# The use of WSR-88D radar data at NCEP

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# Outline

- WSR-88D radar data processing at NCEP
- Radar data quality control (QC)
- Radar reflectivity mosaic
- Radial wind assimilation

# WSR88D-Radar Data Processing at NCEP

# WSR88D-Radar Data Processing at NCEP

- The images from radar observations are successfully used to detect severe weather and warn of thunderstorms.

- The use of high-resolution radar data to improve numerical weather prediction (NWP) is also active in the academic and research communities.

- However, progress in the use of high-resolution Level-II data in operational NWP models has been slower

# WSR88D-Radar Data Processing at NCEP

Problems of using radar data in operation:

- (1) the relatively large volume of radar data restricting the data to be transmitted to the operational center in real time
- (2) the radar data decoding software and storage taking excessive computational resources
- (3) the quality control (QC) problems of radar data further limiting the applications of radar data for operational use

# WSR88D-Radar Data Processing at NCEP

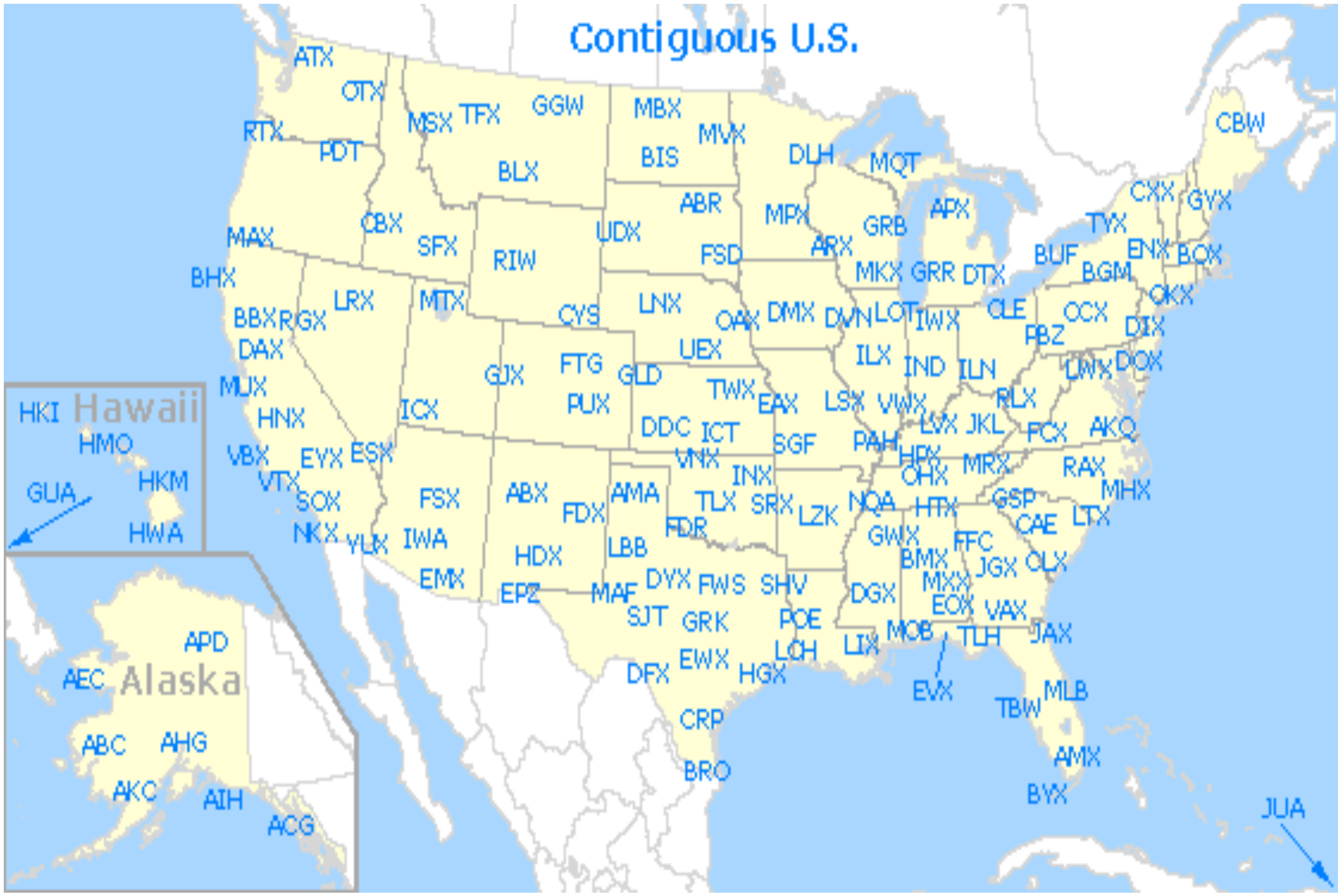


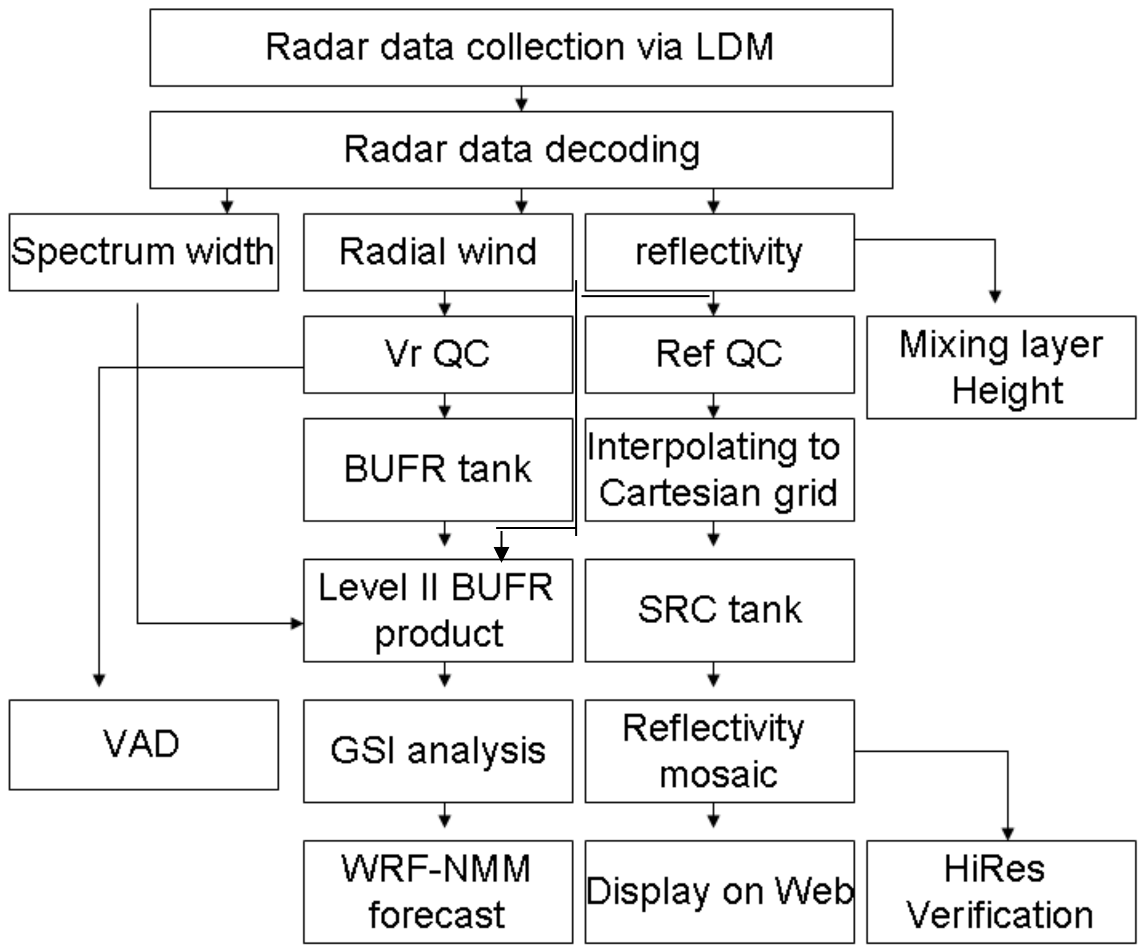

Figure from http://www.rap.ucar.edu/weather/radar/

# WSR88D-Radar Data Processing at NCEP

Radar data received at NCEP:

(1). VAD wind (velocity azimuth display)
(2). WSR88D Level-III (NIDS) data
(3). WSR88D Level 2.5 data
(4). WSR88D Level-II data

