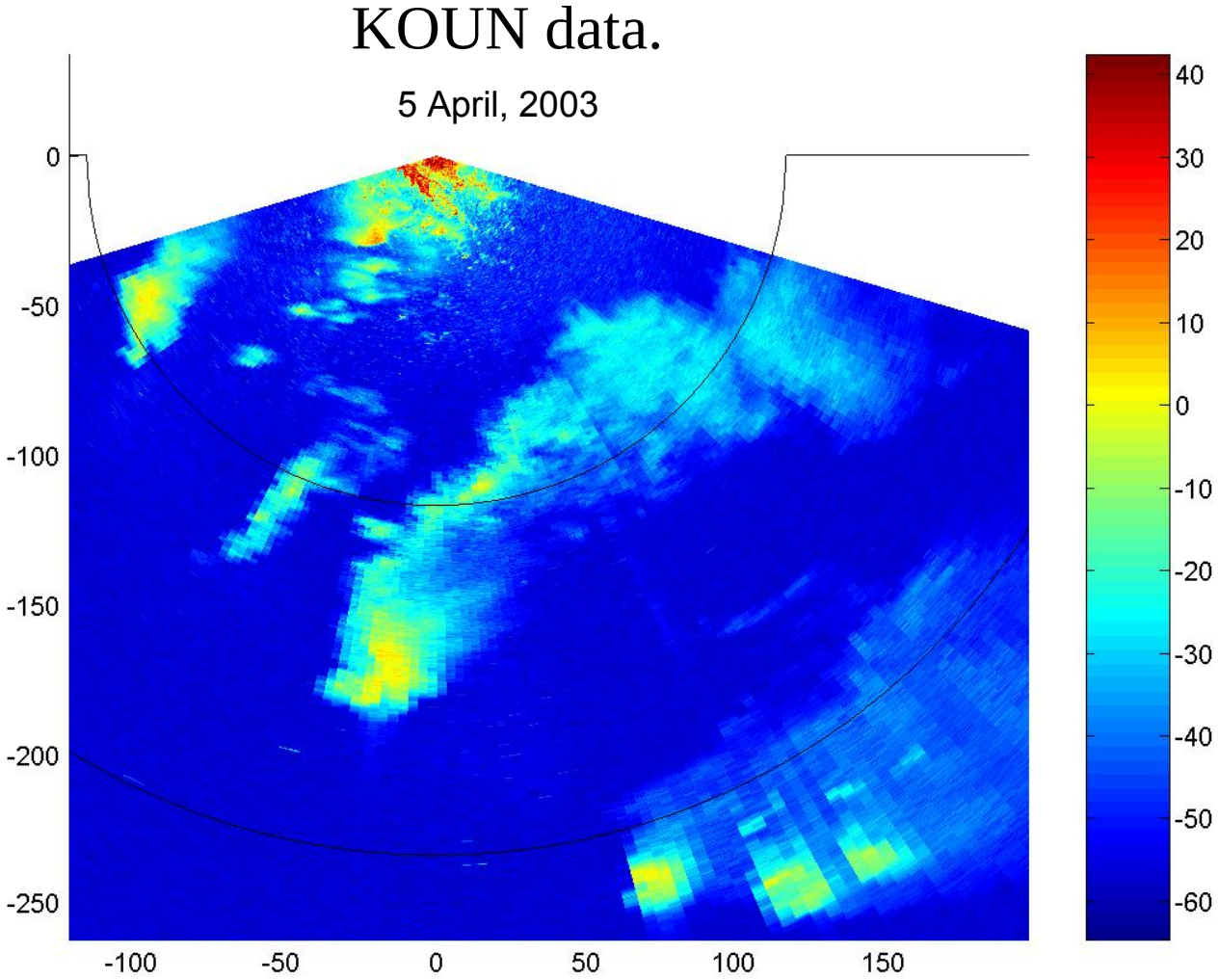


SZ-2 Censoring: Note

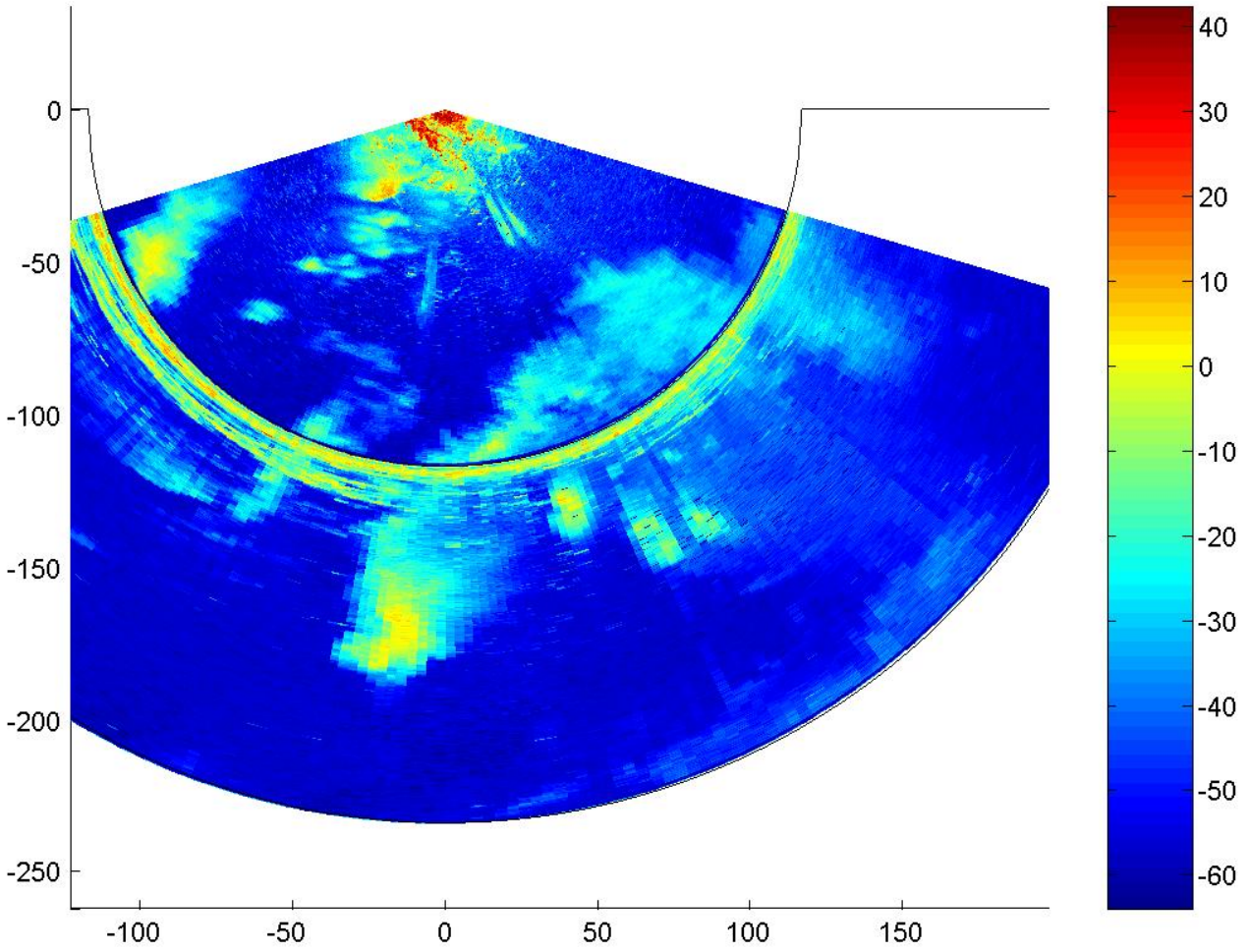
- Widths from long PRT are limited due to short Nyquist
- W_2 from SZ scan are biased

=> Use W_1 from SZ recovered and W_2 from Long PRT data

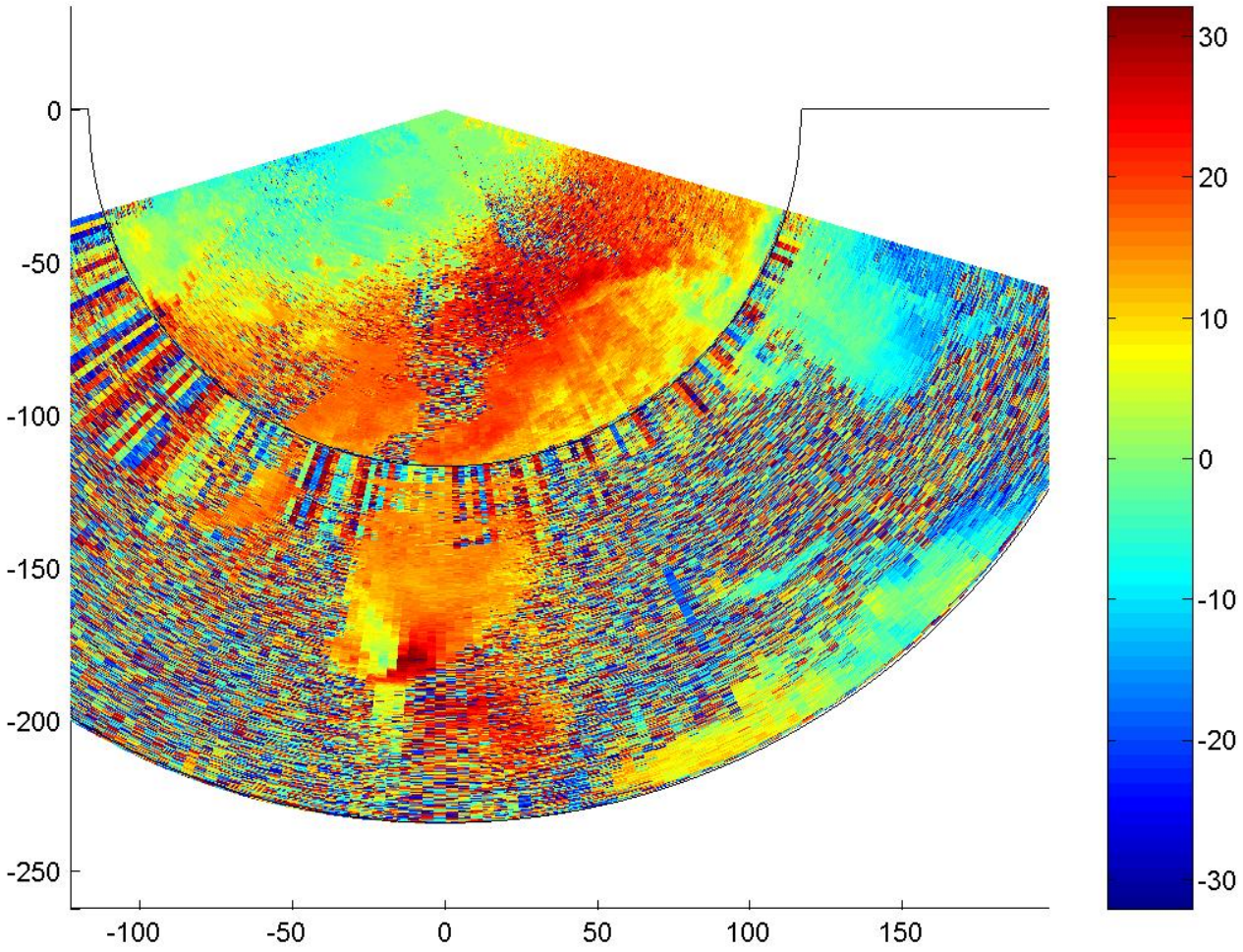
SZ-2 Censoring: Long PRT Power ($I^2 + Q^2$, dB)



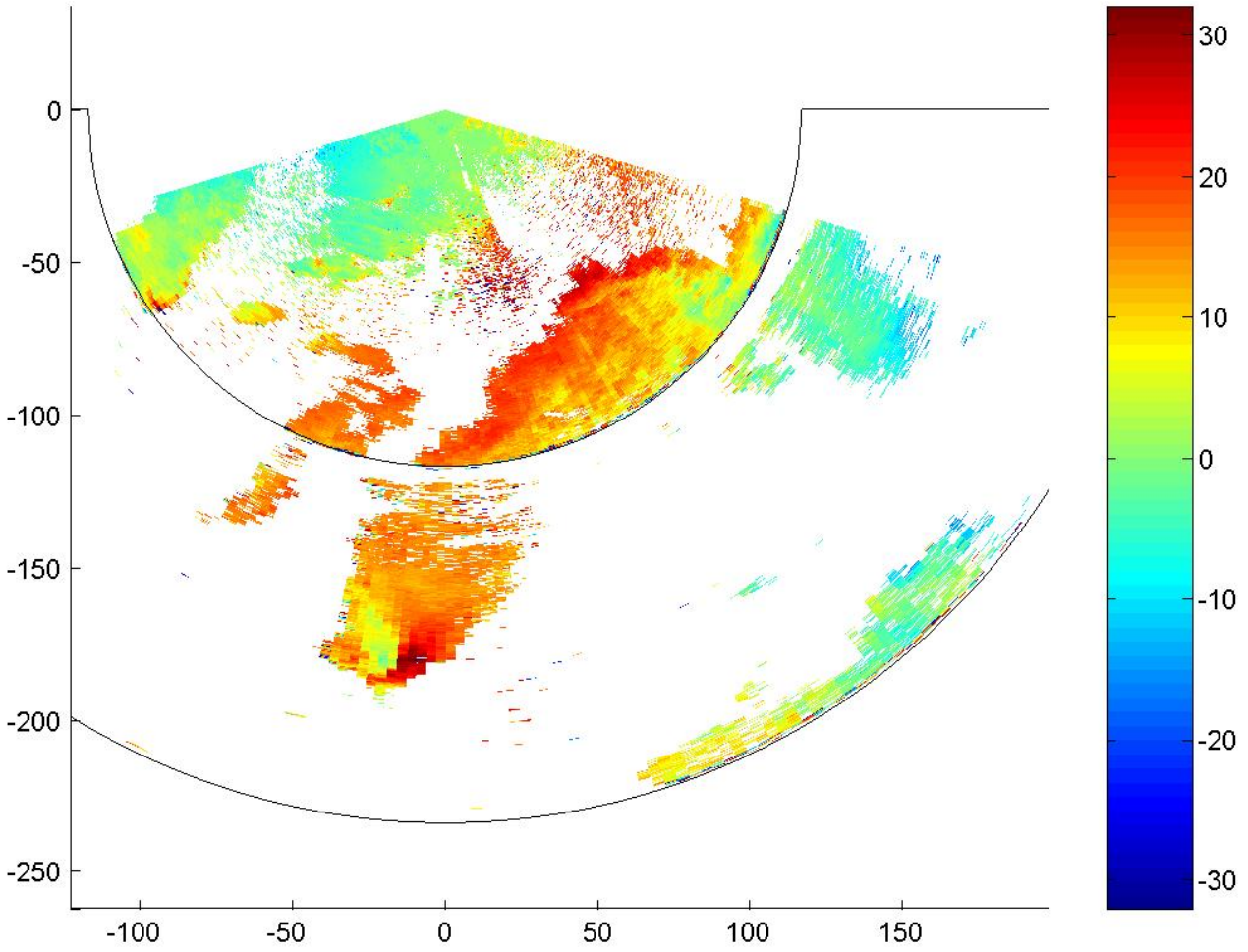
SZ-2 Censoring: Short PRT Power ($I^2 + Q^2$, dB)



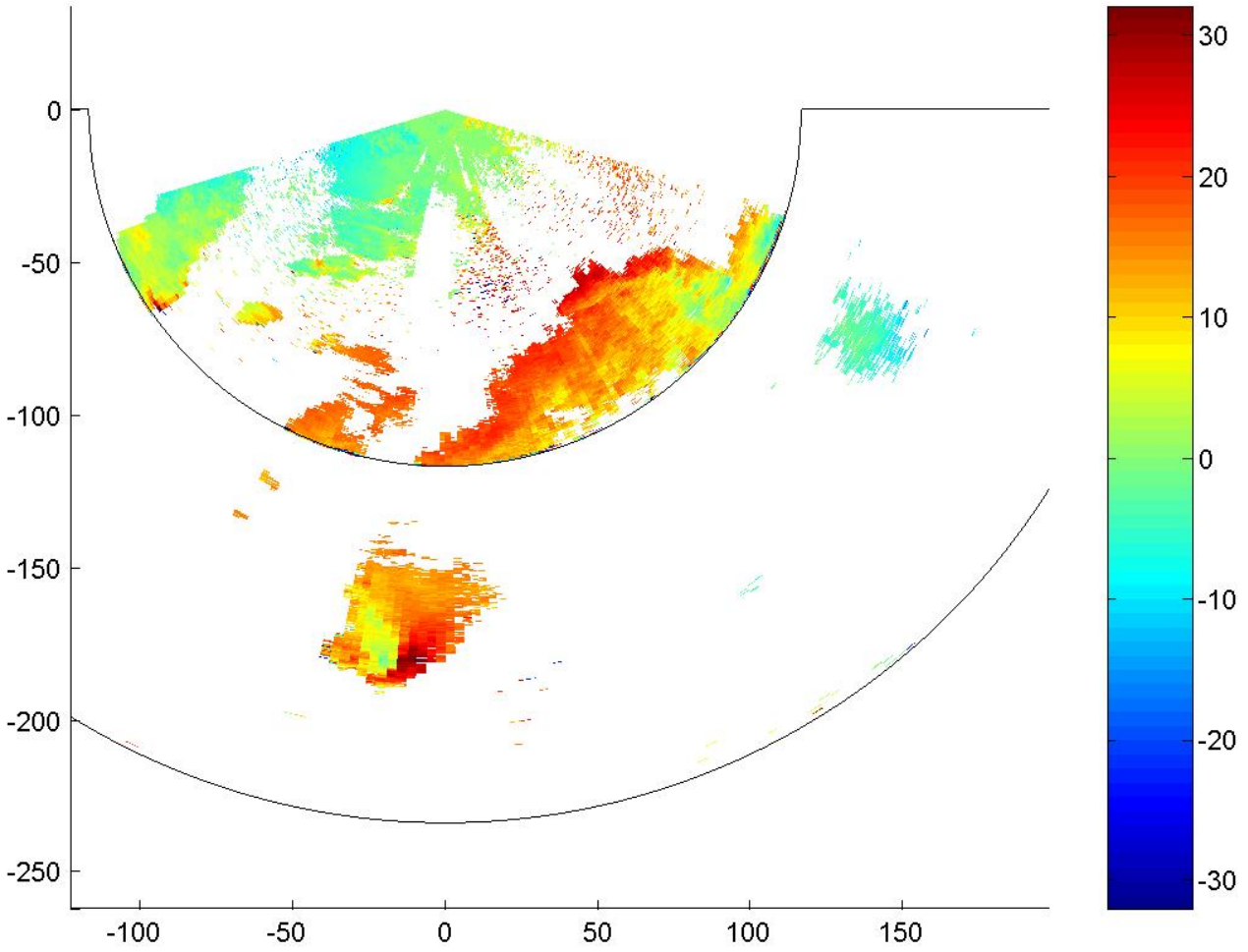
SZ-2 Censoring: SZ Recovered Velocity (m/s)



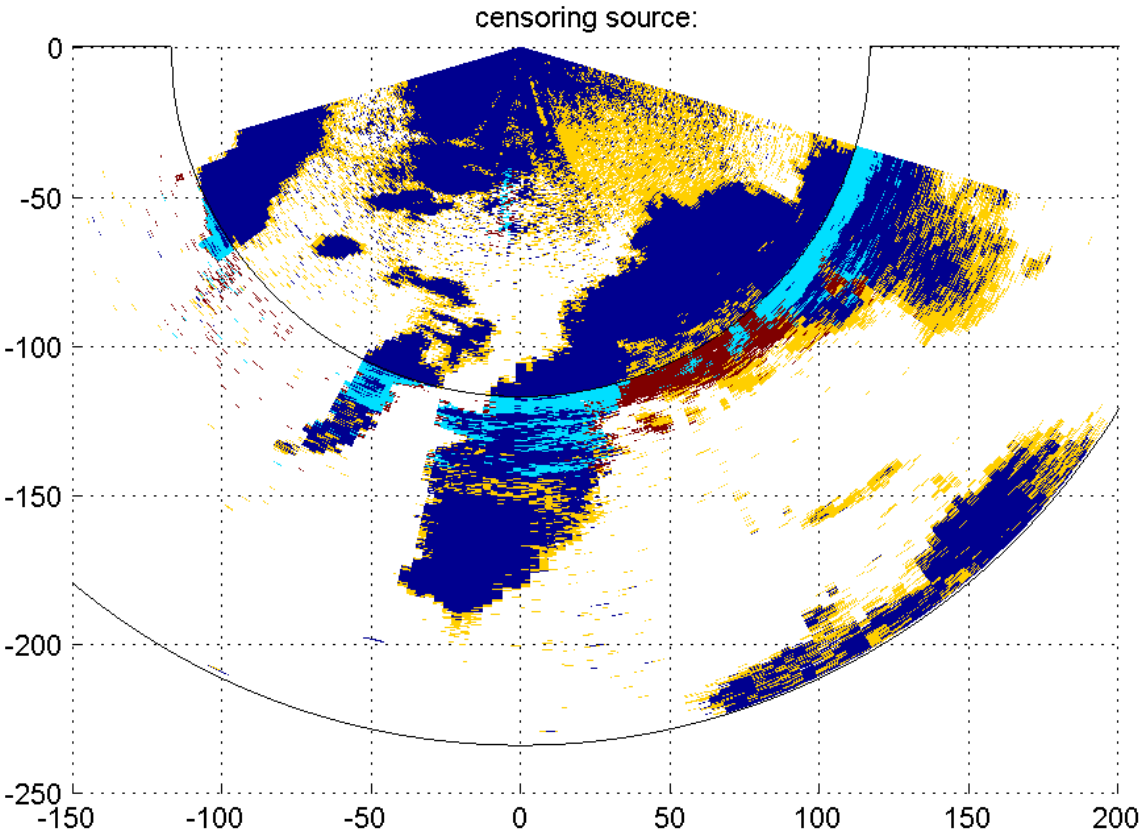
SZ-2 Censoring: SZ-2 Censored Velocity (m/s)

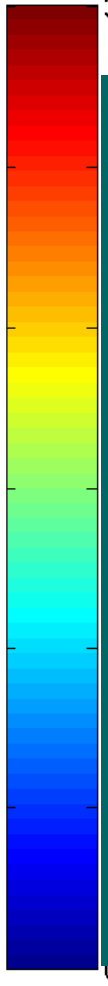


SZ-2 Censoring: Current WSR-88D Censoring (5 dB thresholds)



SZ-2 Censoring: SZ-2 Censoring Source





Blue – Not censored

White – long PRT P < Nsys + 3 dB

Cyan – Power ratio

Gold – SNR (out of trip noise)

Brown – Both power ratio and out of trip contamination

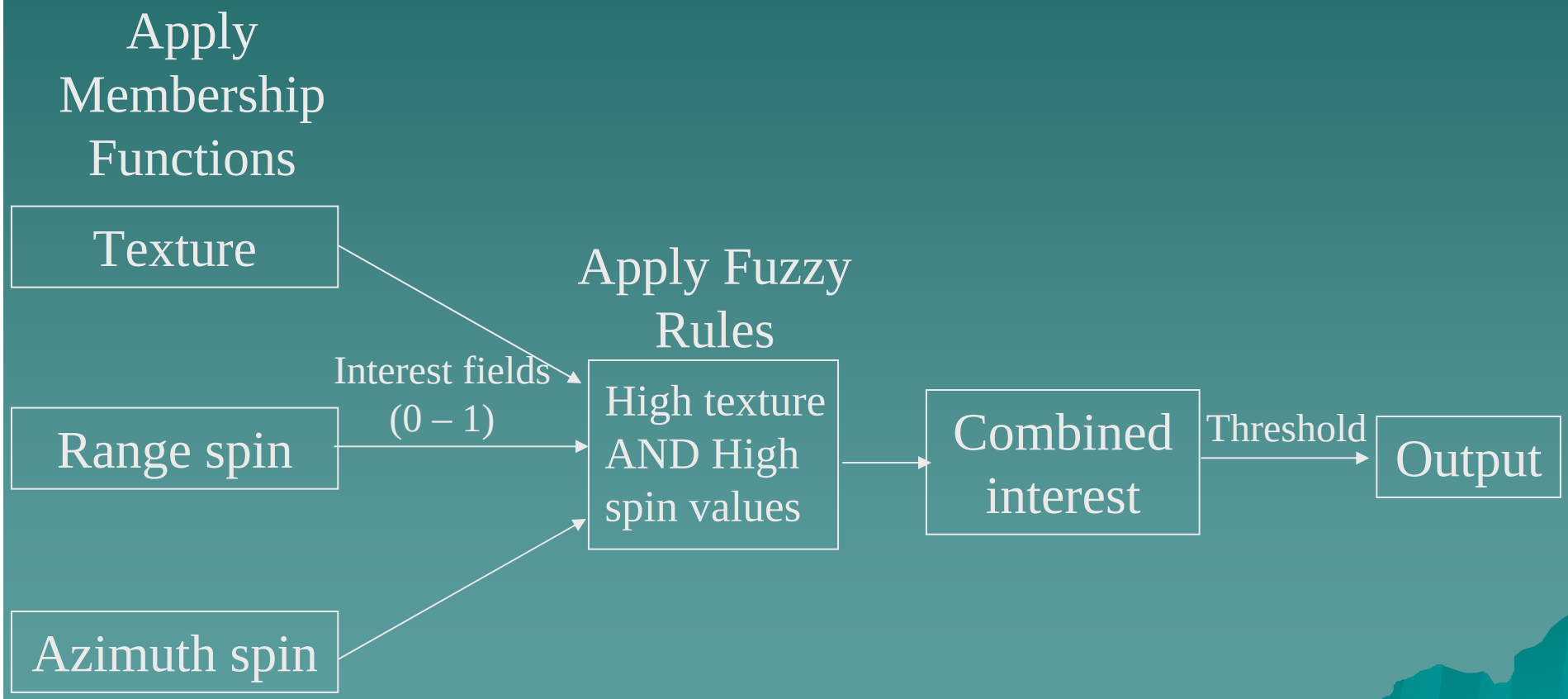
SZ-1 Censoring

- Long PRT scan not available
  - Power ratio estimates not reliable due to leakage
- Solution: Use characteristics of contaminated radial velocity

SZ-1 Censoring

- Fuzzy logic algorithm for censoring
  - Inputs computed over 2-D patch of data
    - Texture of V – (circular differences)
    - Range spin – (inflection points)
    - Azimuth spin
  - Use both range and azimuth spin in order to avoid censoring tornadoes, strong convergence or divergence
  - Censor on system noise only (out of trip power is not known)

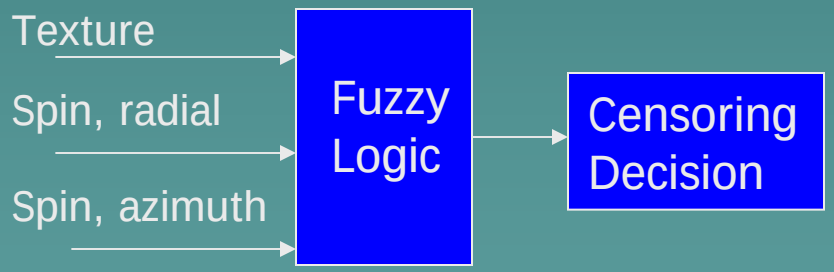
SZ-1 Censoring: Fuzzy logic



Censoring for SZ-1

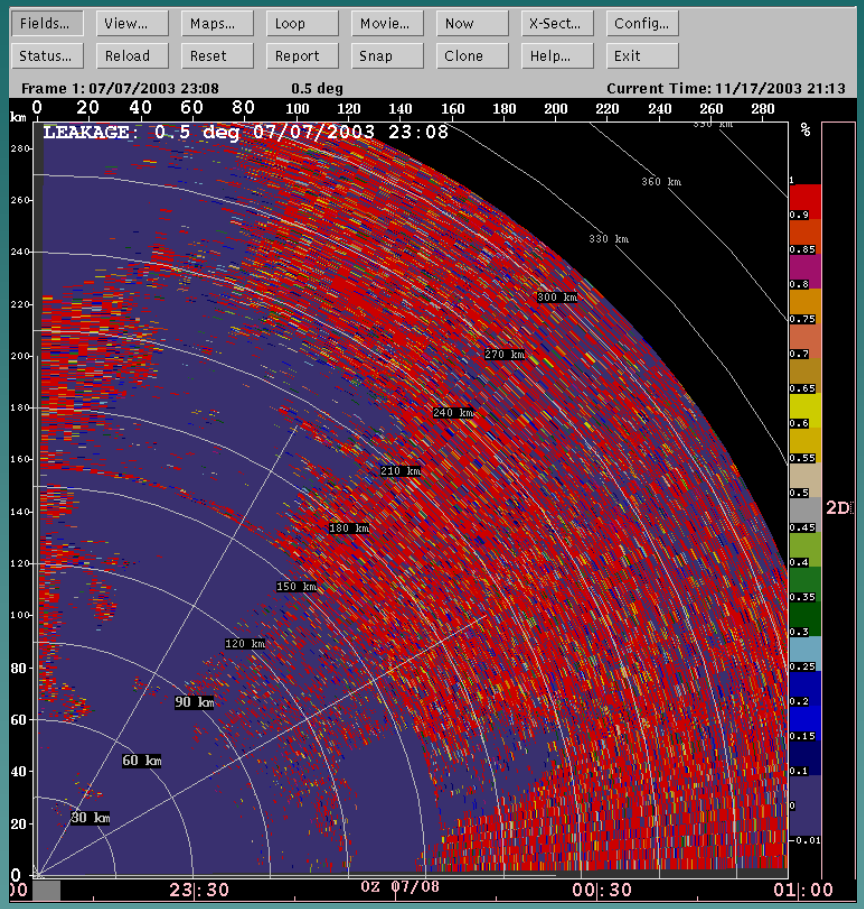
- No truth and estimated parameters are ineffective

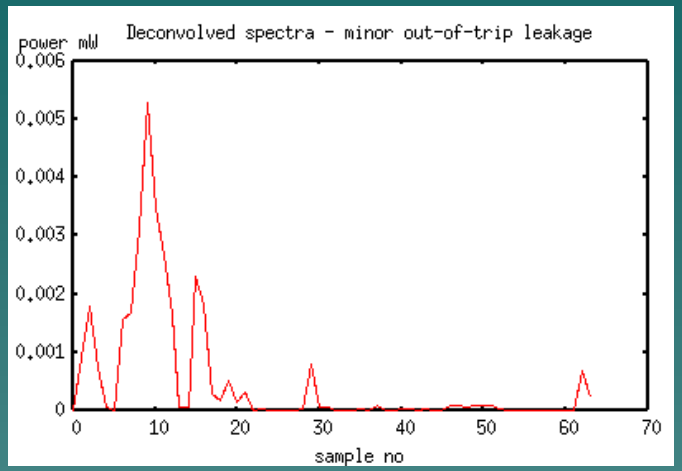
  SOLUTION: Use various estimates of the texture of the recovered velocity field to censor data

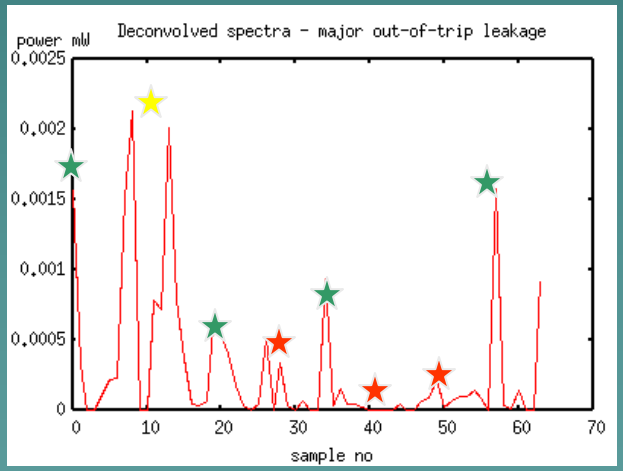


- Also, the strength of the spectral replicas are checked

Out-of-trip leakage – fraction of main peak

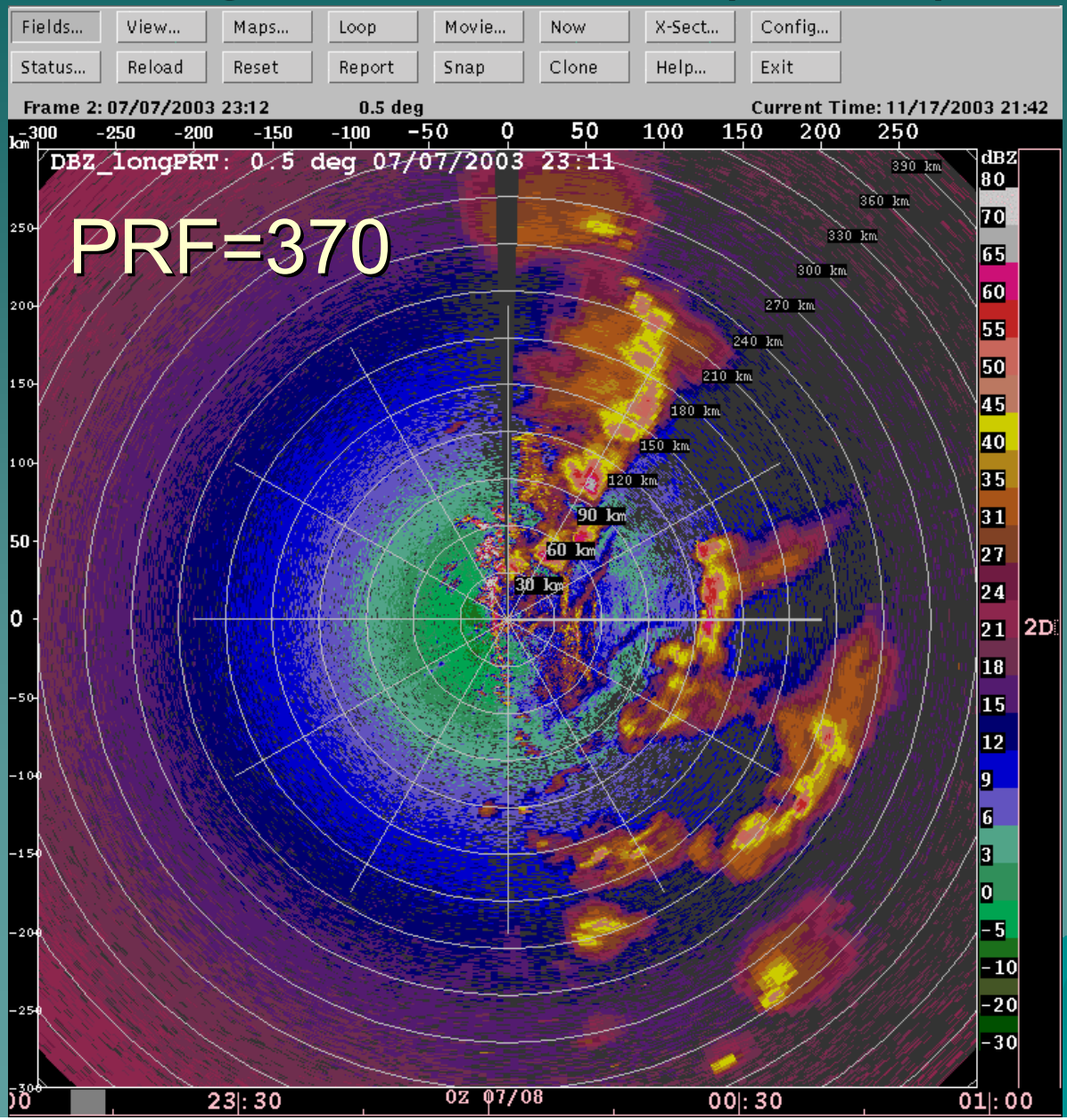




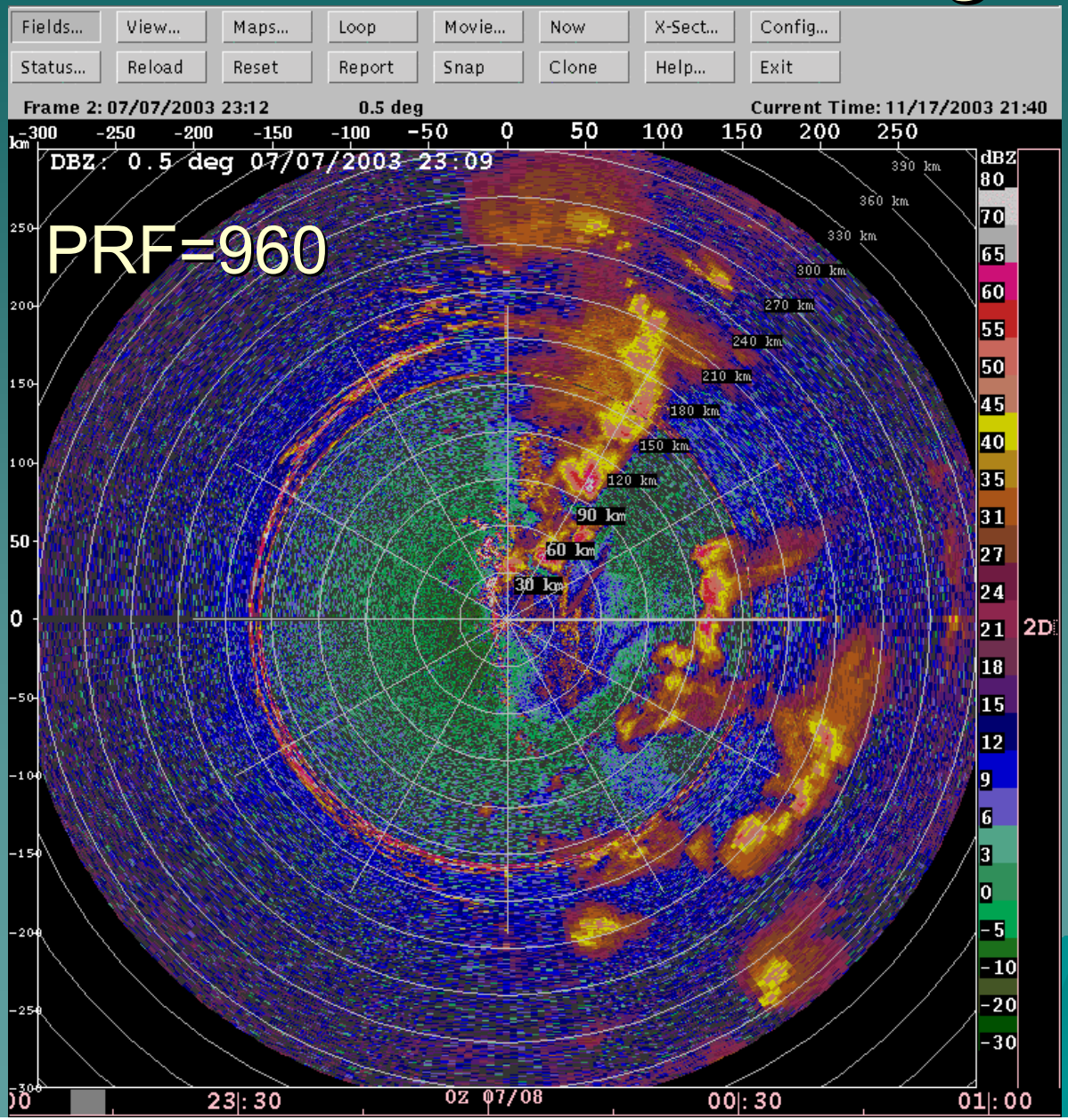


Leakage parameter = (mean of 3 lowest peaks) / (max peak)
Values of interest range from 0.17 to 0.25
These are remapped to the range 0.0 to 1.0

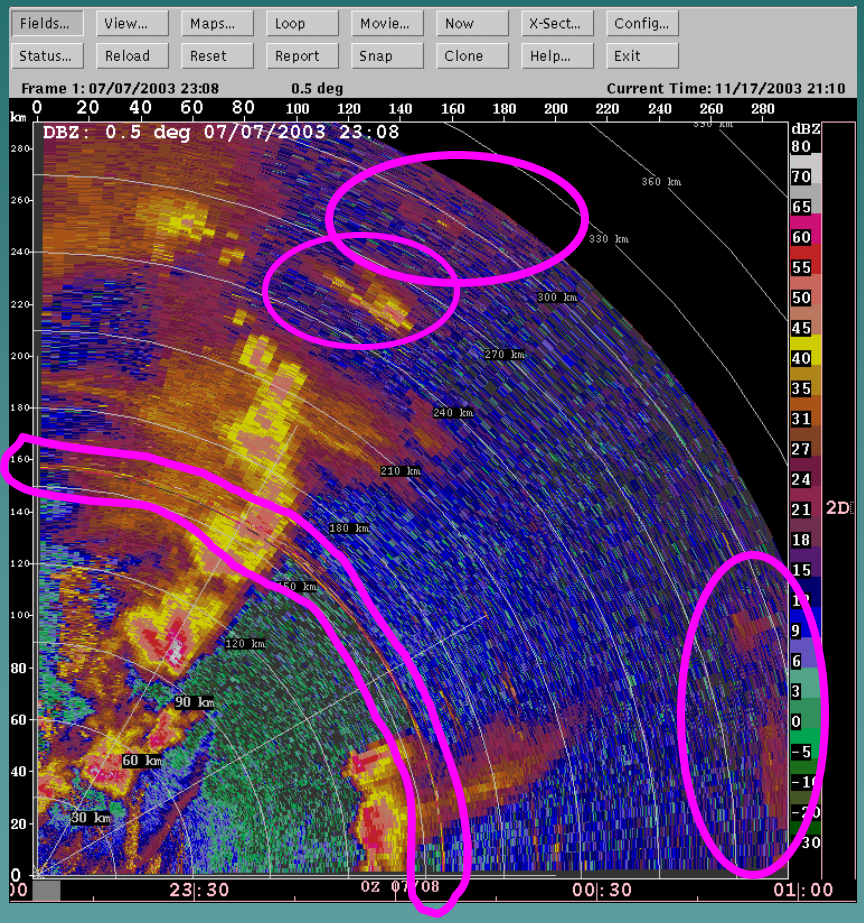
Long-PRT dBZ (truth)