# WSR88D-Radar Data Processing at NCEP



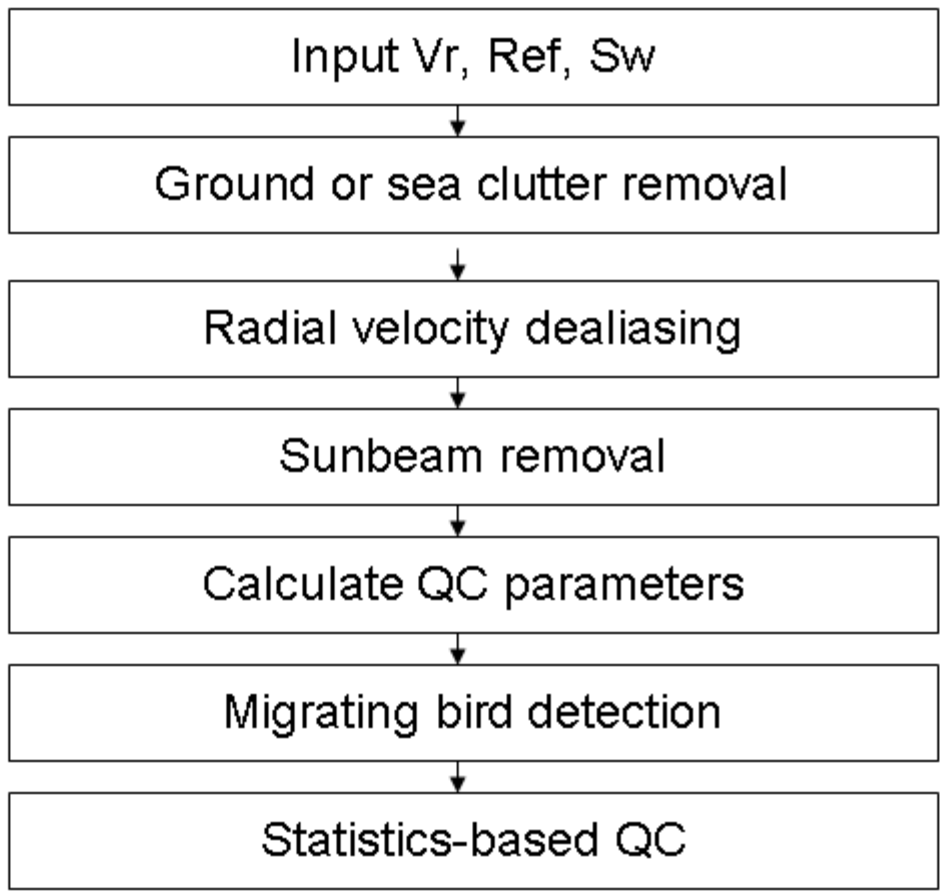

**Flowchart of radar data processing at NCEP**

# Radar data quality control

# Radar data QC at NCEP

- To meet the high standard required by data assimilation, it is necessary to develop simple and efficient QC technique for operational applications.
- Radar data quality control is a necessary and initial step for operational applications of radar data.
- Develop statistically reliable QC techniques for automated detection of QC problems in operational environments
- Among various of radar data quality problems, radar measured velocities can be very different (≥10 m/s) from the air velocities in the presence of migrating birds.