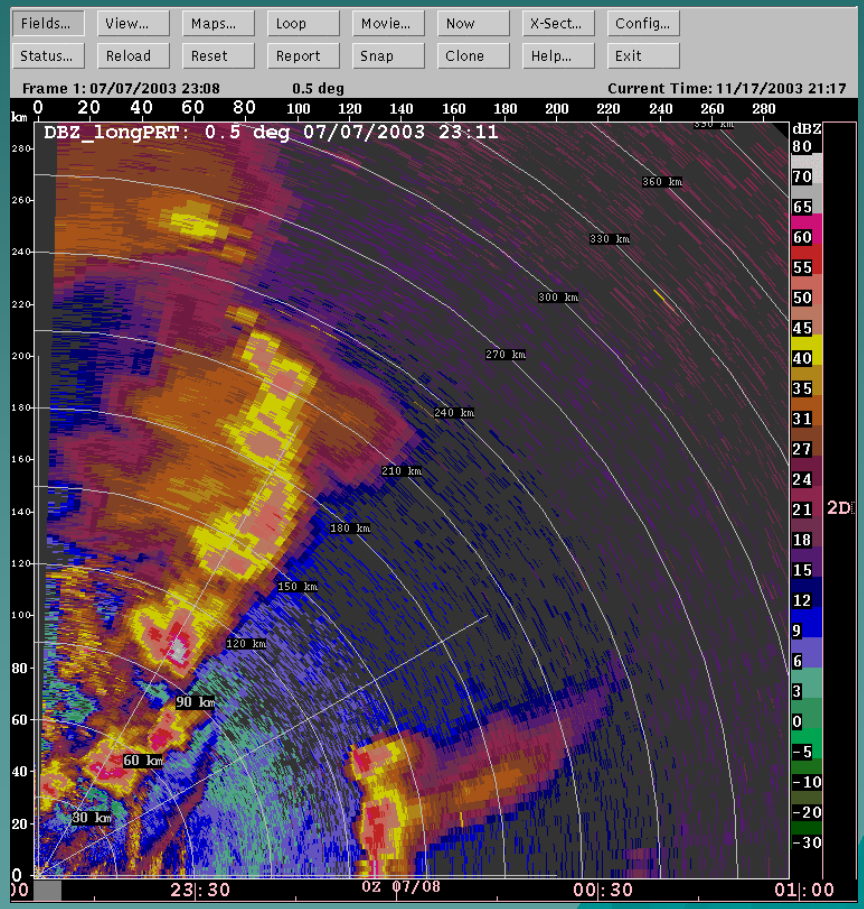
SZ1 dBZ, no censoring



Comparison: SZ1 vs long-PRT

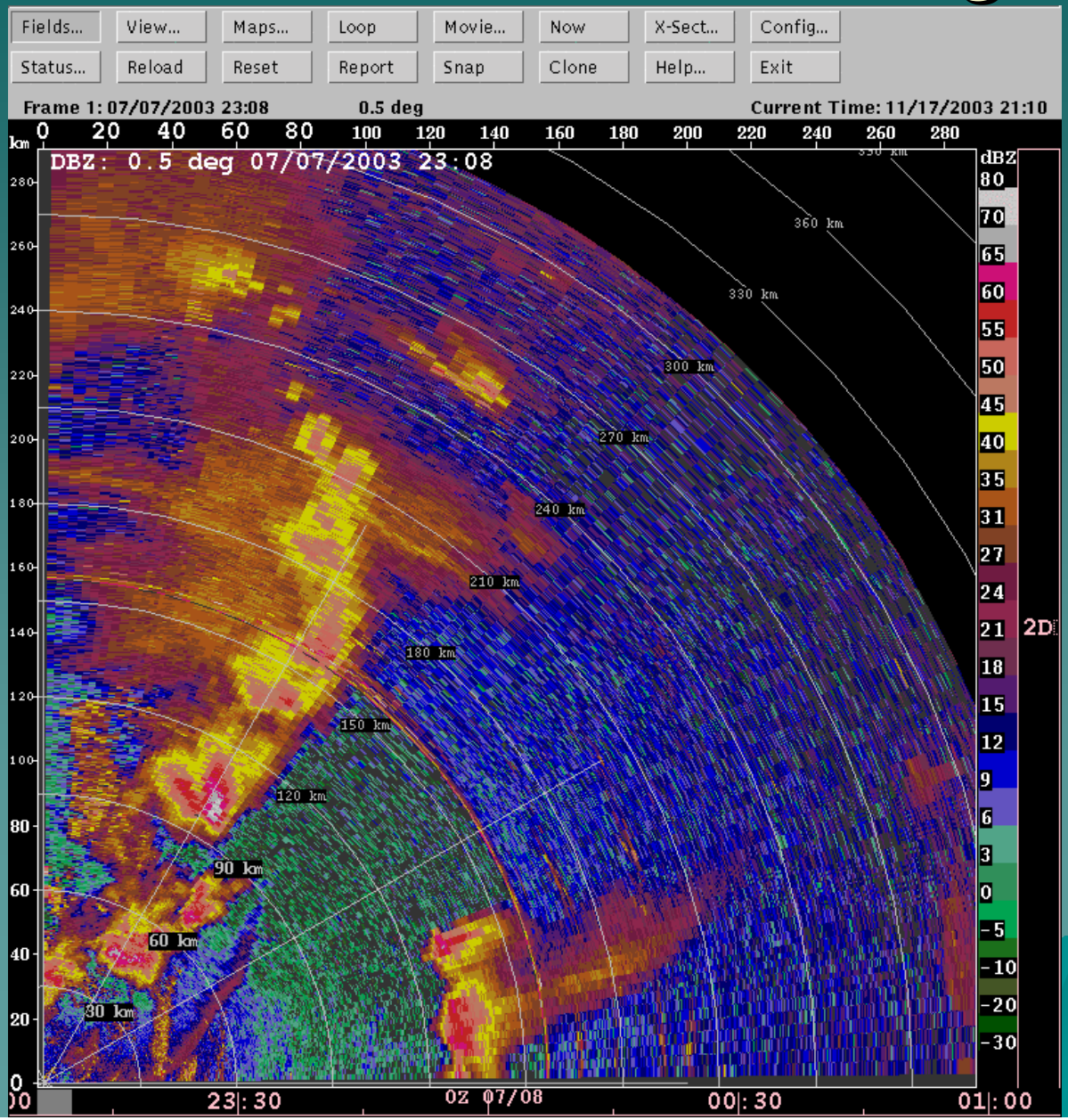


SZ1, no censoring

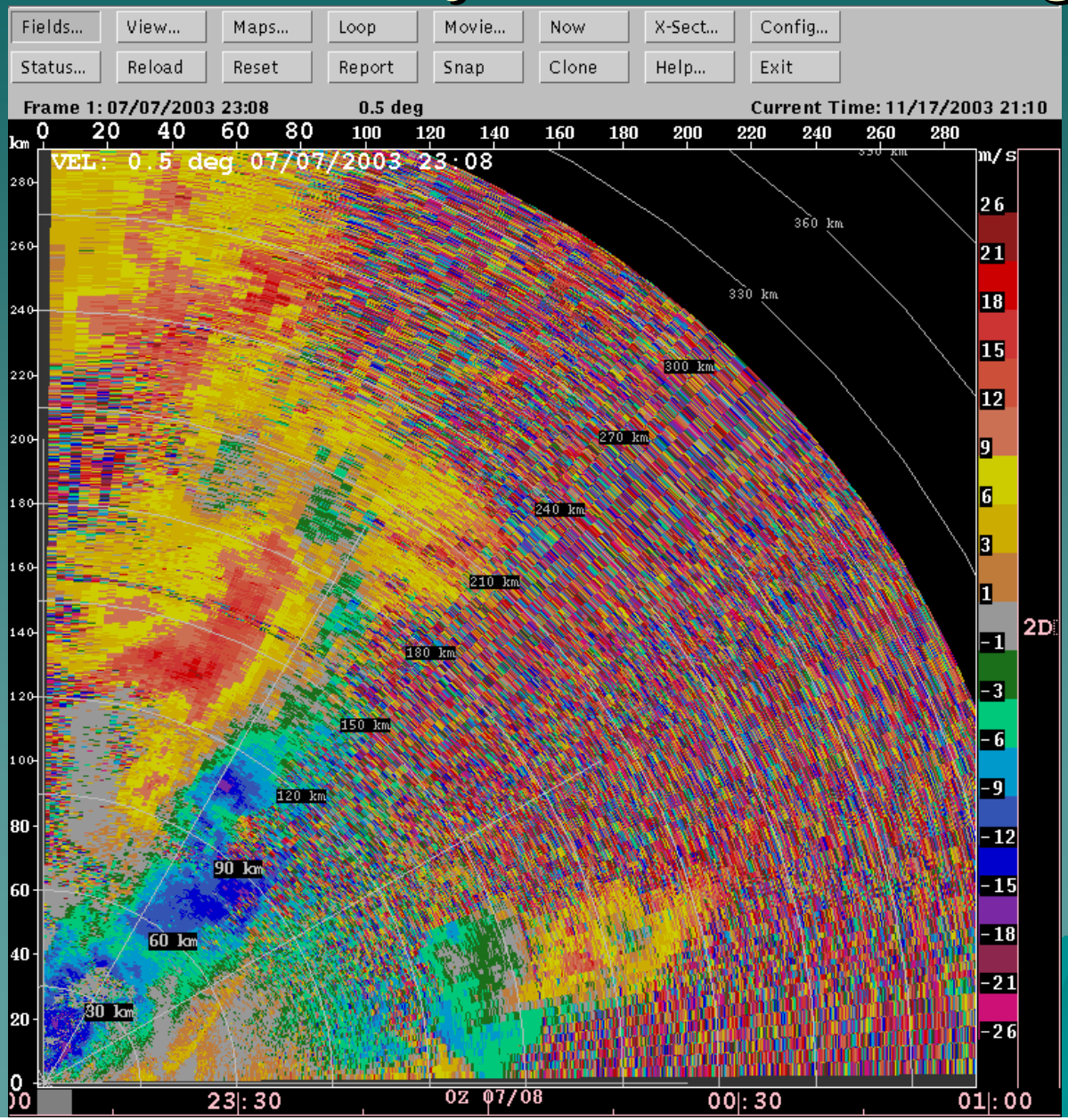


Long-PRT

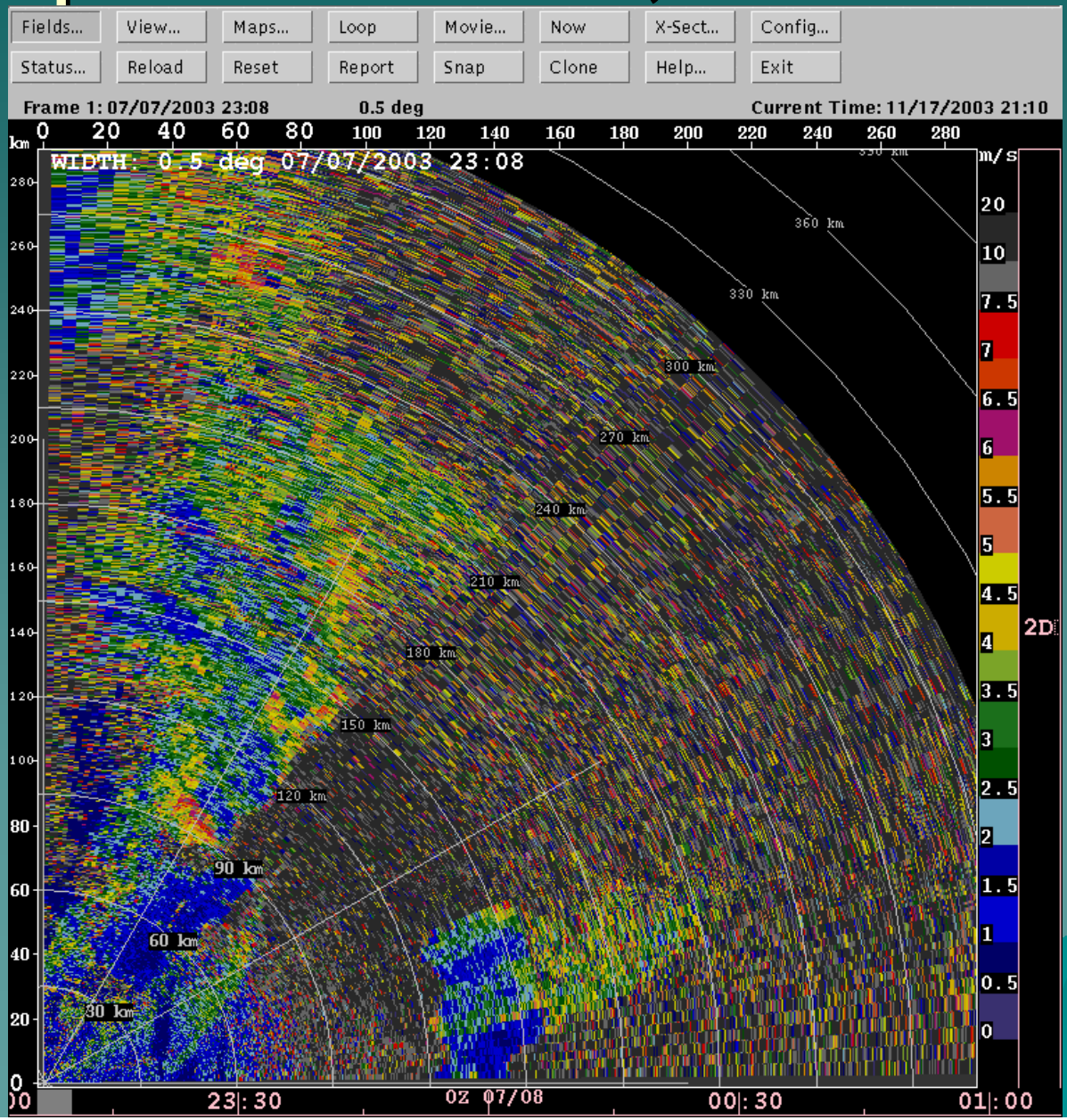
SZ1 dBZ, no censoring



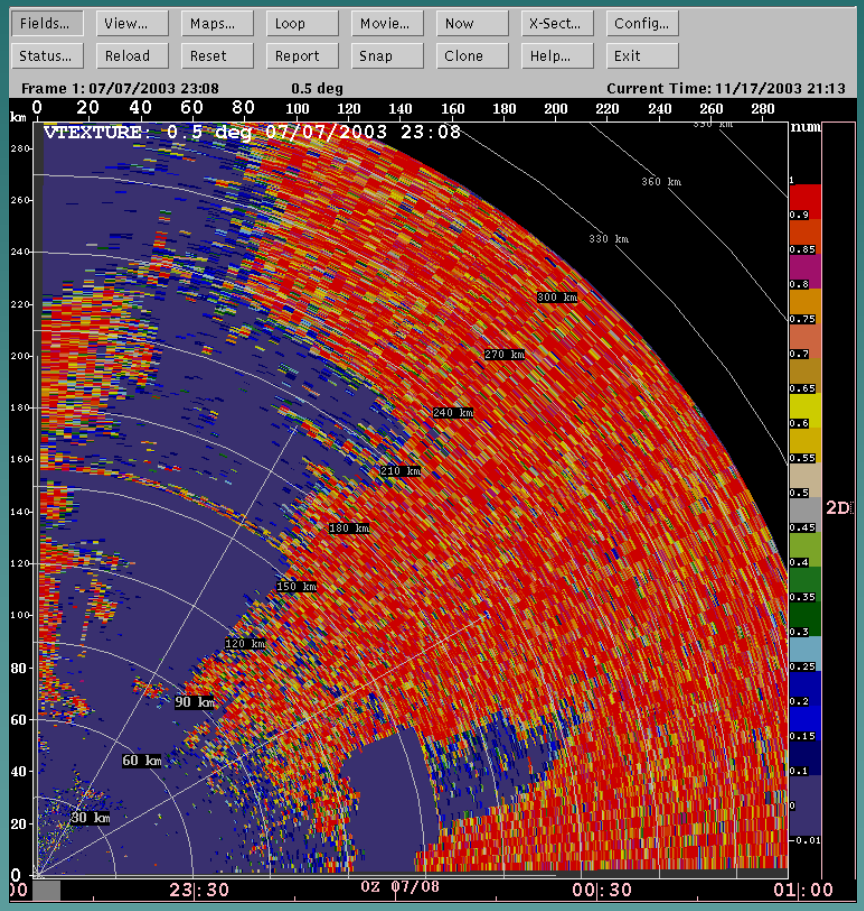
SZ1 velocity, no censoring



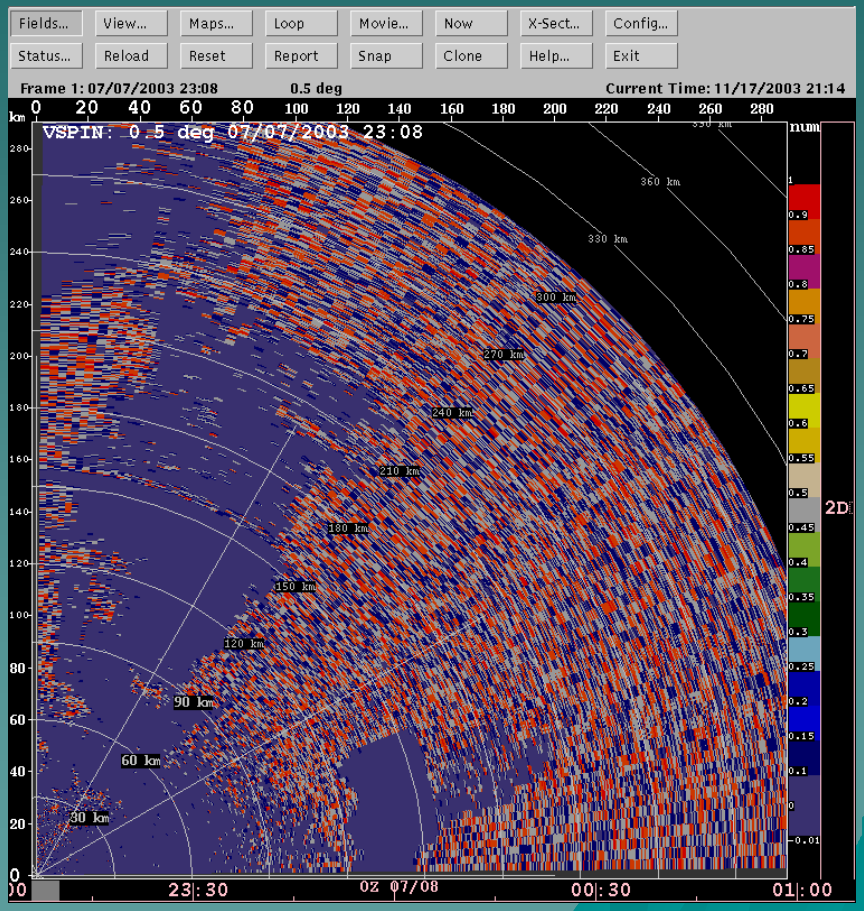
SZ1 spectral width, no censoring



Gate-by-gate velocity texture/spin



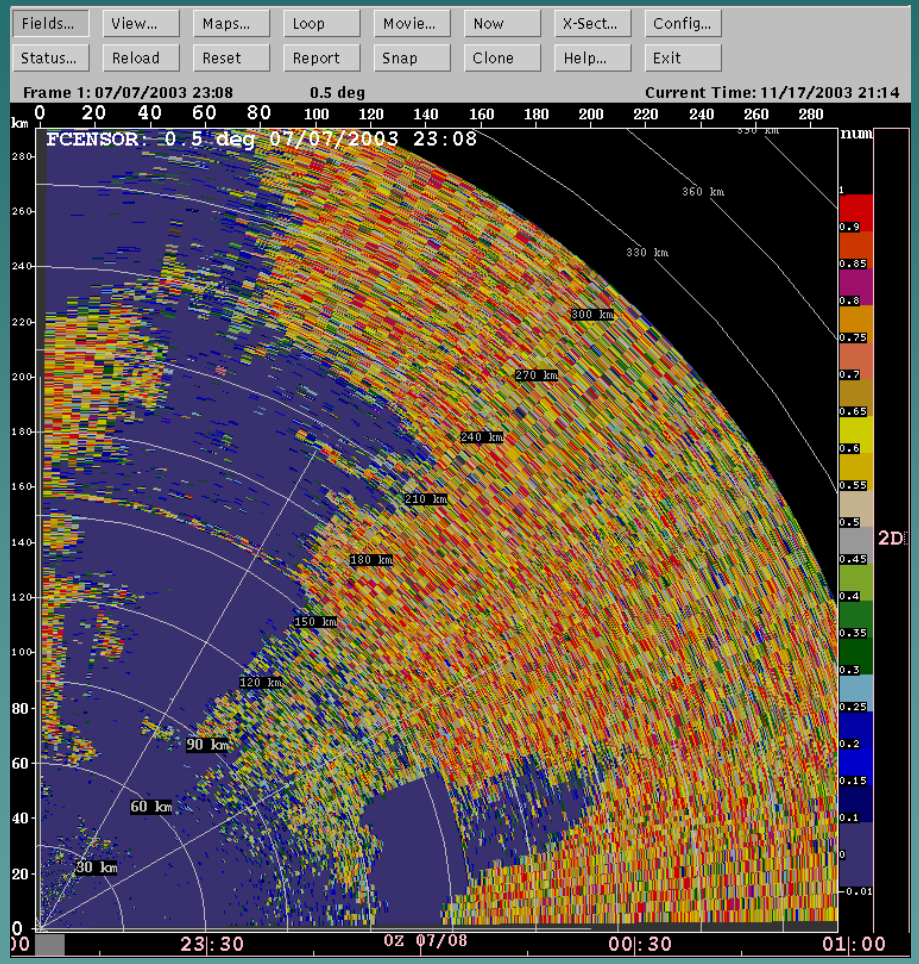
Texture



Spin

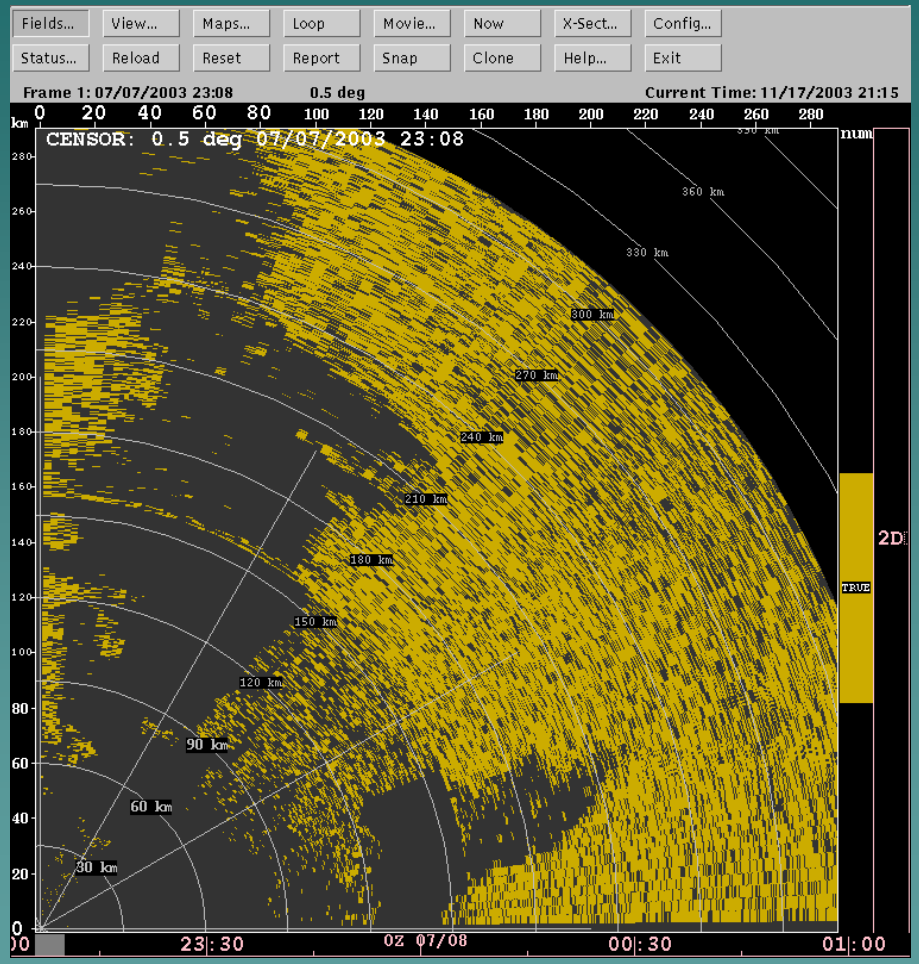
Combined censoring field

Weighted combination: (leakage + texture + spin) / 3

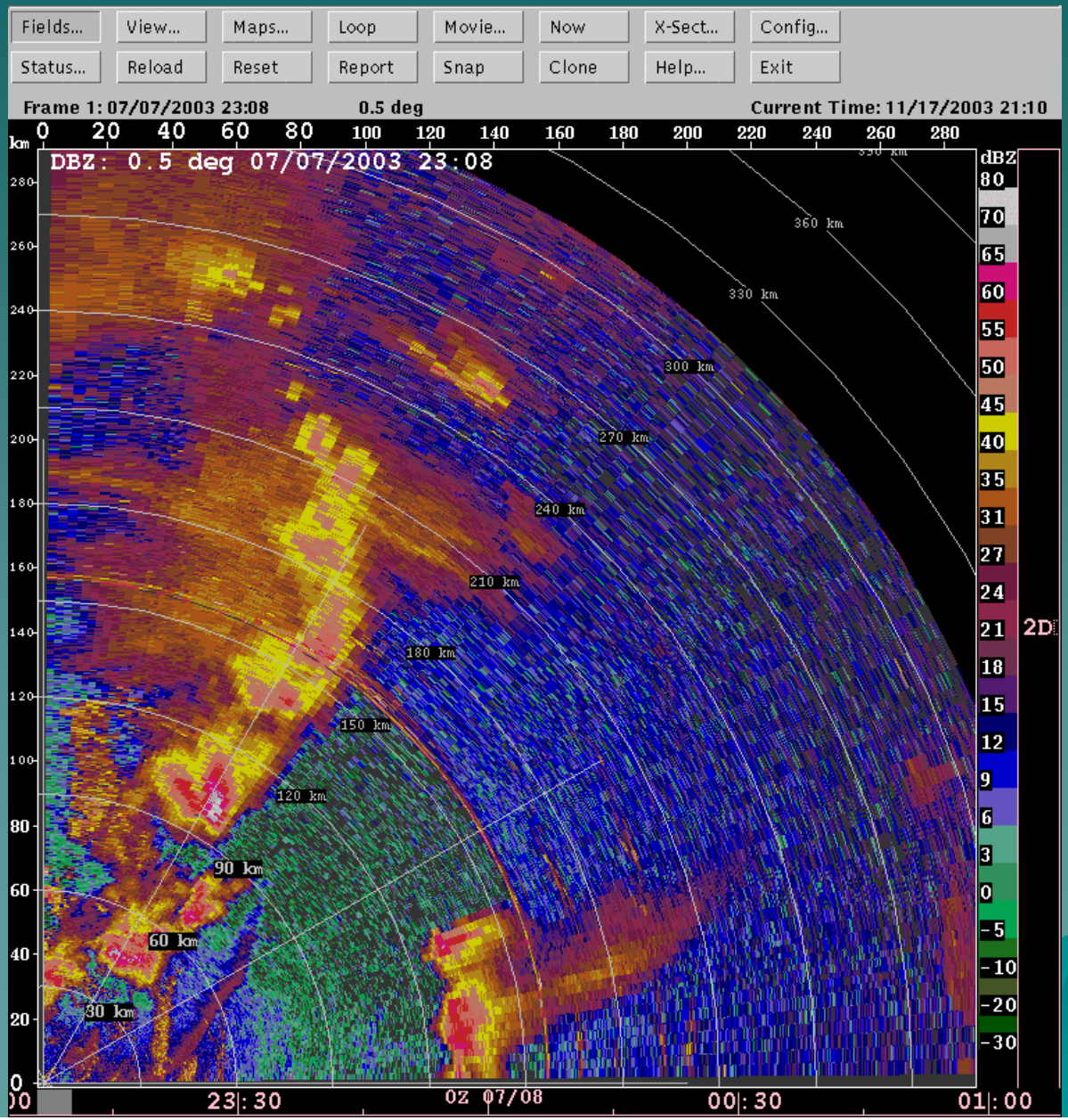


Censoring flag

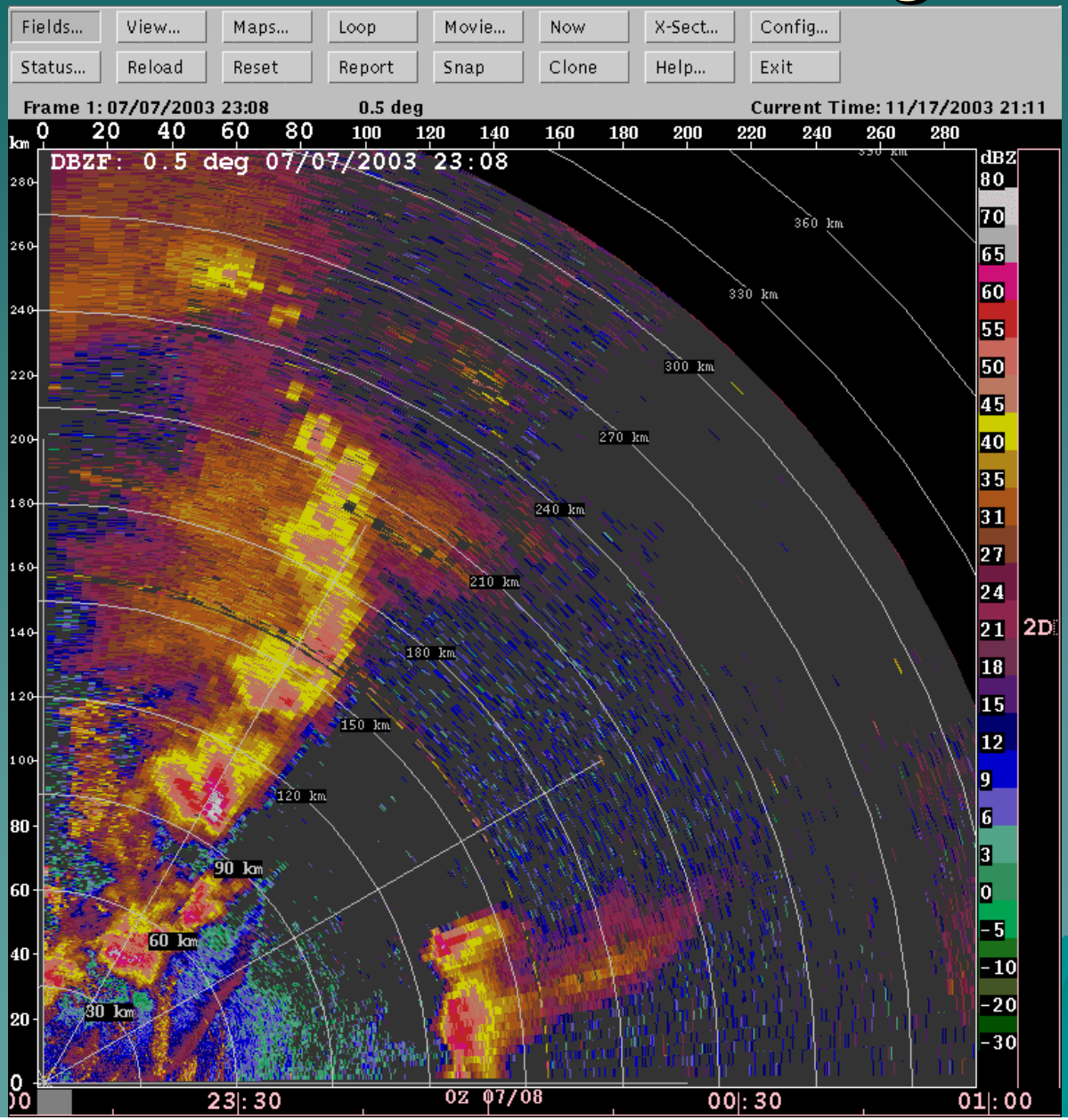
Weighted combination > 0.5



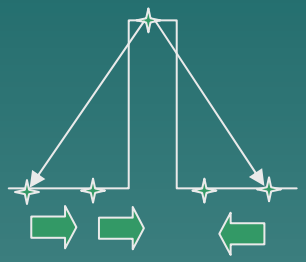
SZ1 dBZ before censoring

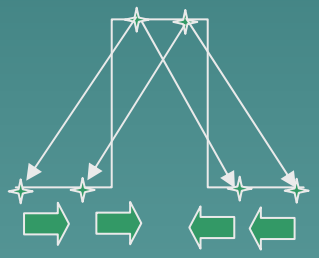


dBZ after censoring



NEXRAD spike filter



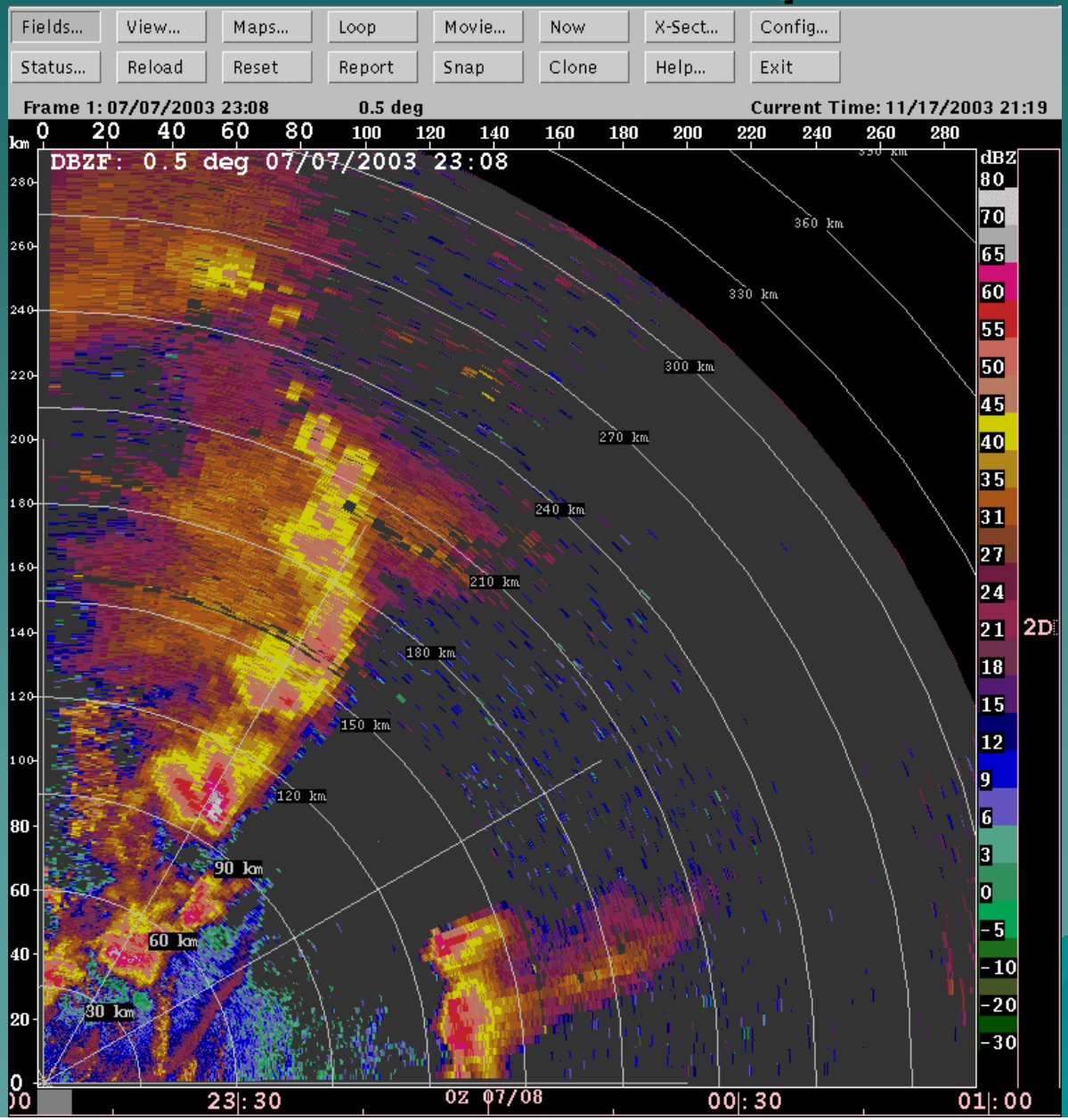


Checks dBZ value for gate n against values for gate n-2 and gate n+2

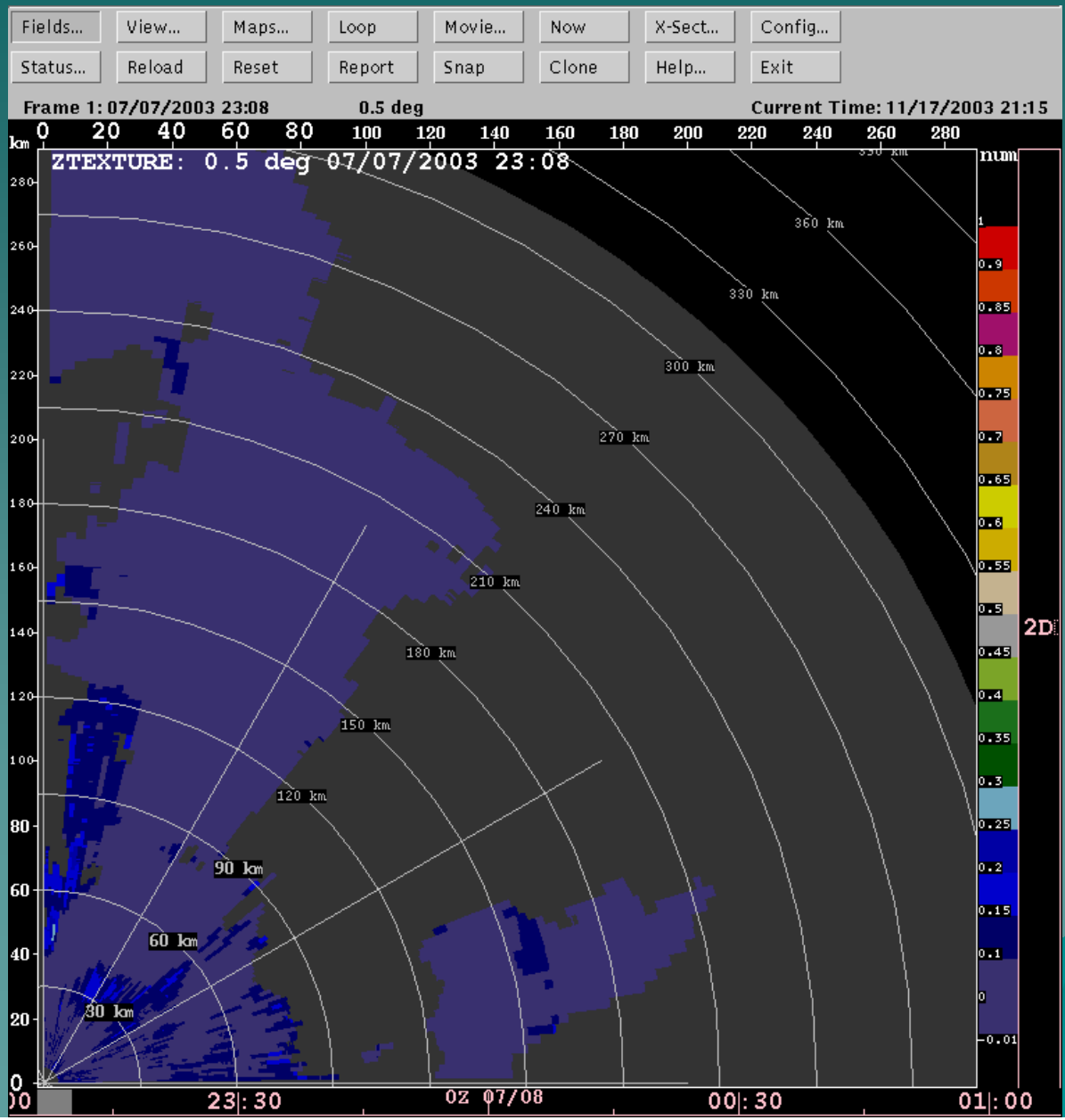
If ratio exceeds a given threshold (8.0)
i.e. diff of 9dB
the spike is replaced according to the scheme shown

Note: in the NEXRAD spec DV1208261F, this filter is referred to as the Strong Point Clutter filter, section 3.2.1.2.2.

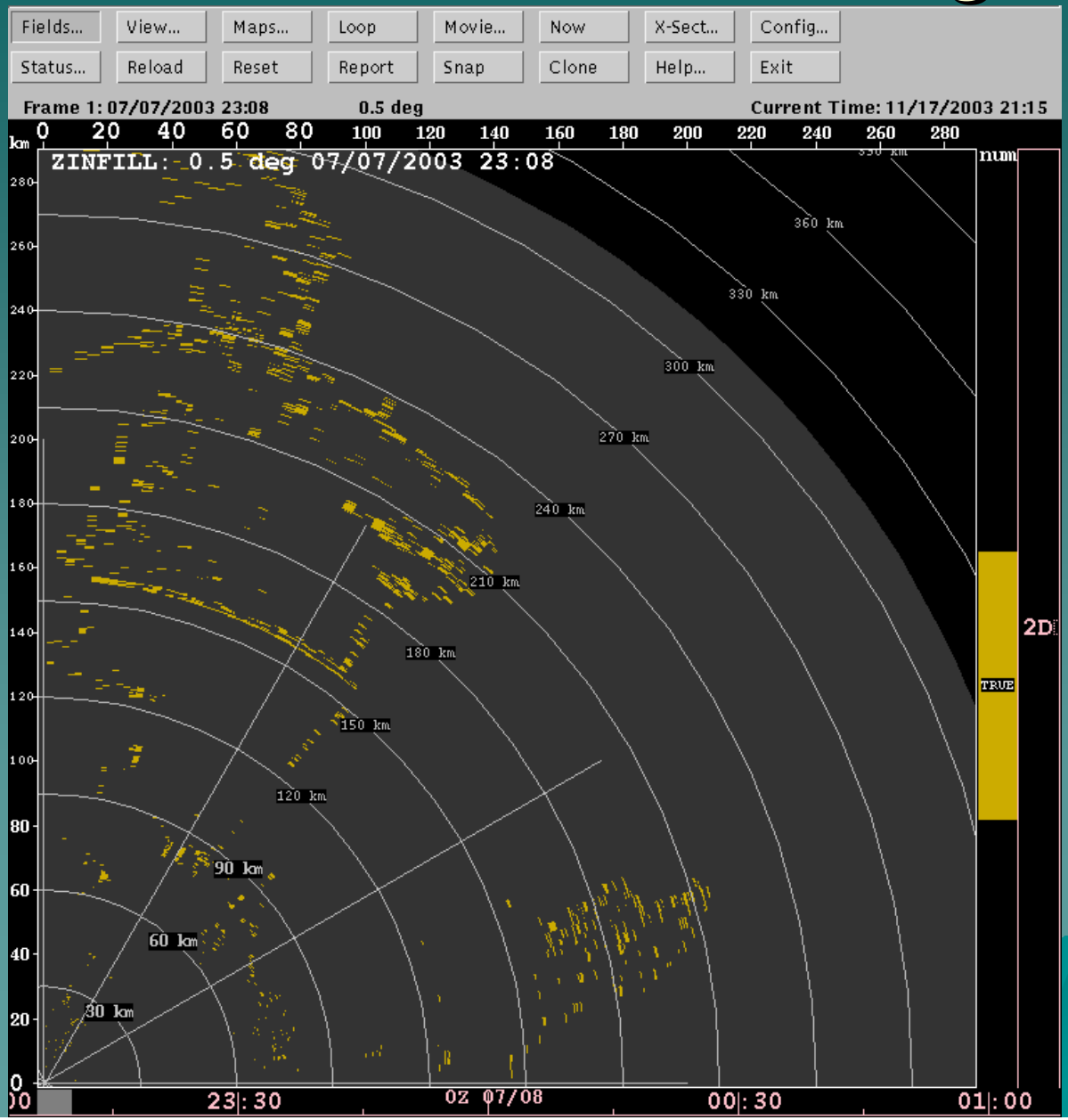
dBZ after NEXRAD spike filter



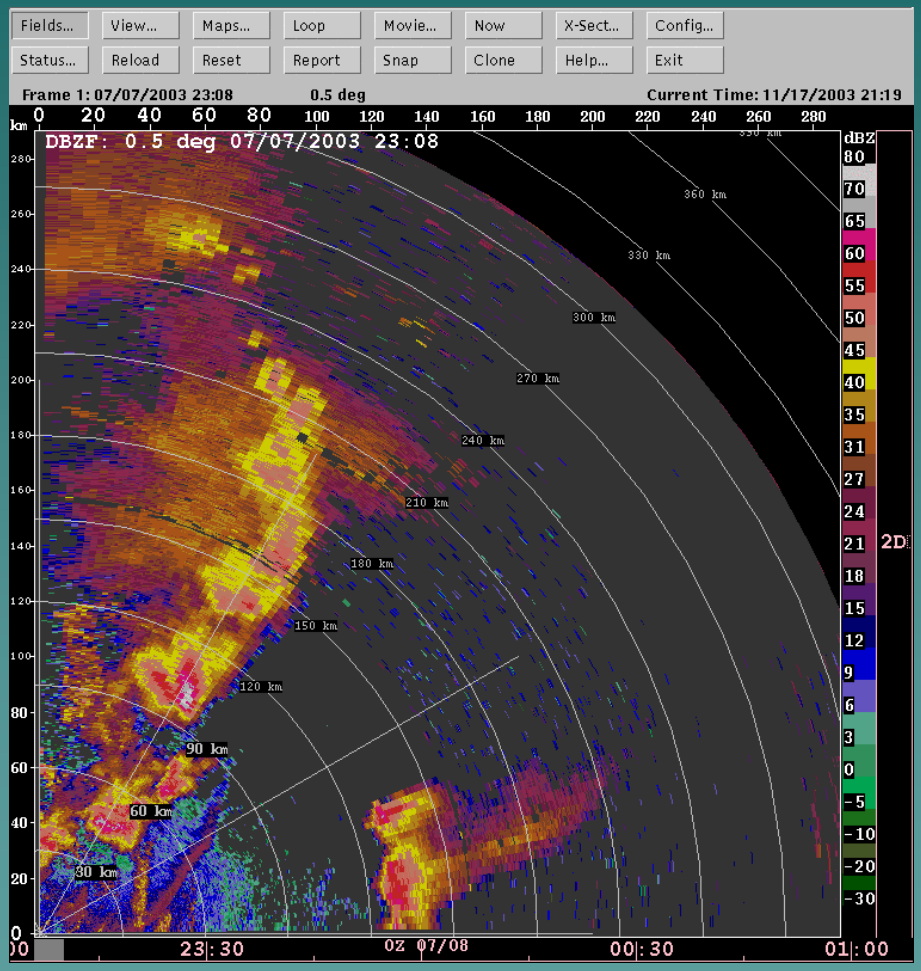
dBZ texture – areas of smooth



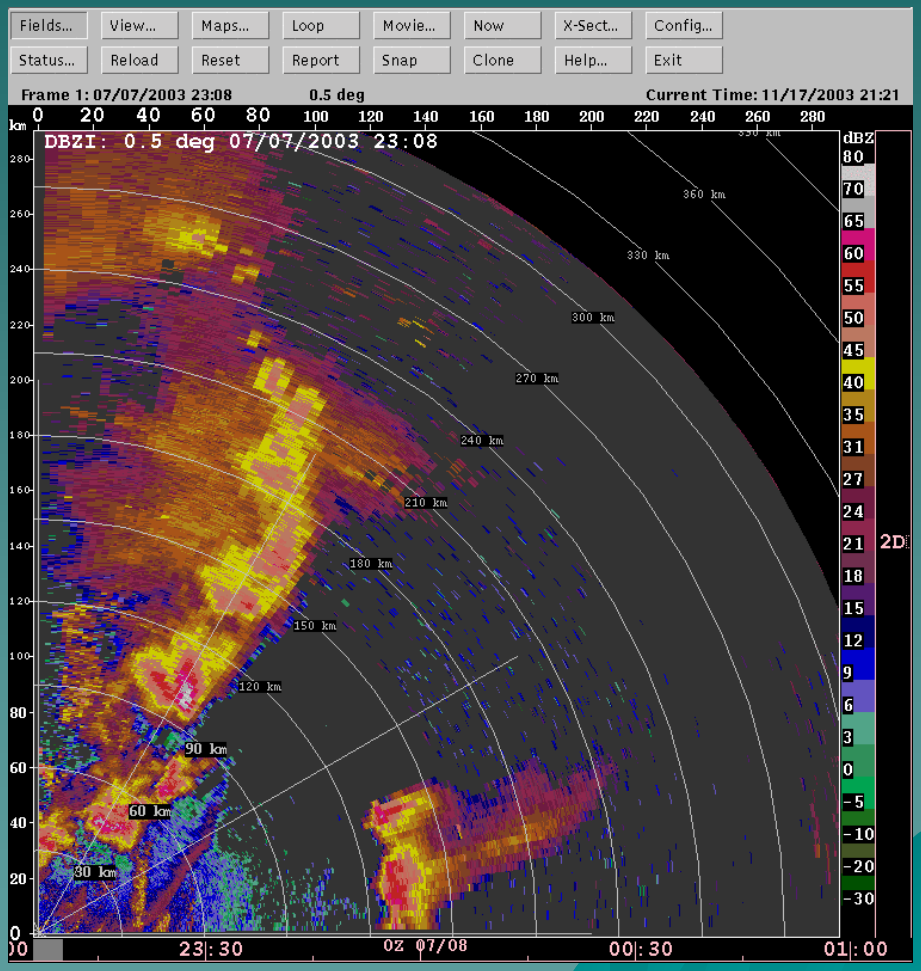
Gates for data infilling



dBZ infilling

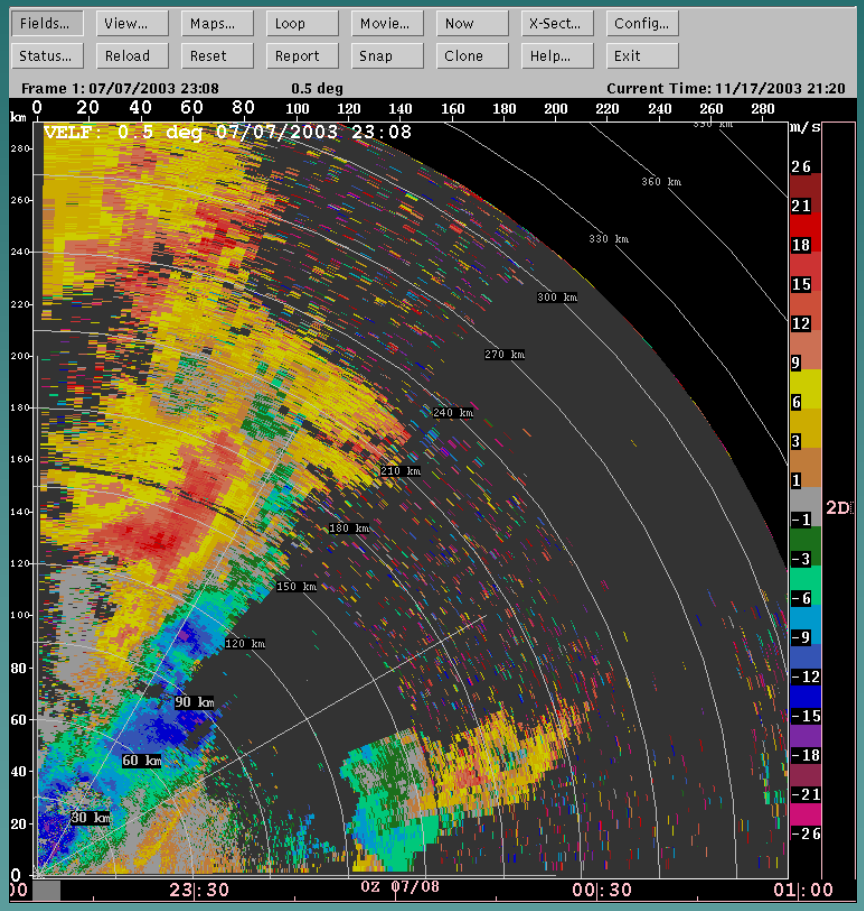


Before infilling

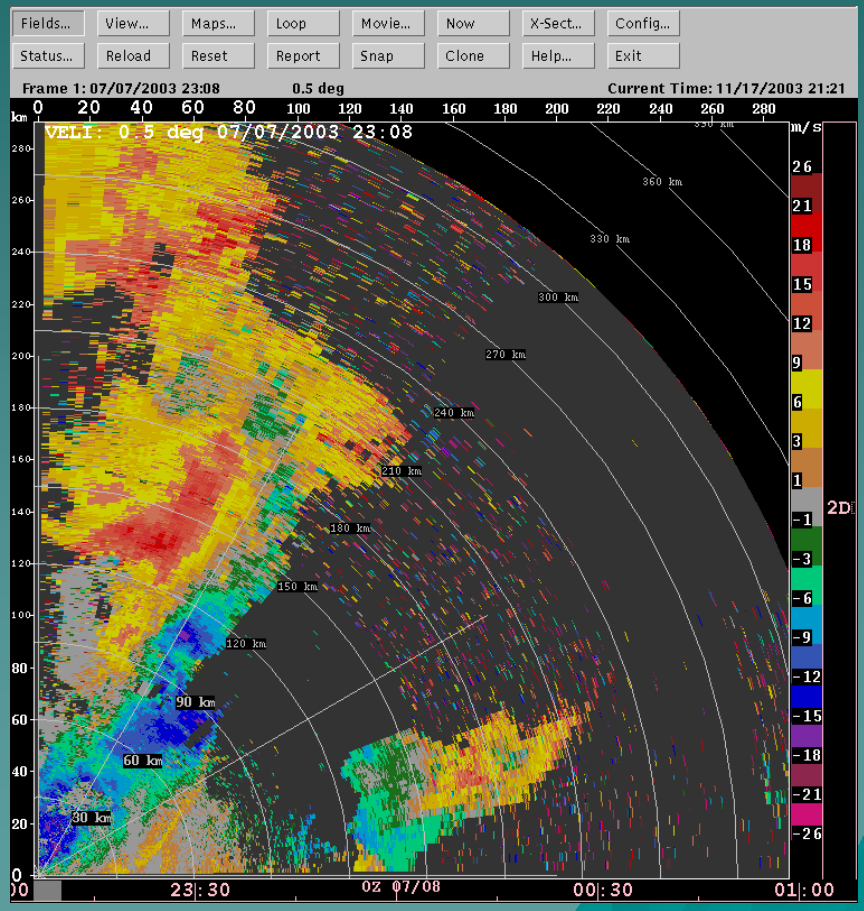


After infilling

Velocity infilling



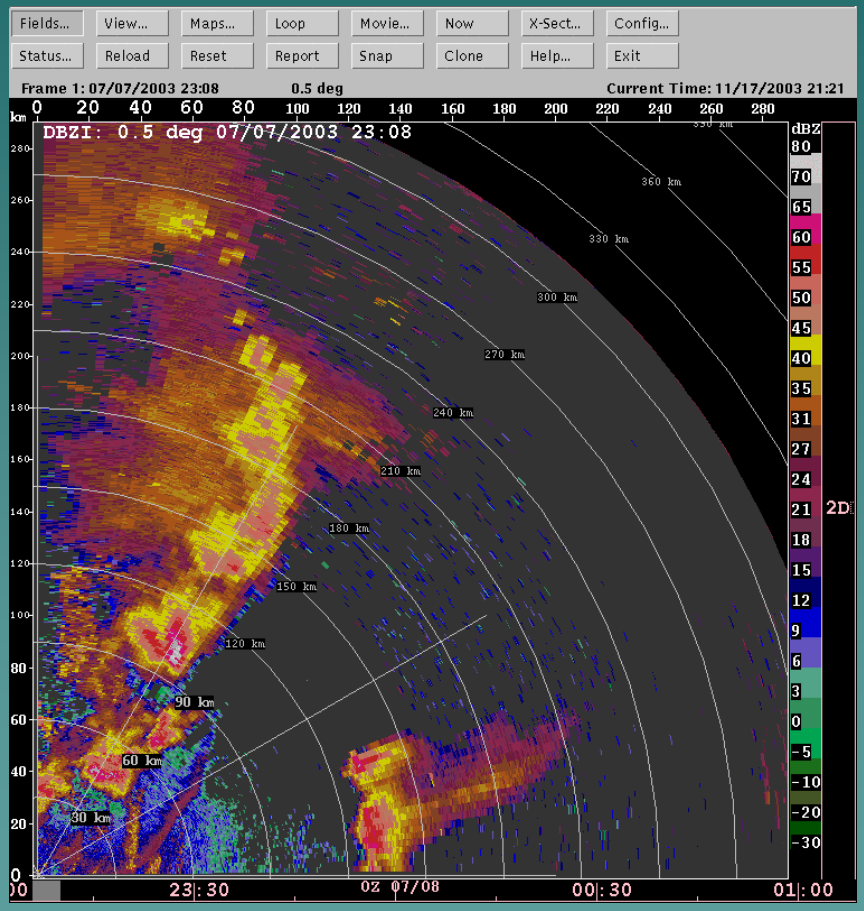
Before infilling



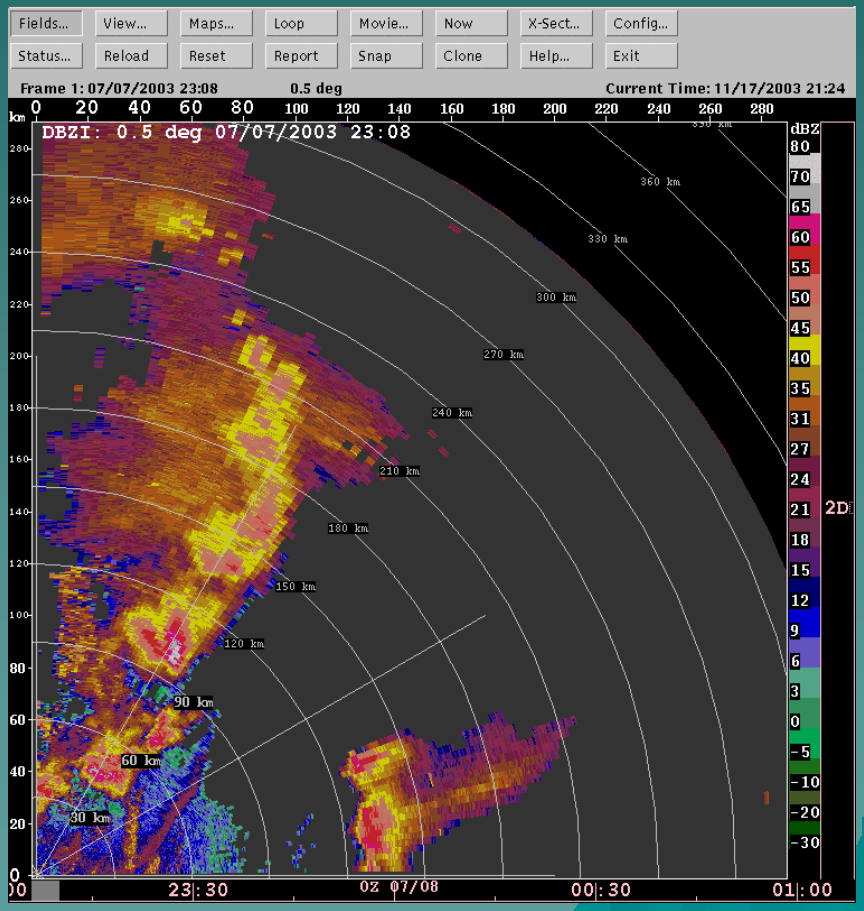
After infilling

Applying the dregs filter - dBZ

This removes small regions of echo which are left.

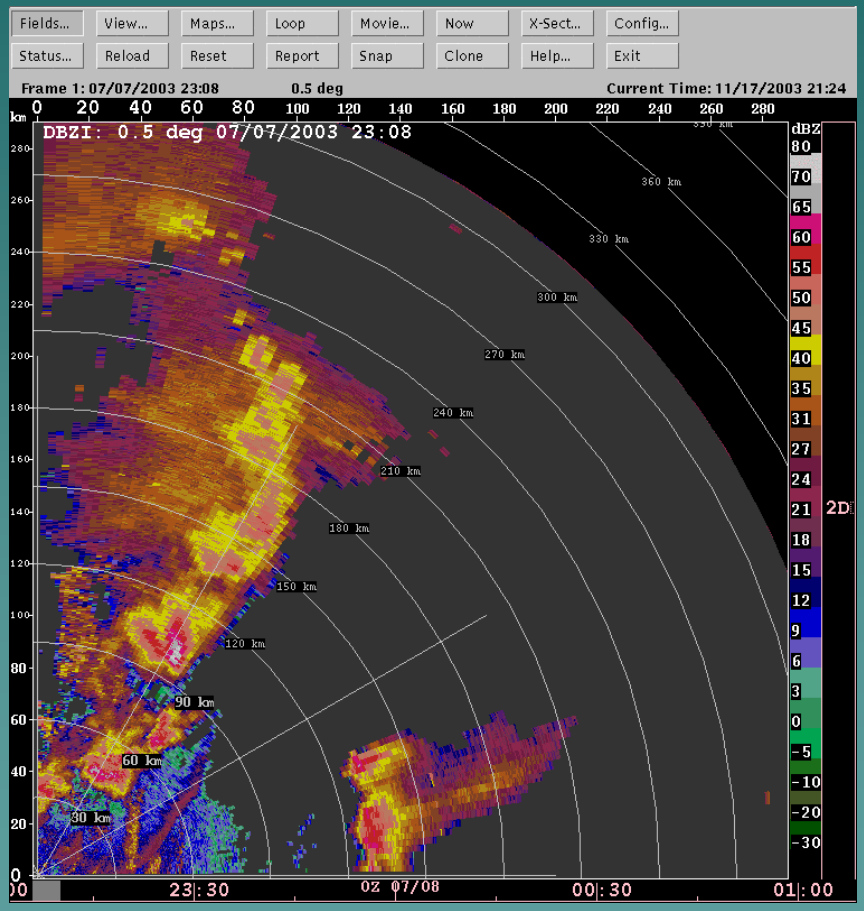


Before filtering

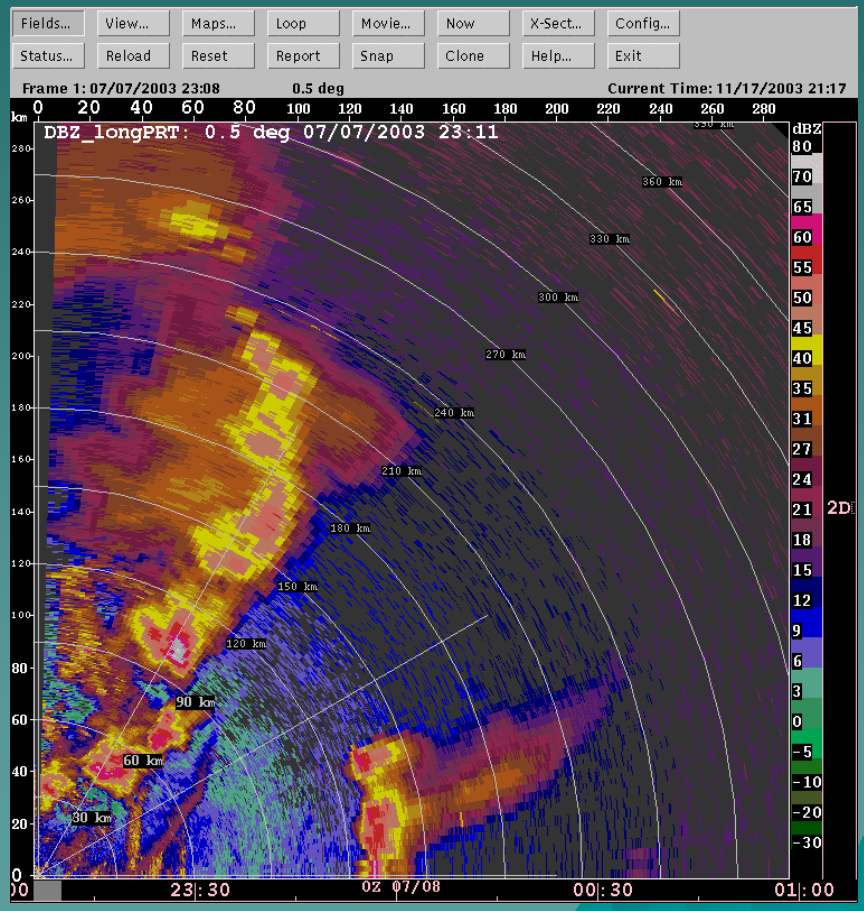


After filtering

SZ1 dBZ vs. long PRT dBZ (truth)

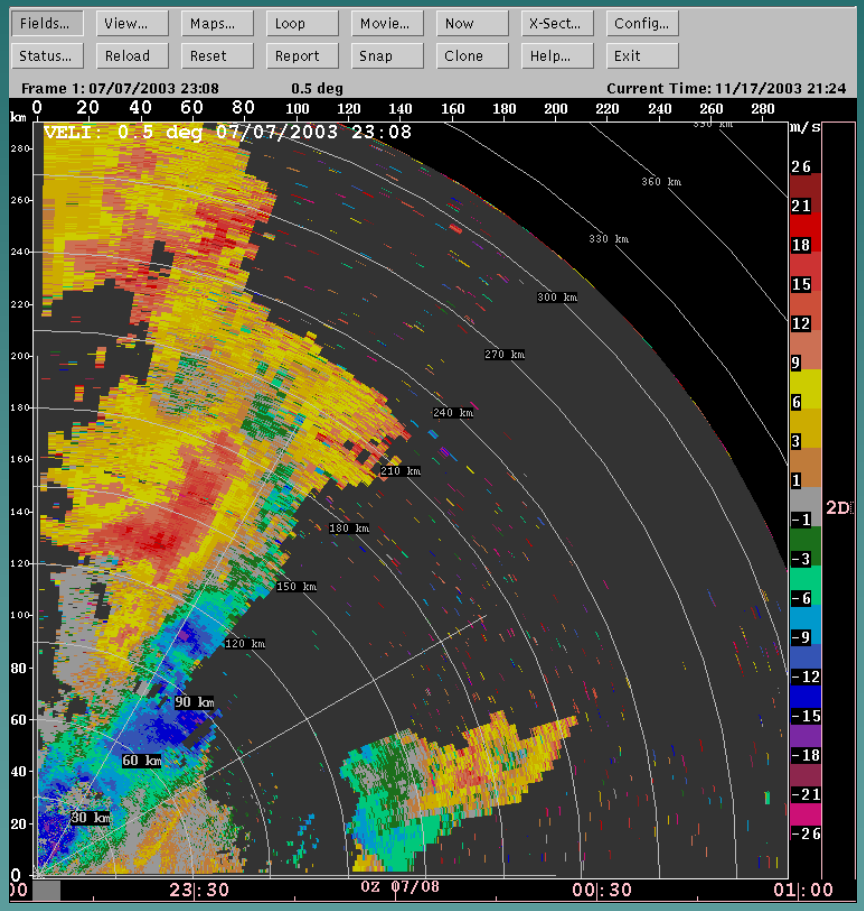


SZ1 dBZ

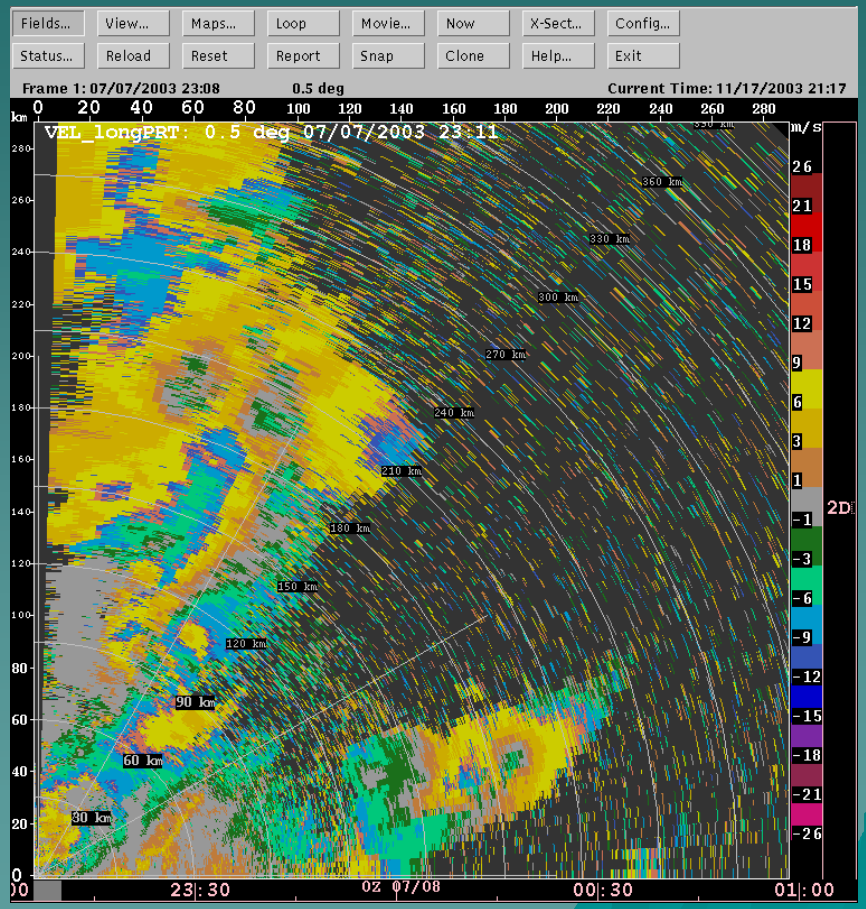


Long-PRT dBZ

SZ1 velocity vs. long-PRT velocity

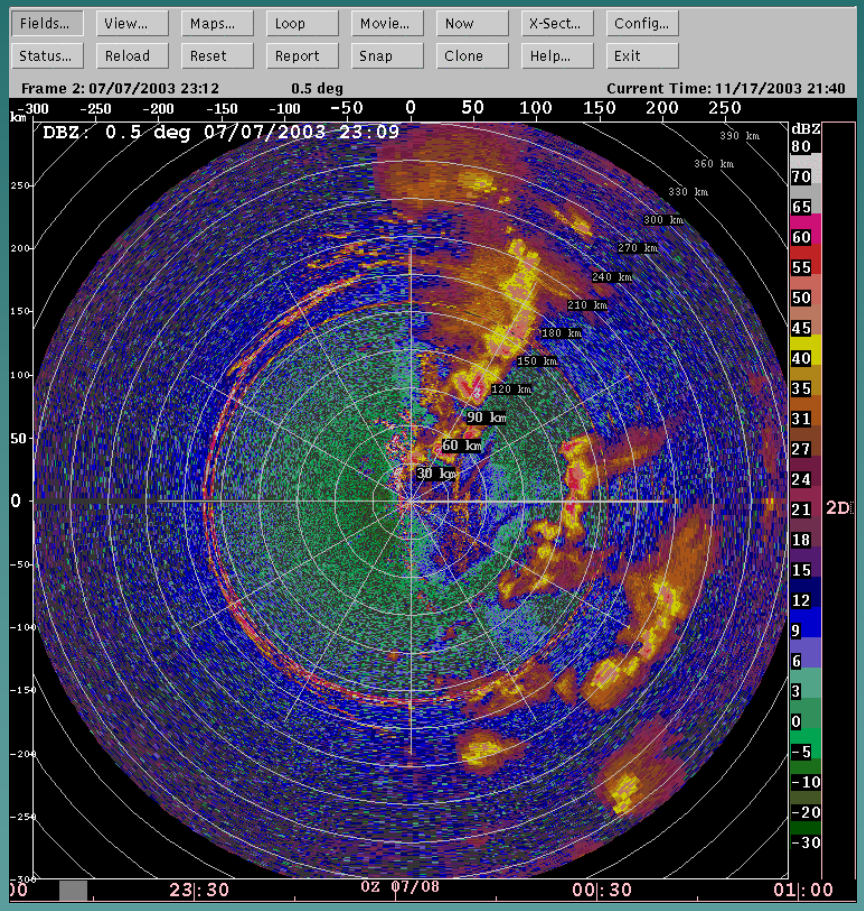


SZ1 velocity

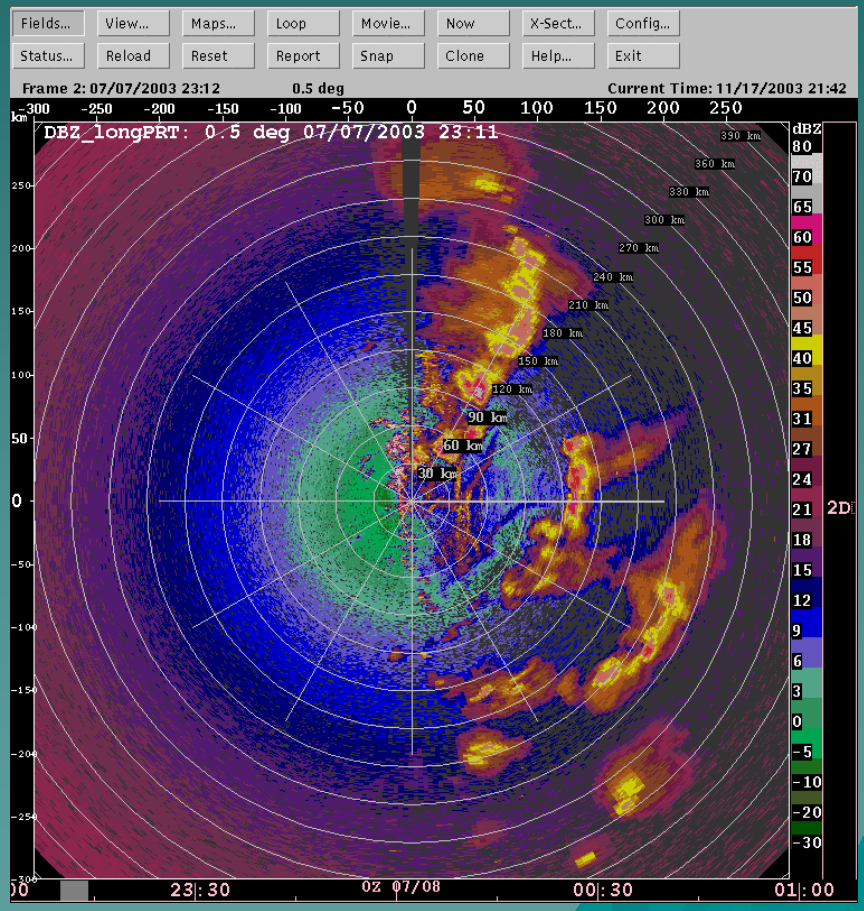


Long-PRT velocity

SZ1 dBZ, no censoring, vs. long-PRT dBZ

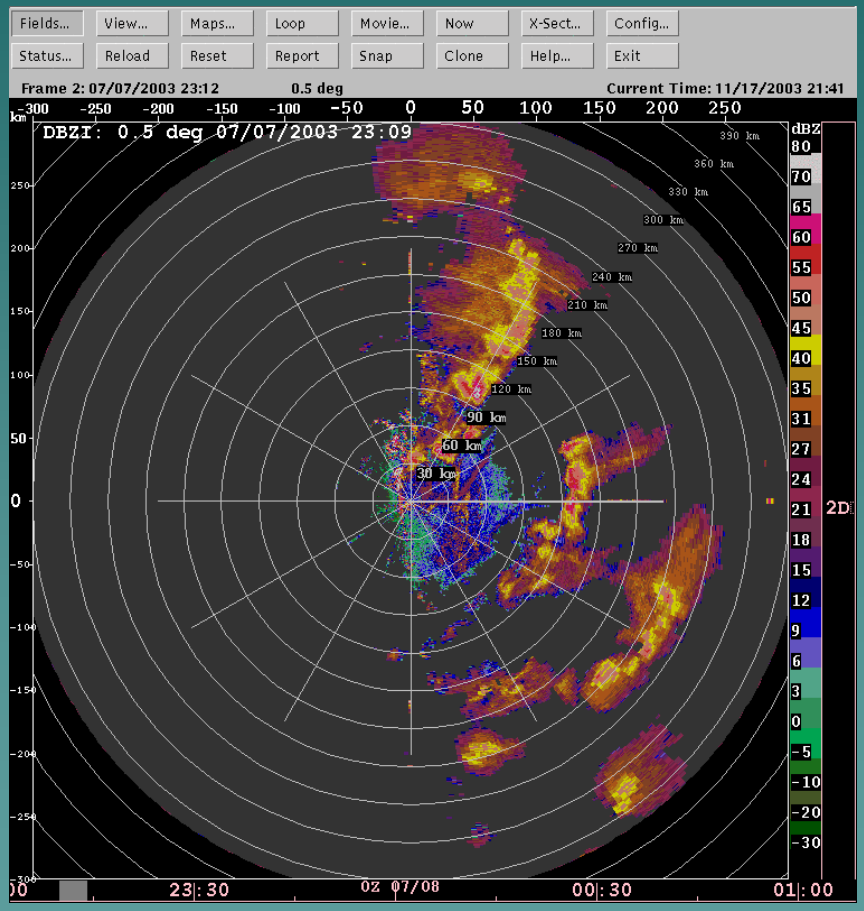


SZ1 dBZ, no censoring

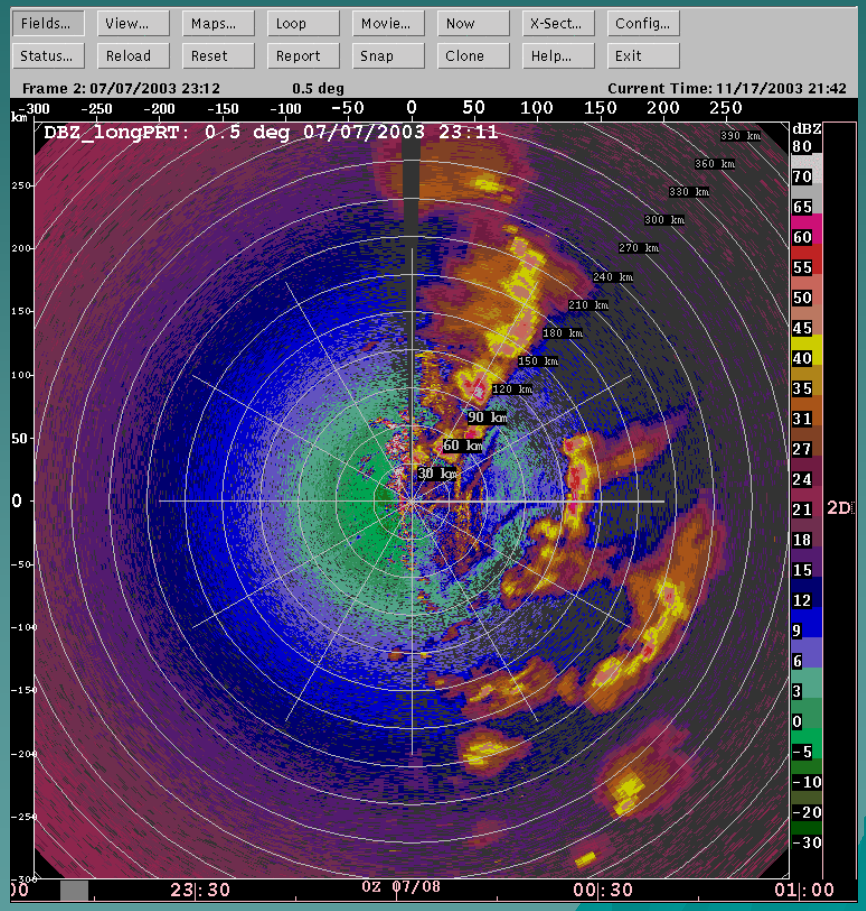


Long-PRT dBZ

SZ1 dBZ vs. long-PRT dBZ (truth)

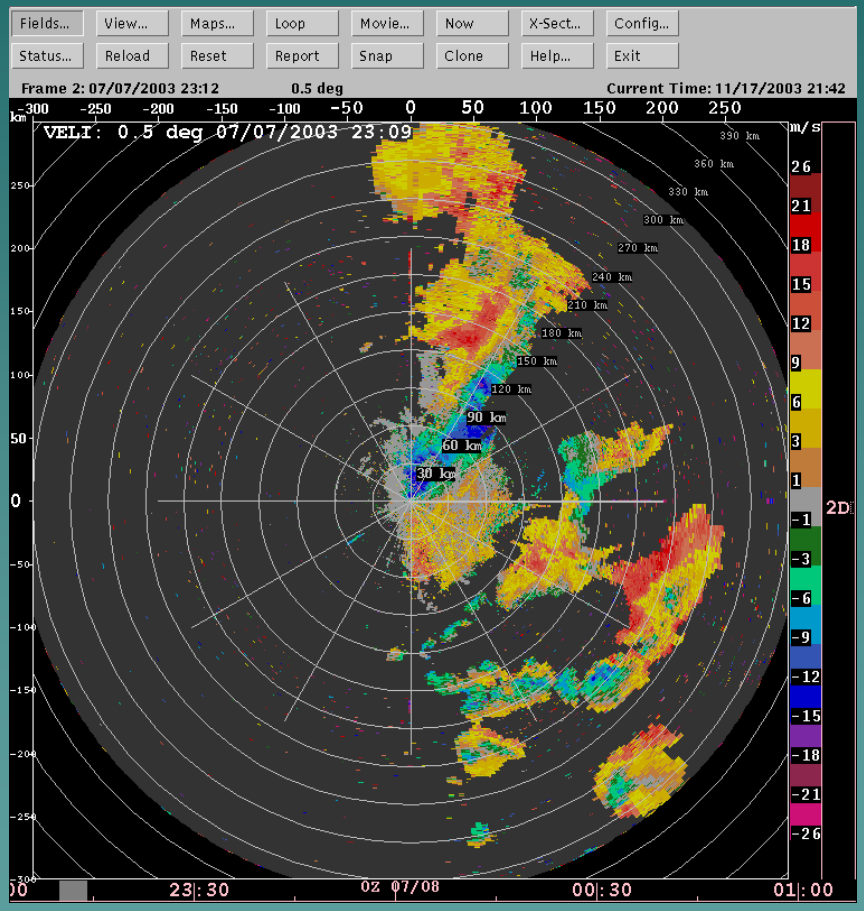


SZ1 dBZ

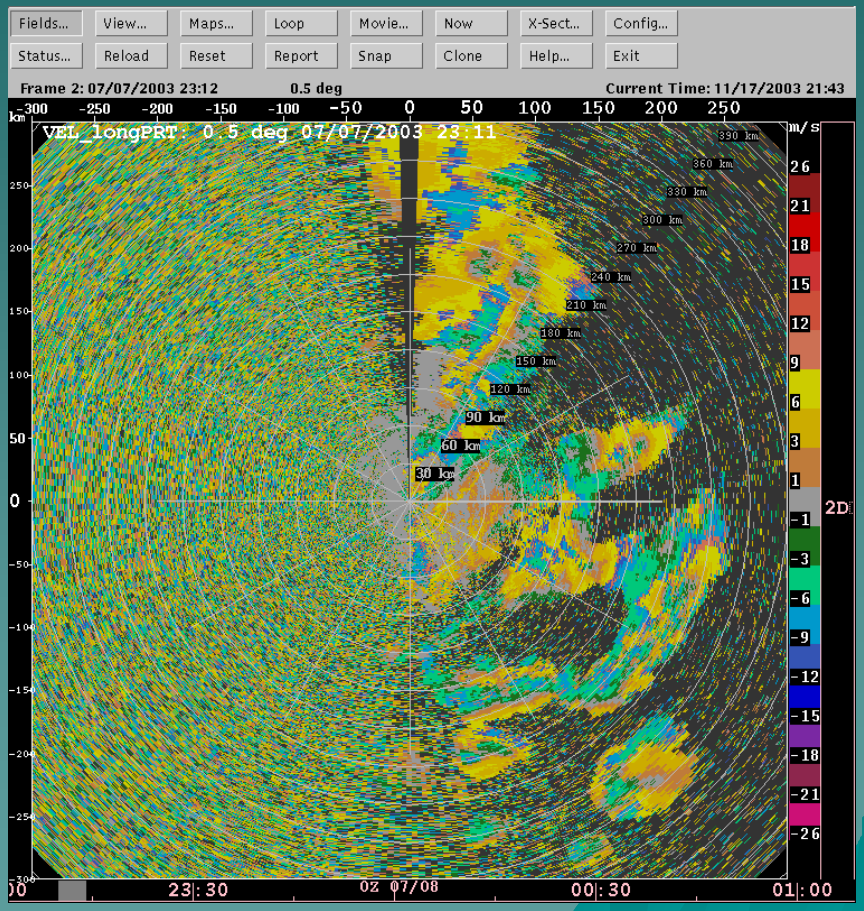


Long-PRT dBZ

SZ1 velocity vs. long-PRT velocity

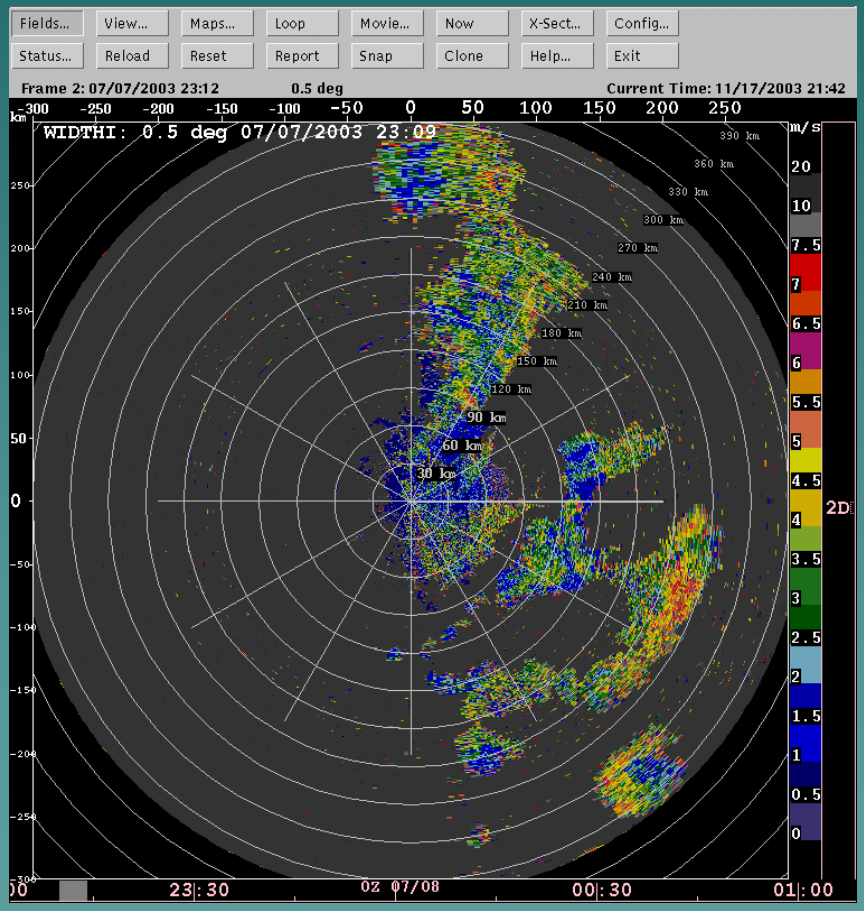


SZ1 velocity

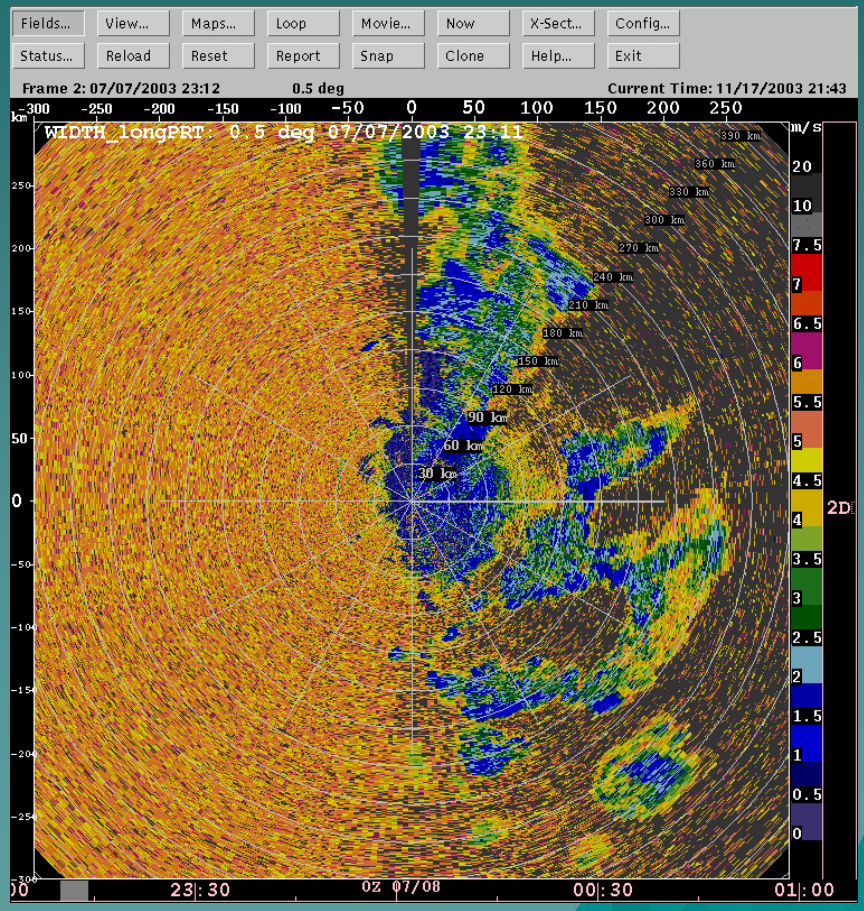


Long-PRT velocity

SZ1 width vs. long-PRT width



SZ1 spectral width



Long-PRT spectral width

Further work

- Scoring SZ1 vs Long-PRT moments
- Optimize censoring / infilling using scoring
- Add support for 3 trips
- Compare PP vs. spectral methods
- Run on SPOL in real-time
- Collect winter data sets
- SZ2

Thank you

15 August NCAR/NSSL Interim Report

- Phase coding recommended for entire VCP
- SZ-2 for first elevations
- SZ-1 for remaining elevations

SZ-2 TRIP SORTING

	TRIPS	CONDITION	SZ MODULATION CODE
CASE 0	00∅∅	$\beta = 0$	No Decode
CASE 1	12∅∅	$\alpha(1) = 1$ and $\alpha(2) = 2$	SZ(8/64)
CASE 2	21∅∅	$\alpha(1) = 2$ and $\alpha(2) = 2$	SZ(8/64)
CASE 3	$1\bar{2}$∅∅	$\alpha(1) = 1$ and $\alpha(2) \neq 2$	Only Strong Trip Cohere
CASE 4	$\bar{2}$1∅∅	$\alpha(1) \neq 2$ and $\alpha(2) = 1$	Only Strong Trip Cohere
CASE 5	∅21∅	$\alpha(2) = 2$ and $\alpha(3) = 1$	SZ(8/64)
CASE 6	∅2∅1	$\alpha(2) = 2$ and $\alpha(4) = 1$	SZ(16/64)
CASE 7	2∅1∅	$\alpha(1) = 2$ and $\alpha(3) = 1$	SZ(16/64)
CASE 8	2∅∅1	$\alpha(1) = 2$ and $\alpha(3) = 1$	SZ(8/64)

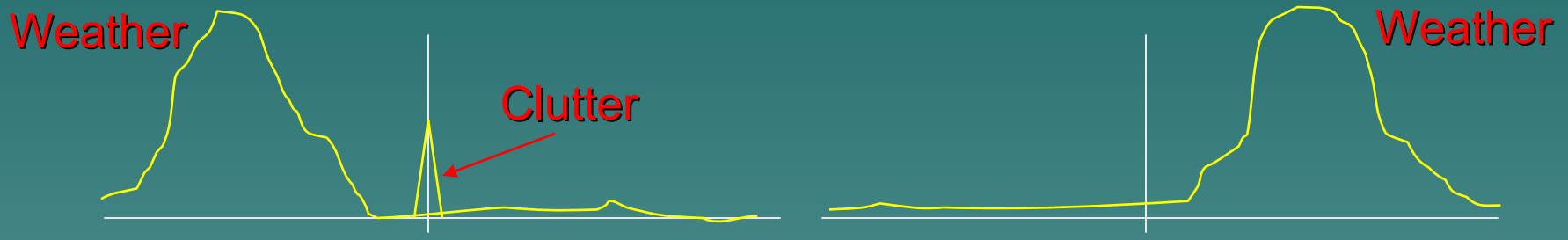
SZ-2: Interim Report and New NCAR Algorithm

- Interim Report SZ-2:
  - Ground clutter limited to first trip.
  - Ground clutter filter long PRT first
  - Then rank the 4 powers $P_{L(1)}$- $P_{L(4)}$
- Short PRT Scan:
  - First, always cohere to first trip and clutter filter regardless of relative power levels
  - Always determine strongest trip from coherent power calculated from short PRT

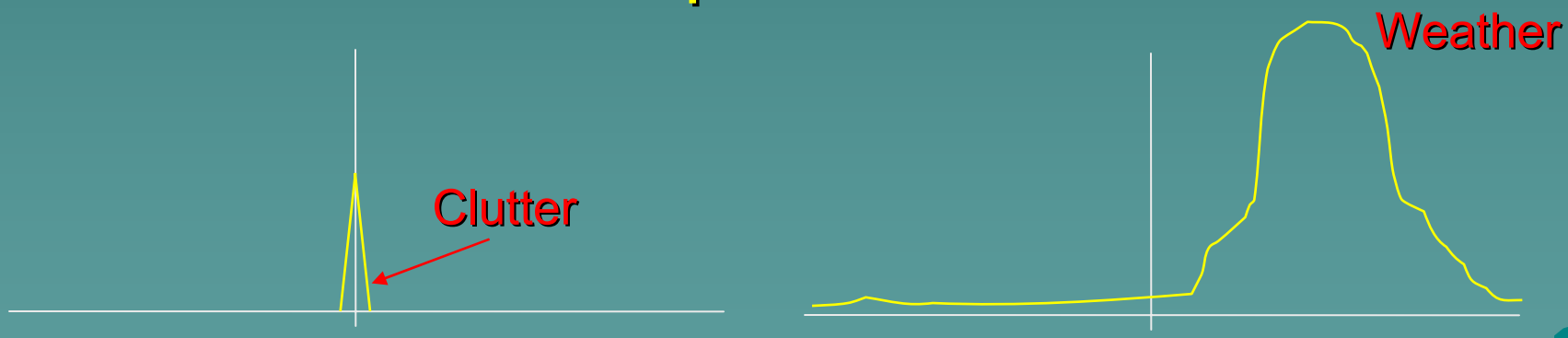
SZ-2 Examples

First Trip

Second Trip



Spectra

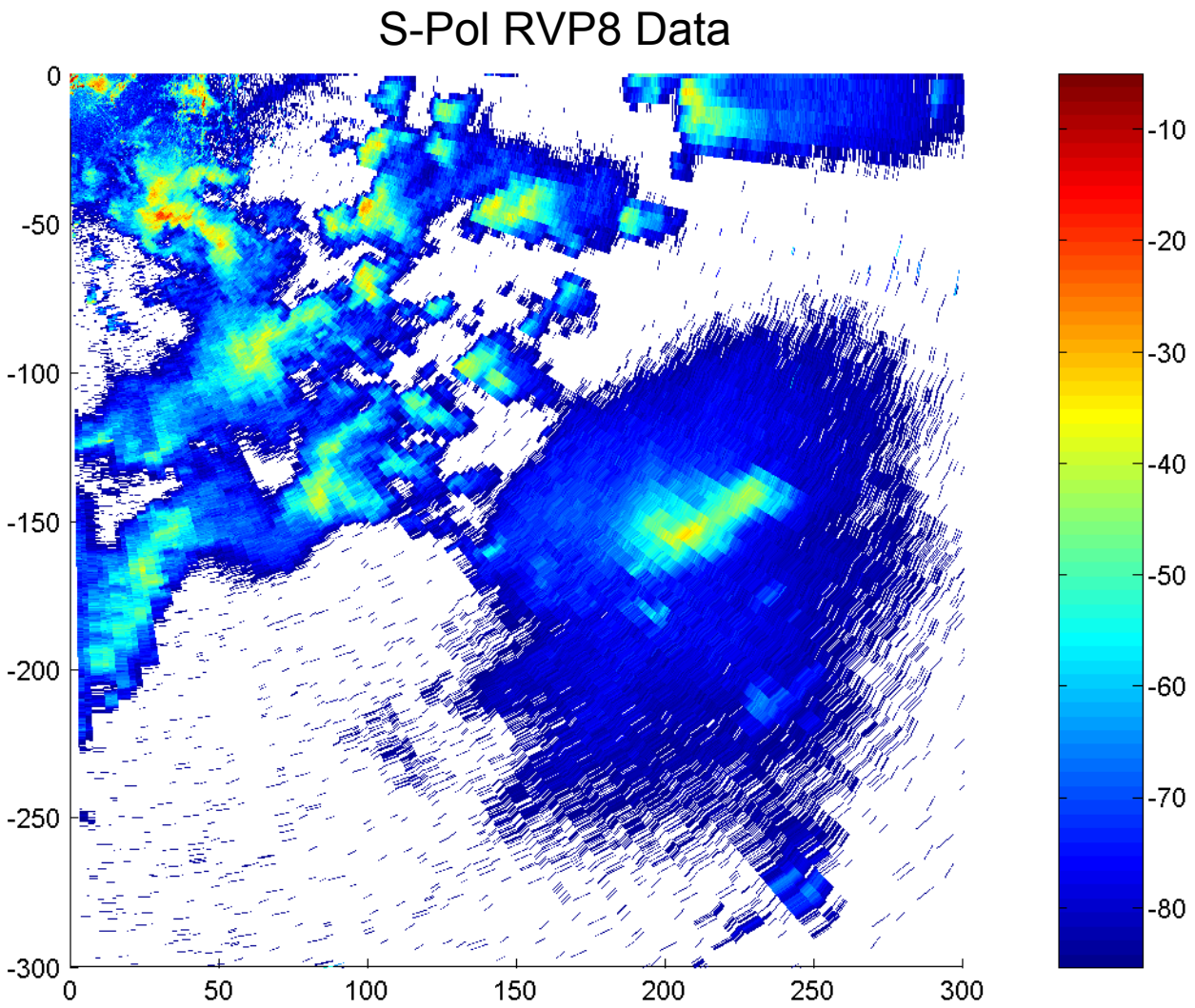


- Clutter filtering first would likely decrease data quality.

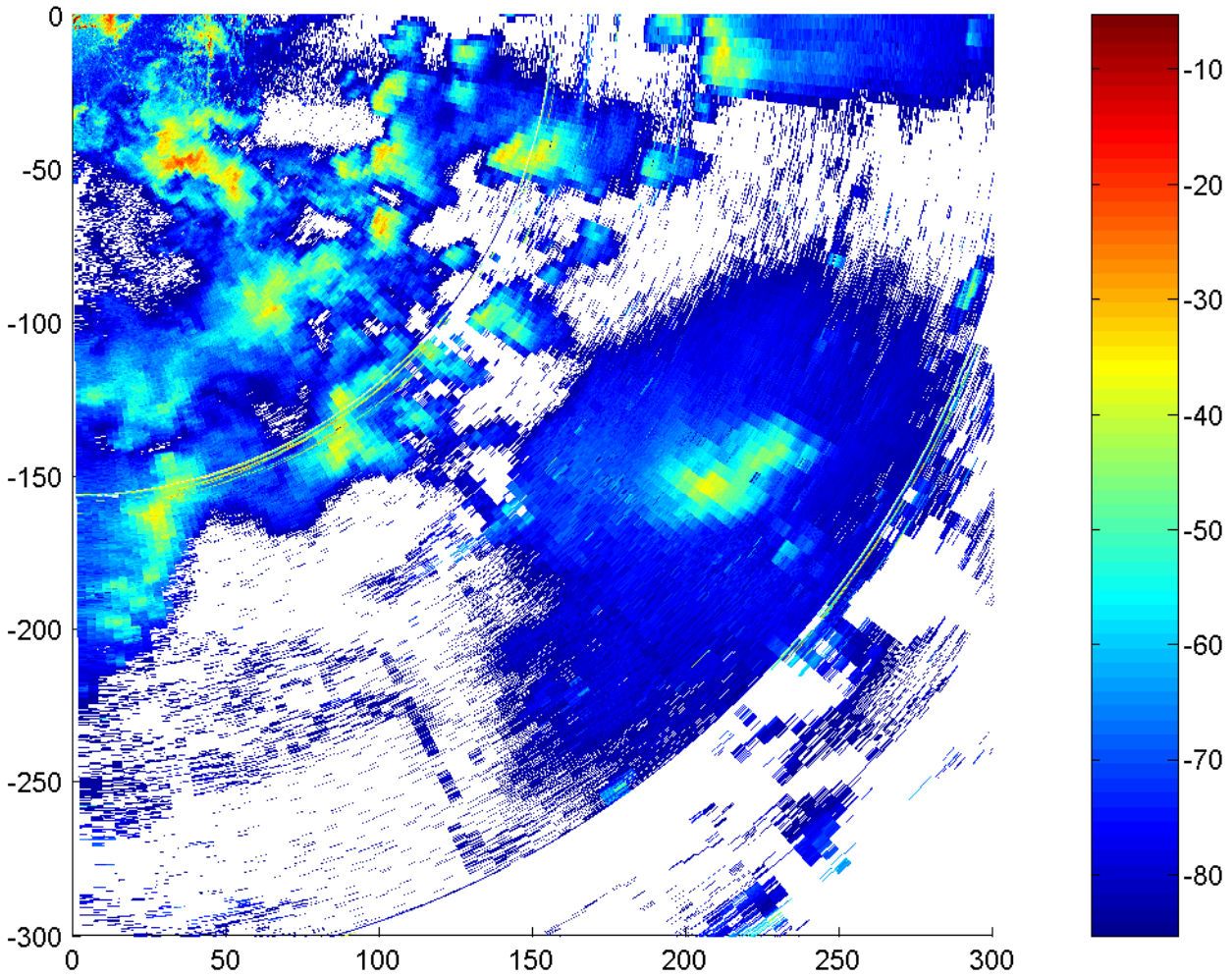
SZ-2: Interim Report and New NCAR Algorithm

- Alternate NCAR SZ-2:
  - First rank the 4 total powers $P_{L(1)}$- $P_{L(4)}$
  - Estimate clutter power and weather power for each trip
- Short PRT Scan:
  - Cohere to the strongest trip and decide what to do next based on power estimates from long PRT
  - Clutter can be in any trip
- Algorithm is programmed in MAT Lab
  - Need to test and then program RVP8 for real time testing on S-Pol

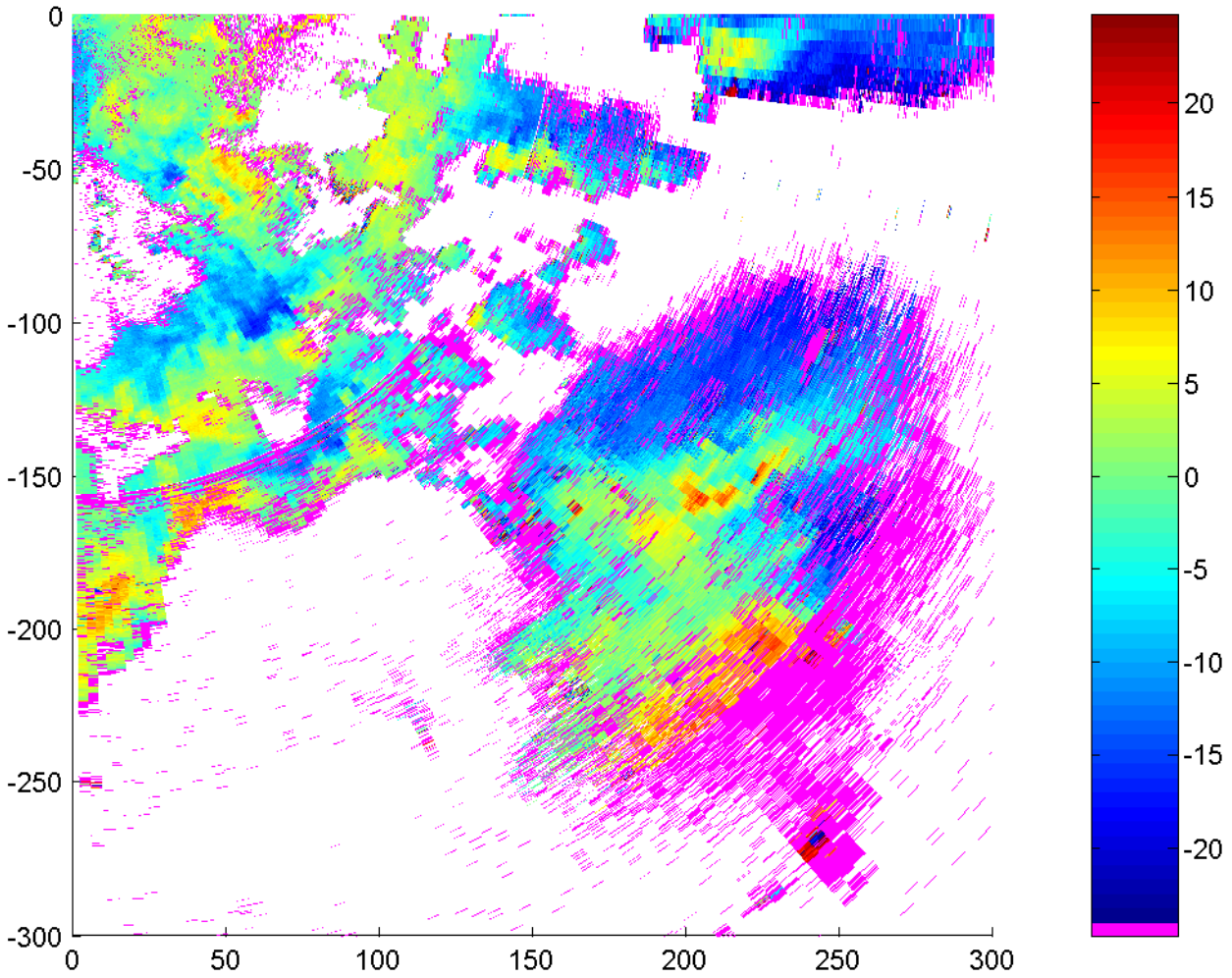
Long PRT power



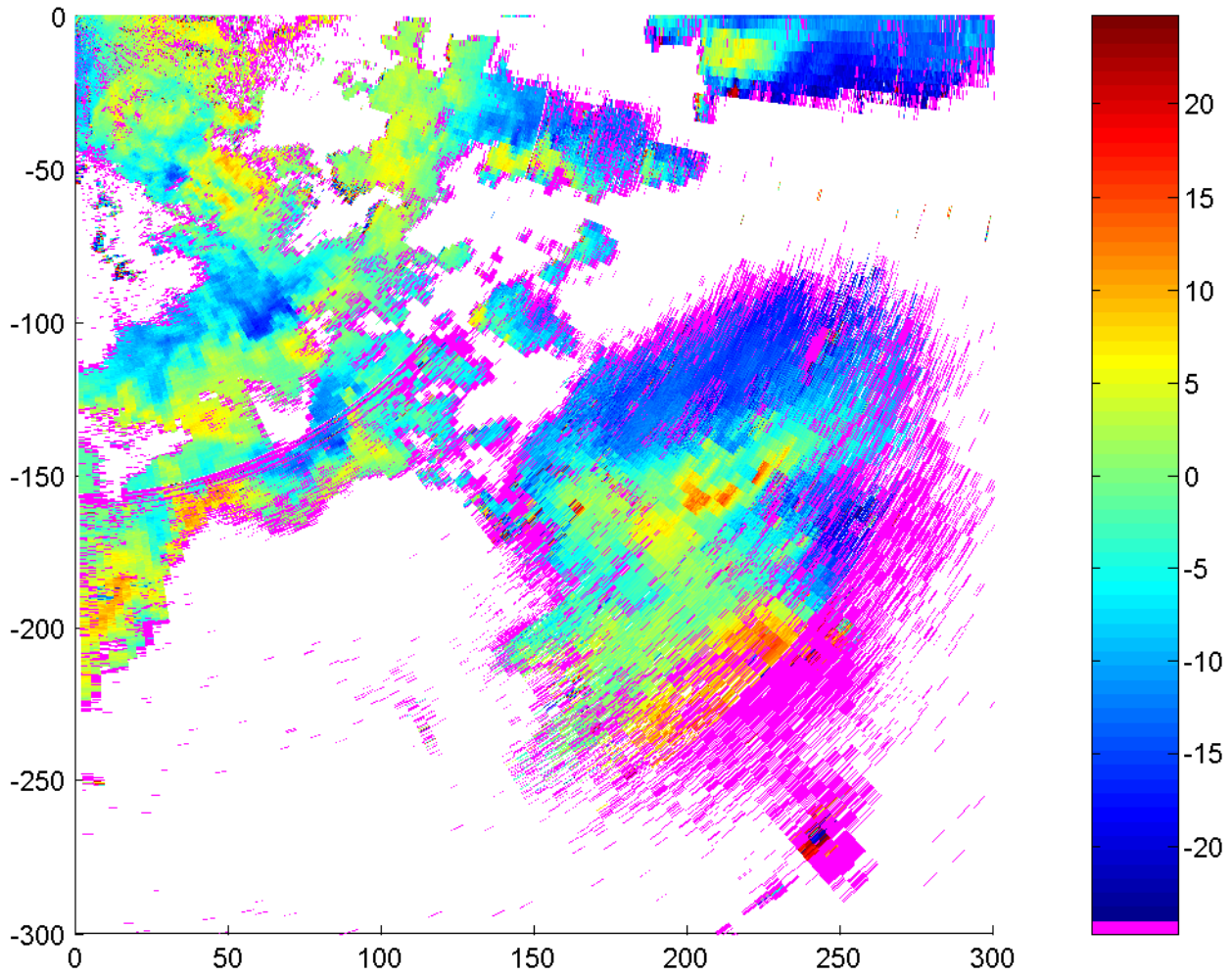
Short PRT power



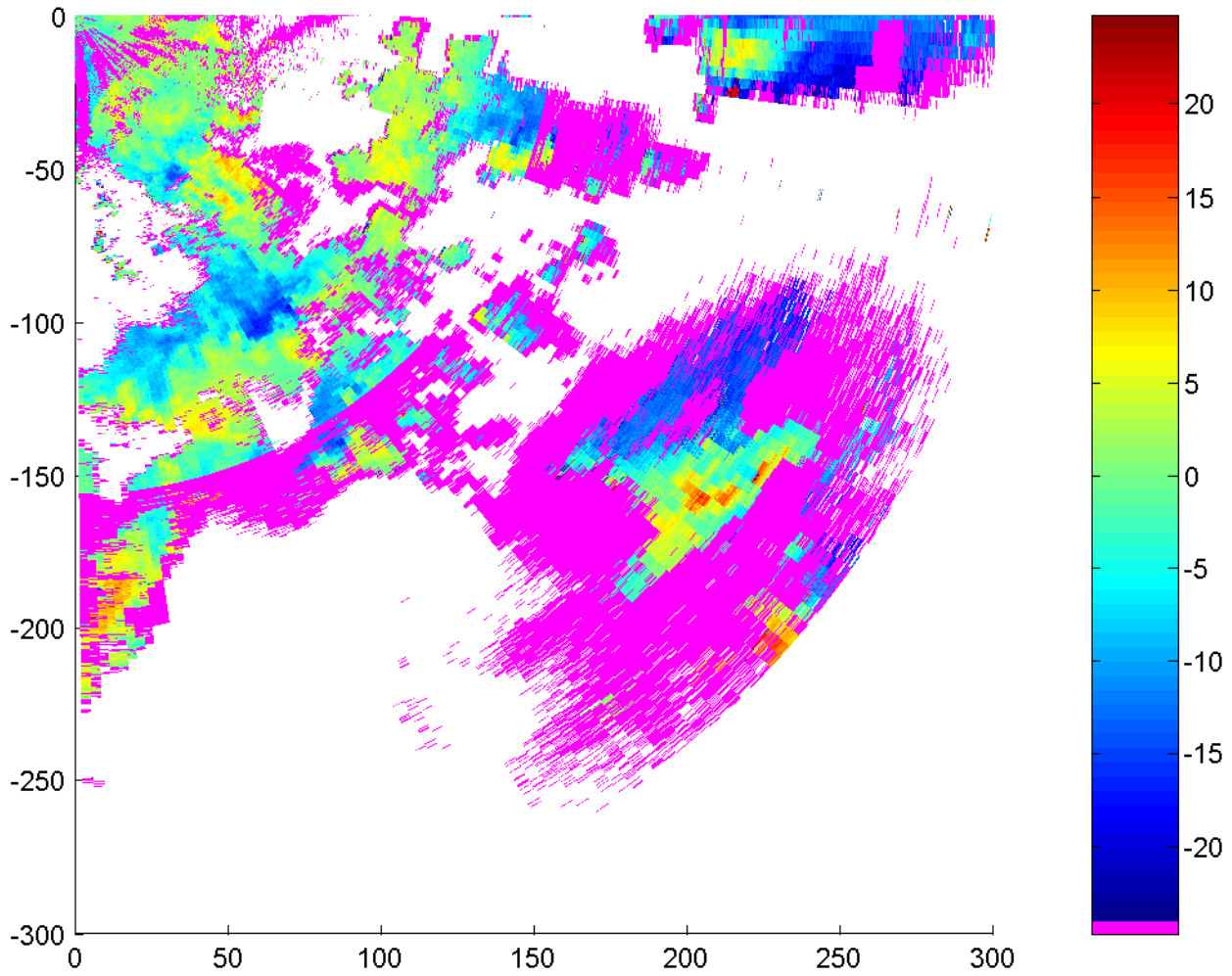
SZ-2 velocity (m s^{-1})



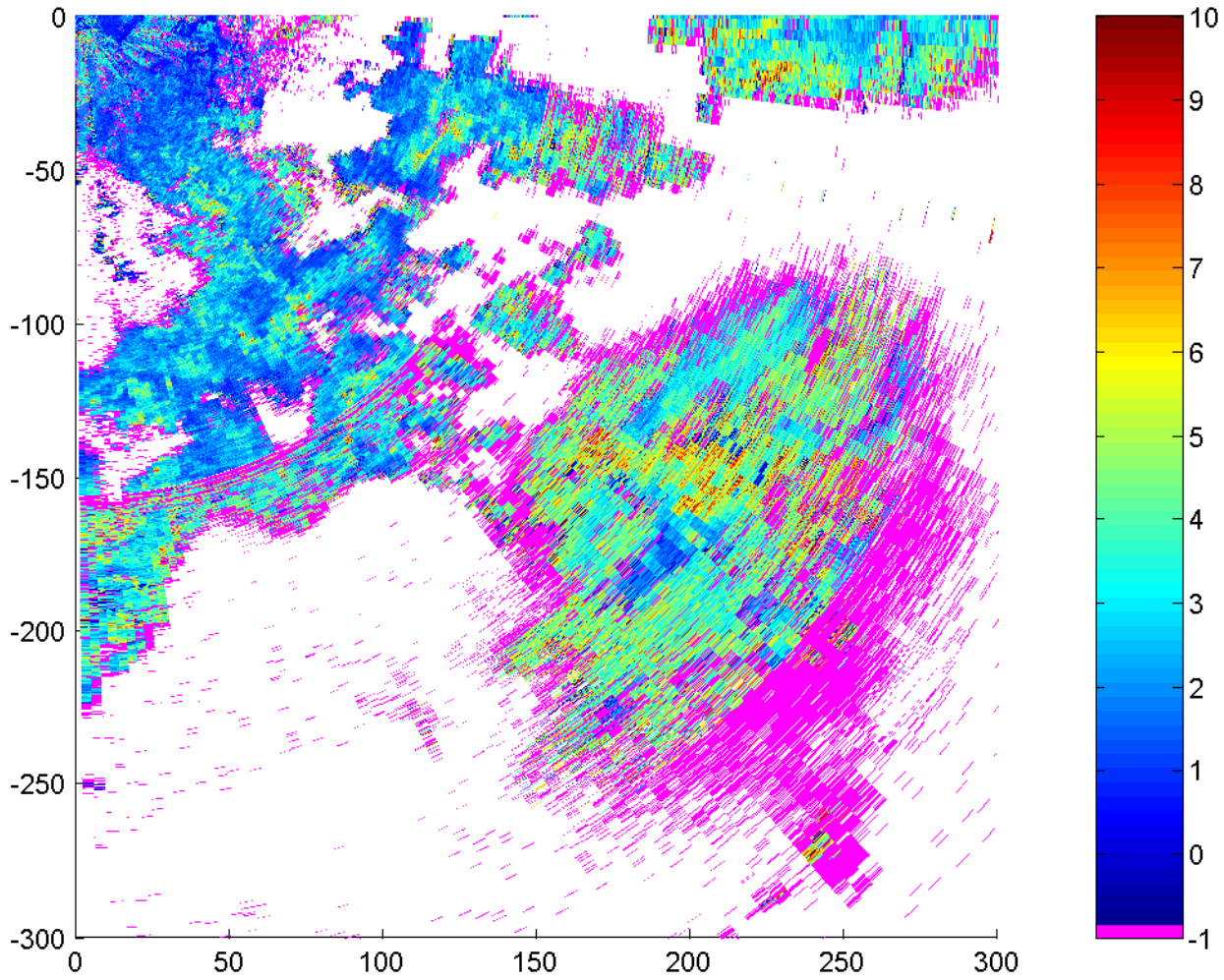
SZ-2 velocity (m s^{-1}) (clutter processing)



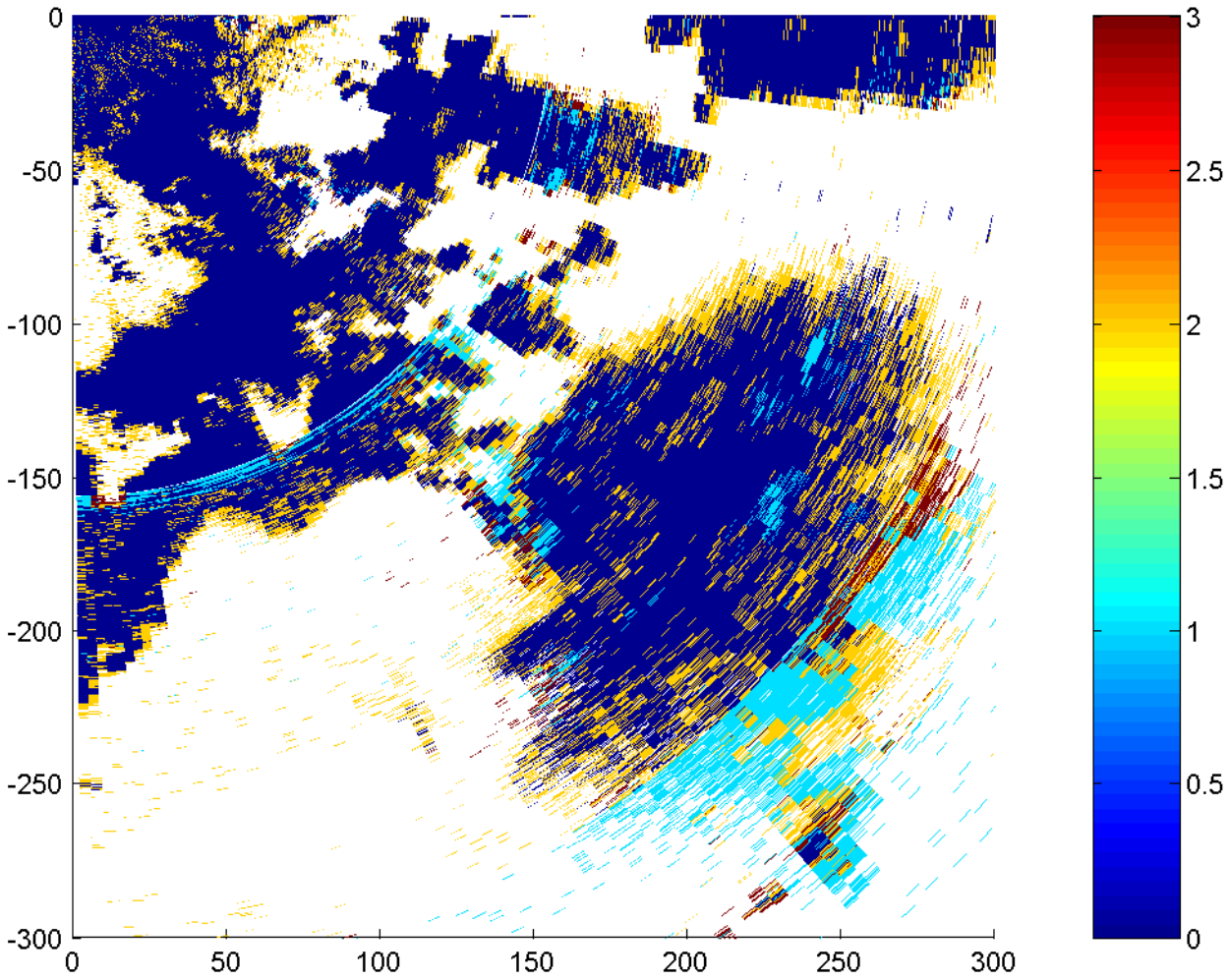
NEXRAD censoring: 5 dB threshold



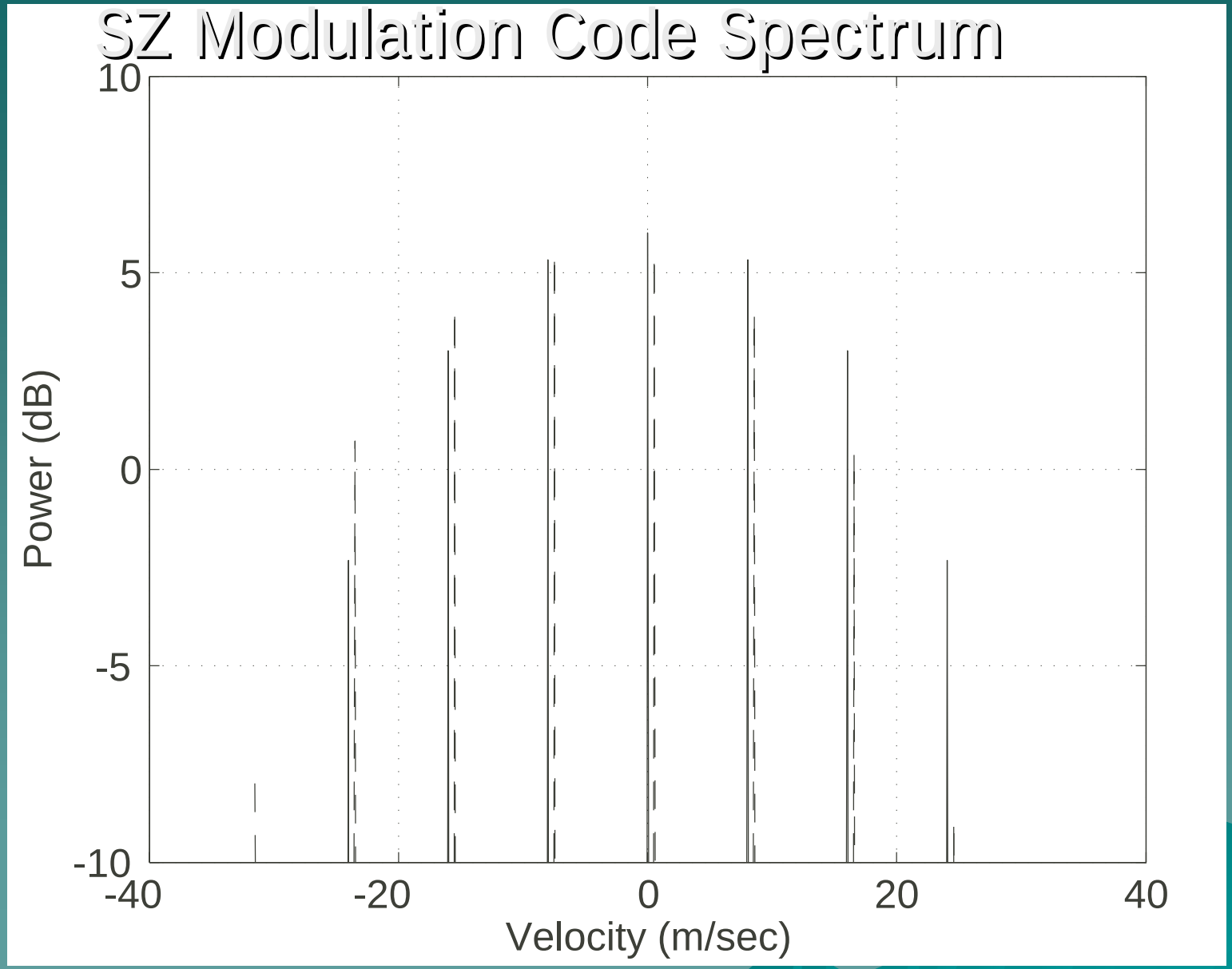
SZ-2 spectrum width (m s^{-1})



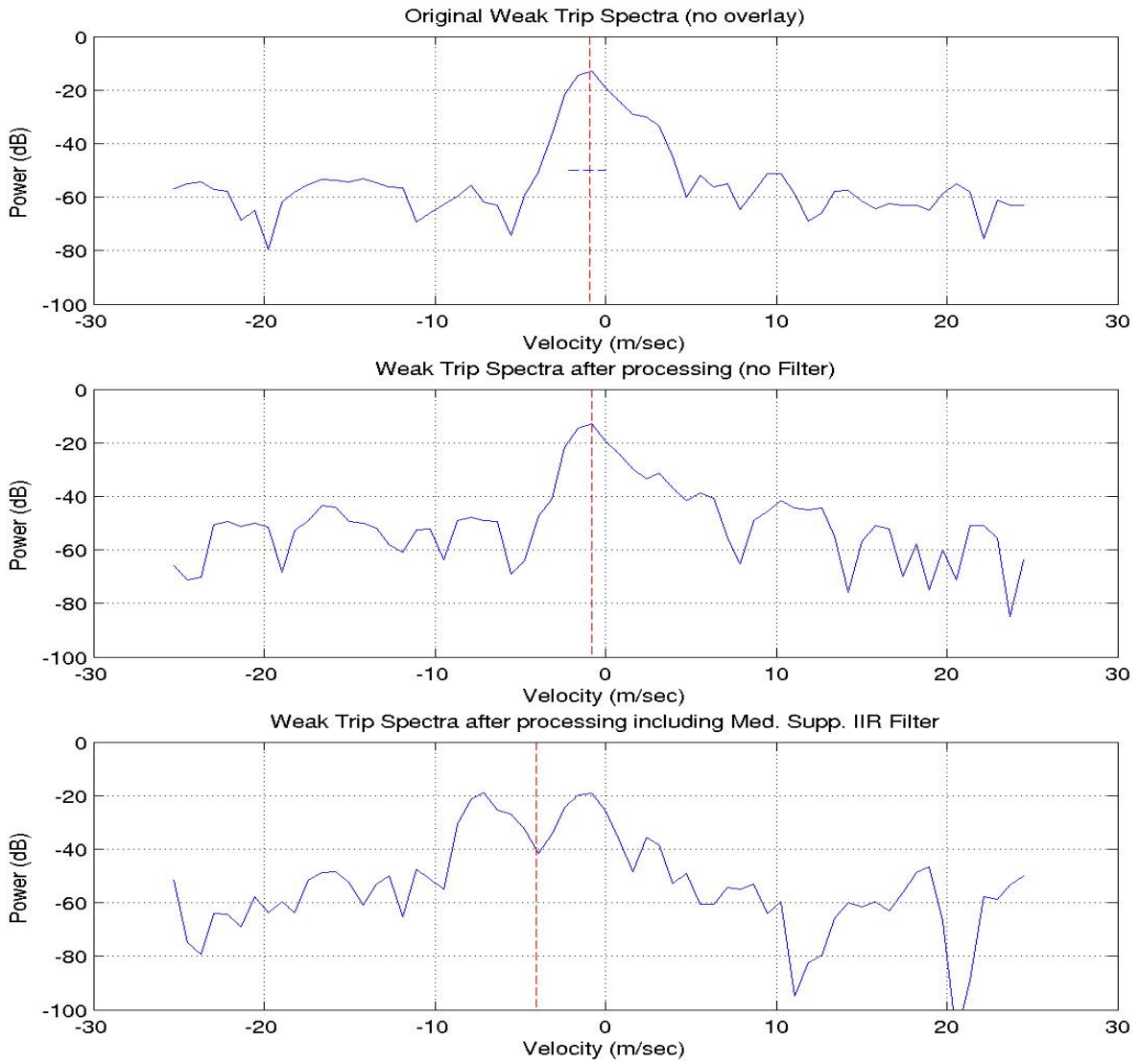
Censoring cause



Effects of IIR Clutter Filter on SZ Modulation Code Spectrum



SZ Phase Coding and IIR Clutter Filter



Summary

- Phase noise problems with RVP8/S-Pol exposed
  - SIGMET will release new TX-card
  - Burst pulse phase should be measured
  - Need more quality data sets!
- SZ-2 algorithm to be delivered 1 June
- SZ-1 needs further development
- NCAR modeled and showed problem with legacy IIR clutter filters.

  Result: GMAP
- Phase noise of S-Pol about 0.42 degrees.

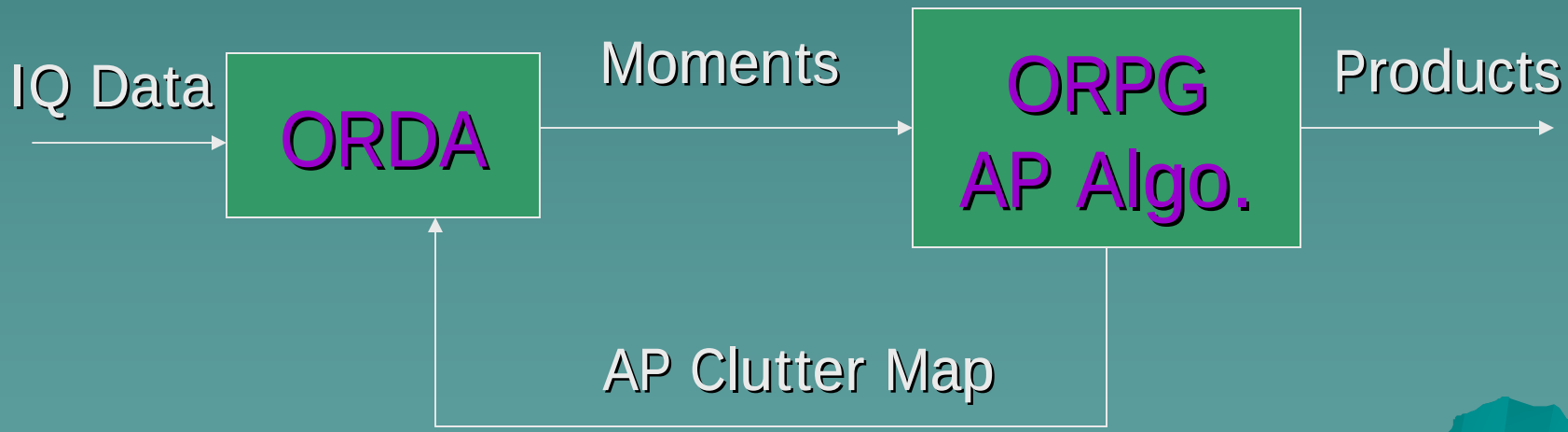
  NEXRAD should be significantly better. Thus, phase coding recovery should improve.

NEXRAD Data Quality Optimization

- REC AP Detection Algorithm
  - Code errors found
  - Algorithm performance improved after correction made
  - Corrections in Build 5
- REC Precipitation Detection Algorithm and Reflectivity Compensation
  - Ready for implementation
  - Will be used in EPRE
- Next REC algorithm
  - Convective/stratiform partition (Steiner et al)
    - Implement in polar space rather than Cartesian space
    - Devise a fuzzy logic version

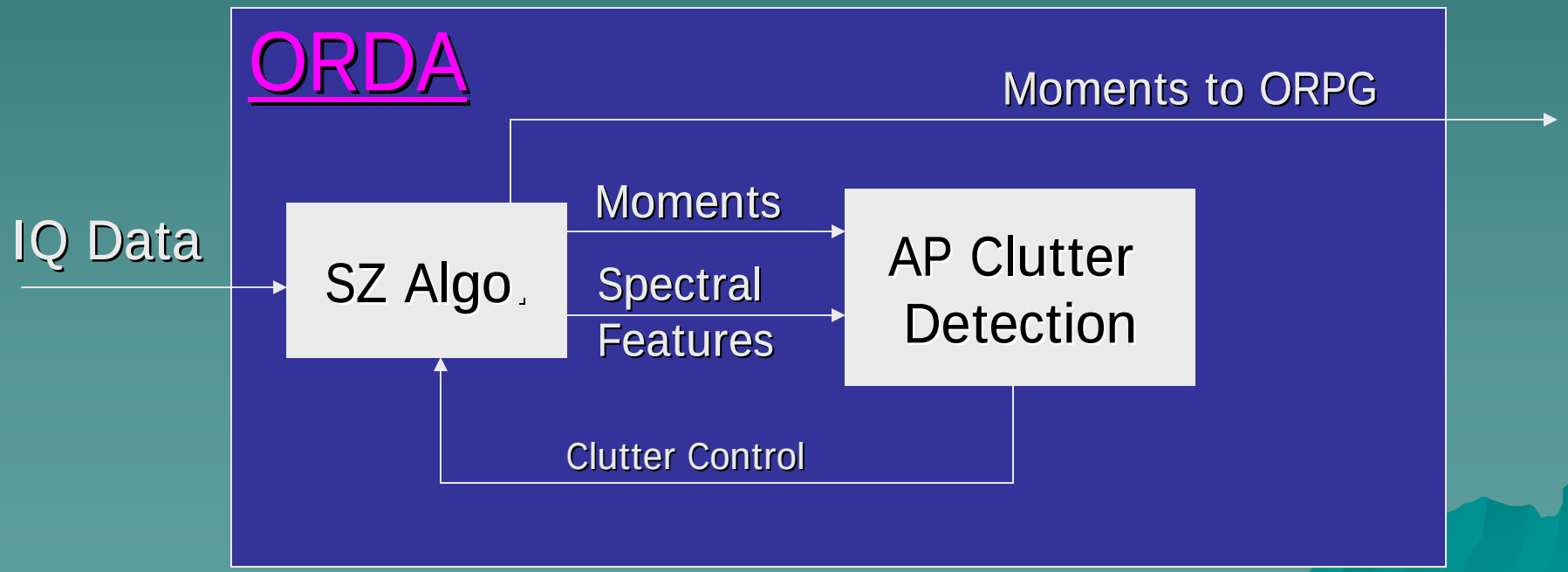
Migration of AP Detection into ORDA

Current System



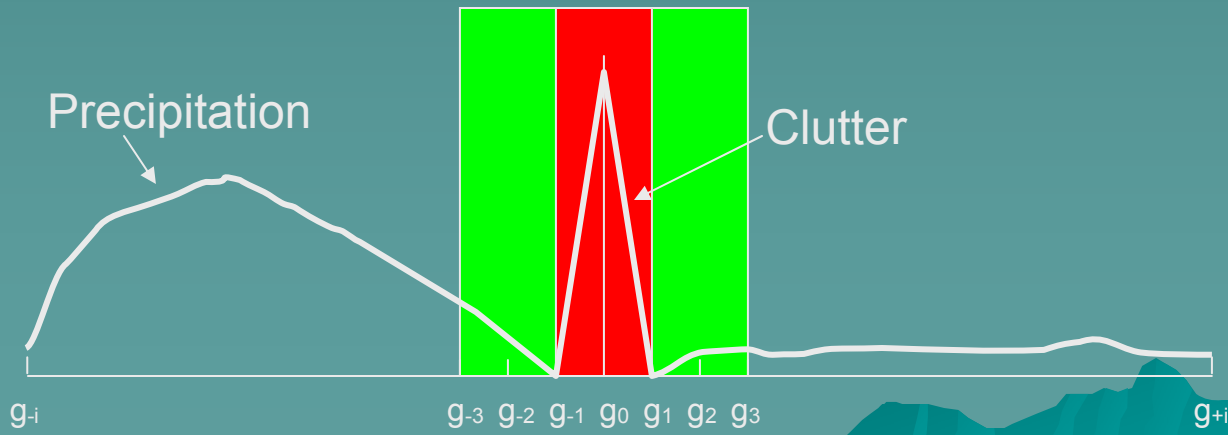
Migration of AP Detection into ORDA

New RVP8 Based RDA



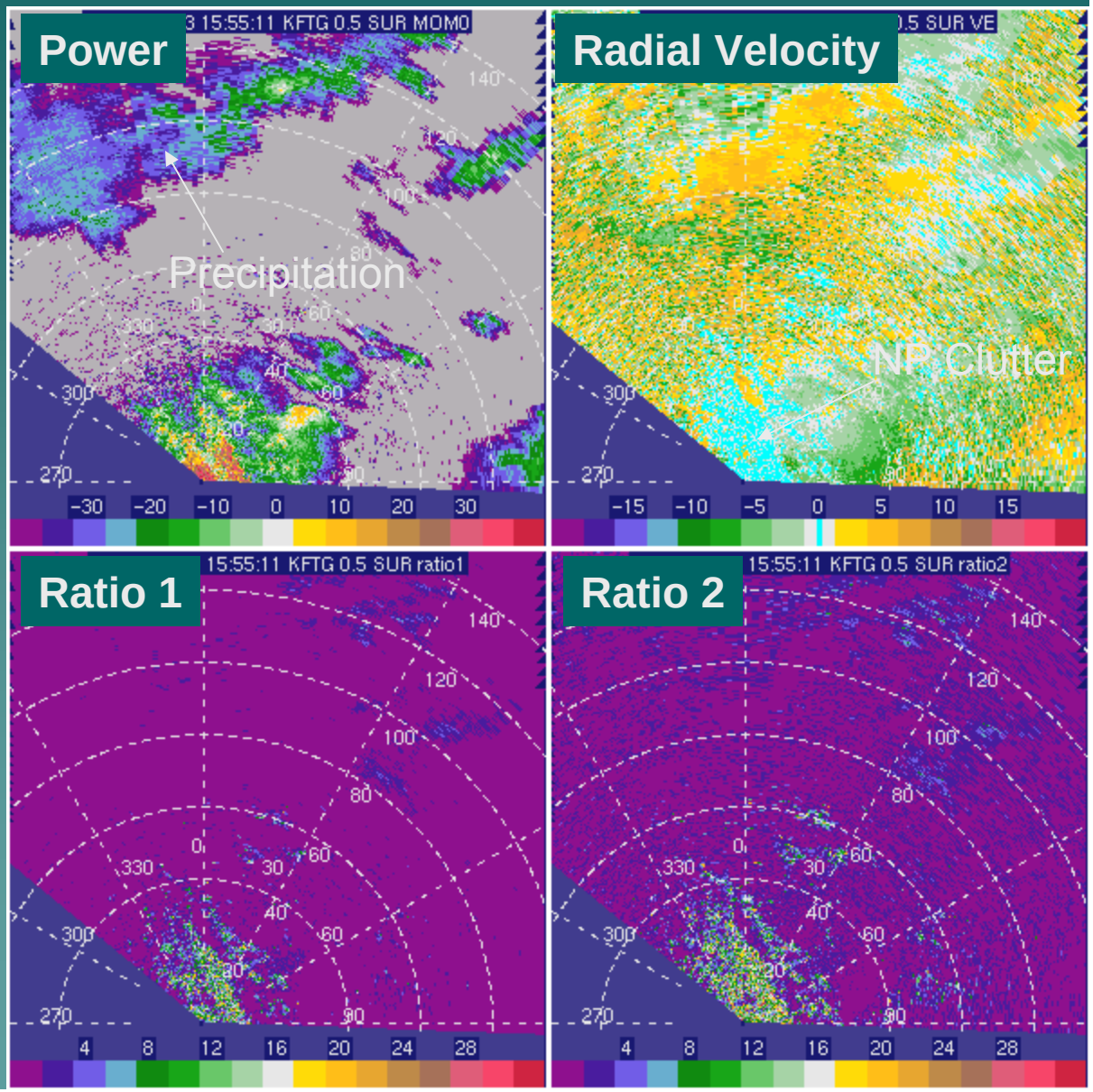
NEXRAD Data Quality Optimization

- Inclusion of ORDA variables into REC
  - Spectral domain variables under test
    - $C_p = \sum g_0 + g_{-1} + g_{+1}$ (i.e., location of possible clutter power)
    - $P_{nz} = \sum g_{-3} + g_{-2} + g_{+2} + g_{+3}$ (power adjacent to clutter power region)
    - P_{tot} = total power (summation of all g_i)
    - Ratio 1 = $C_p/(P_{tot} - C_p)$
    - Ratio 2 = C_p/P_{nz}



NEXRAD Data Quality Optimization

- Example of Ratio 1 and Ratio 2
  - Precipitation has values near zero
  - Clutter has high values



Development Model

- ORPG
  - Develop DQ algorithms
  - Translate to AEL
  - Translate to ORPG platform
- RESULT: ERRORS
- Solution: Install ORPG platform at NCAR and test algorithms

Development Model

- ORDA
  - Develop RV & DQ algorithms on IQ PC
  - Translate to RVP8 (Help from ROC)
  - Test RVP8 algorithm in parallel with IQ PC algorithm
- RESULT: Translations errors eliminated
  - Efficient, save time & $$