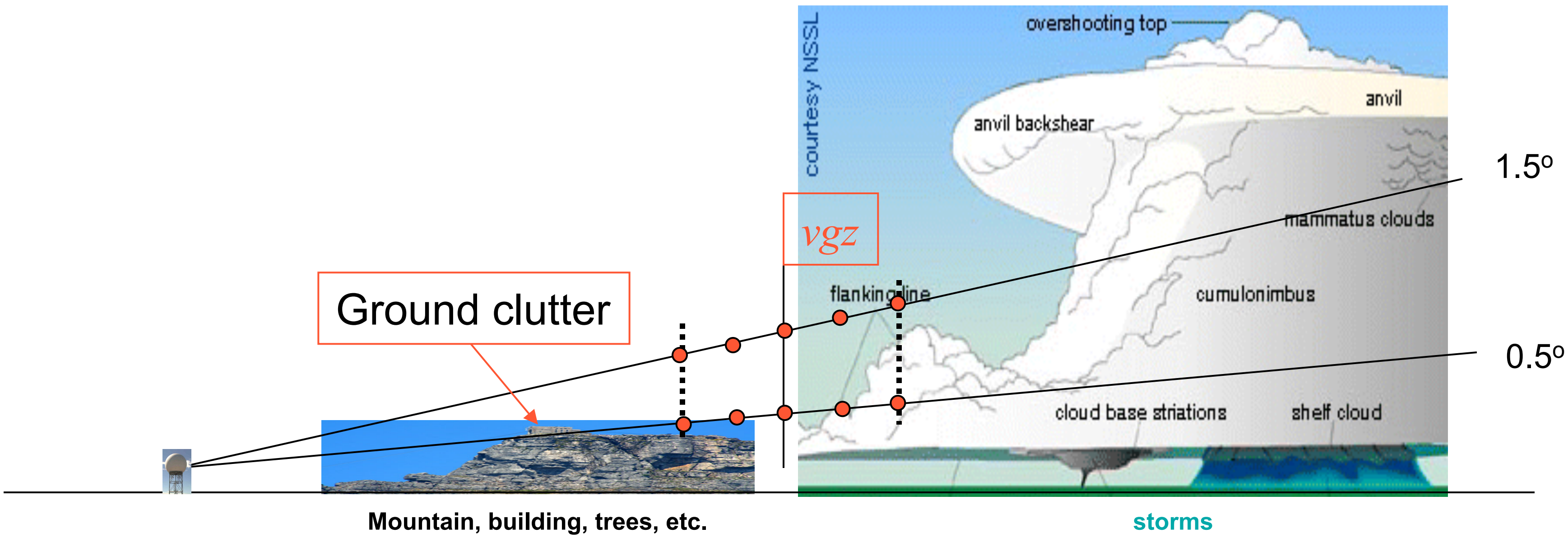
# Radar data QC at NCEP



# Clutter removal

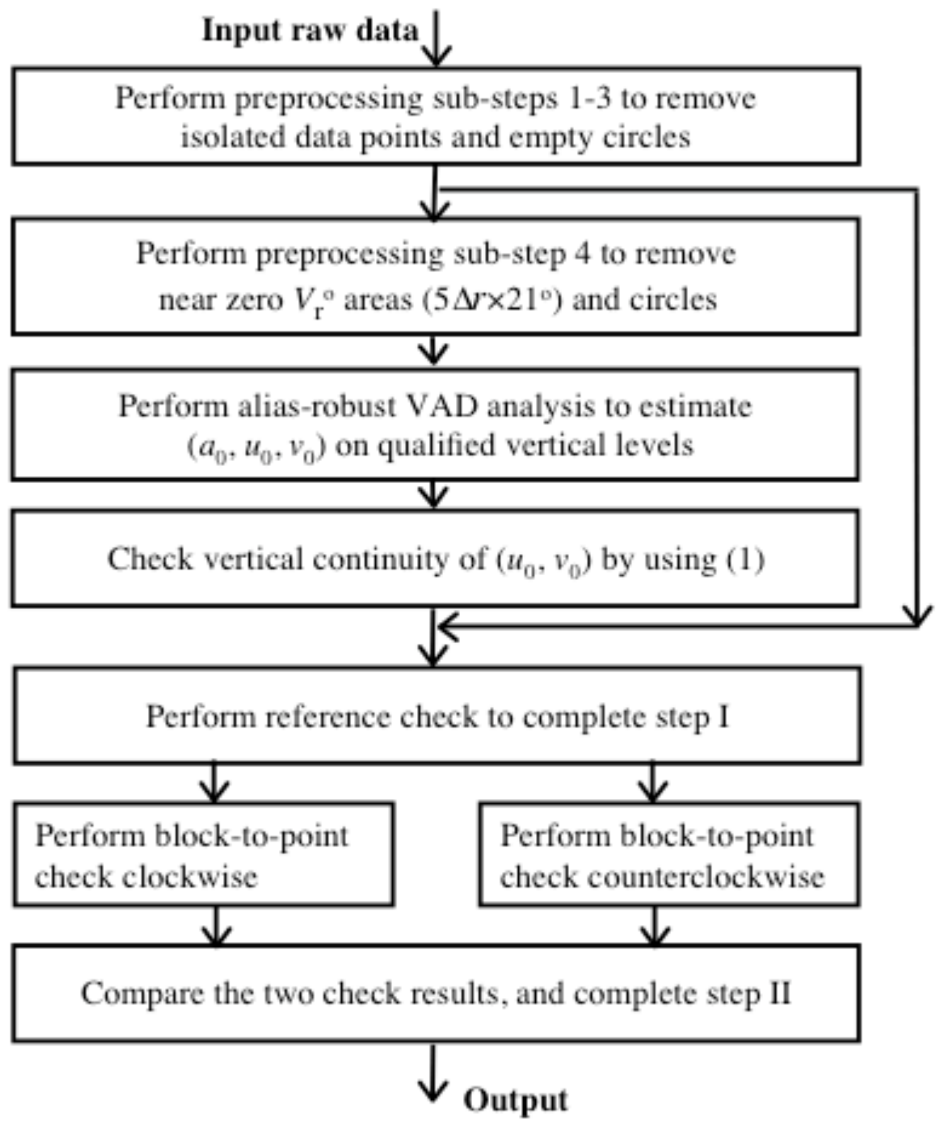
3 parameters are selected:

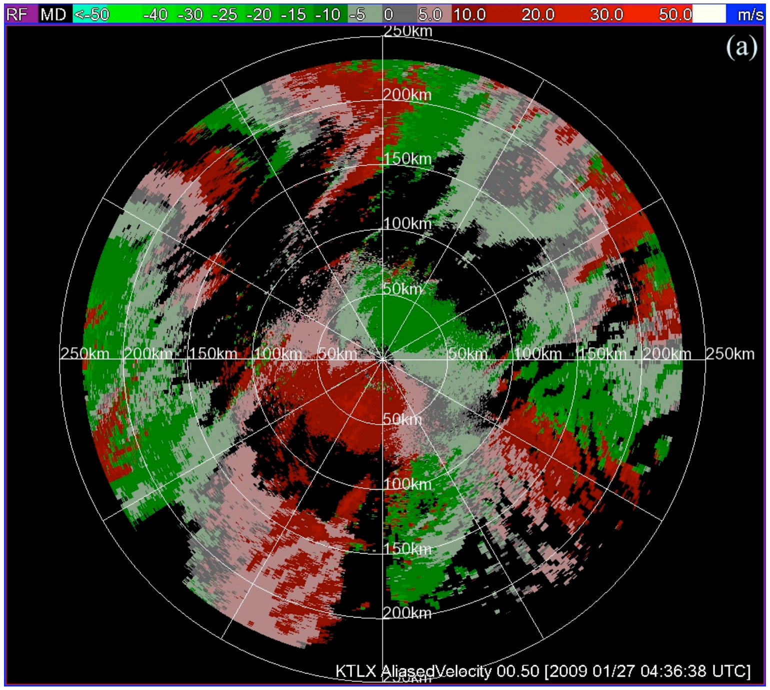
- *Vertical gradient of reflectivity (vgz) at lowest two tilts*
- *Averaged vgz over a specified area*
- *Doppler velocity at 0.5$^o$ elevation angle*

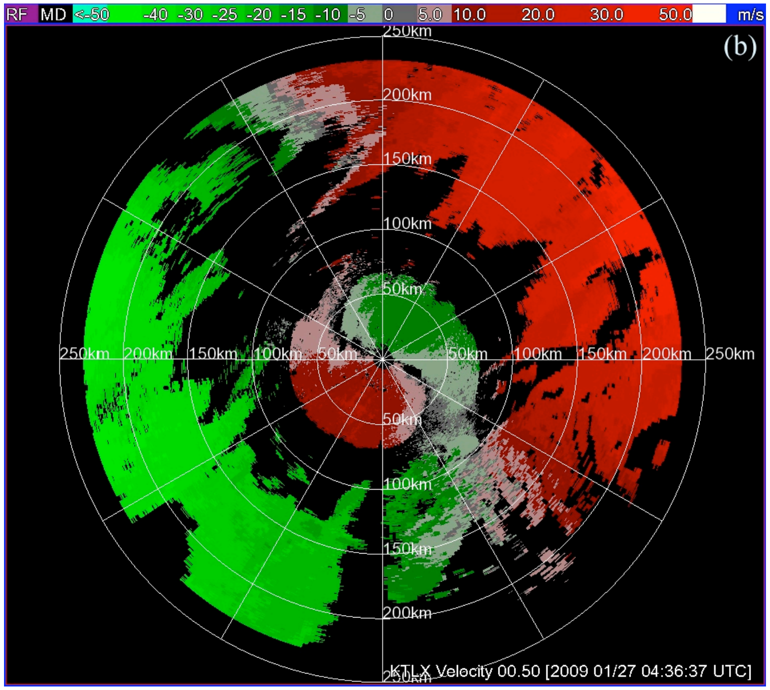



If 2 of 3 parameters are over the thresholds, then the gate at 0.5$^o$ elve. angle is marked as ground/sea clutter.

# Radial wind dealiasing






Raw radial-velocity from KTLX with VCP 31 and Nyquist velocity = 11.5 m/s

Dealiased radial-velocity

# QC Parameters

Mean reflectivity (MRF)

$$MRF = \sum ref(n) / N_{ref}$$

Velocity data coverage (VDC)

$$VDC = N_{vr} / N_{\max}$$

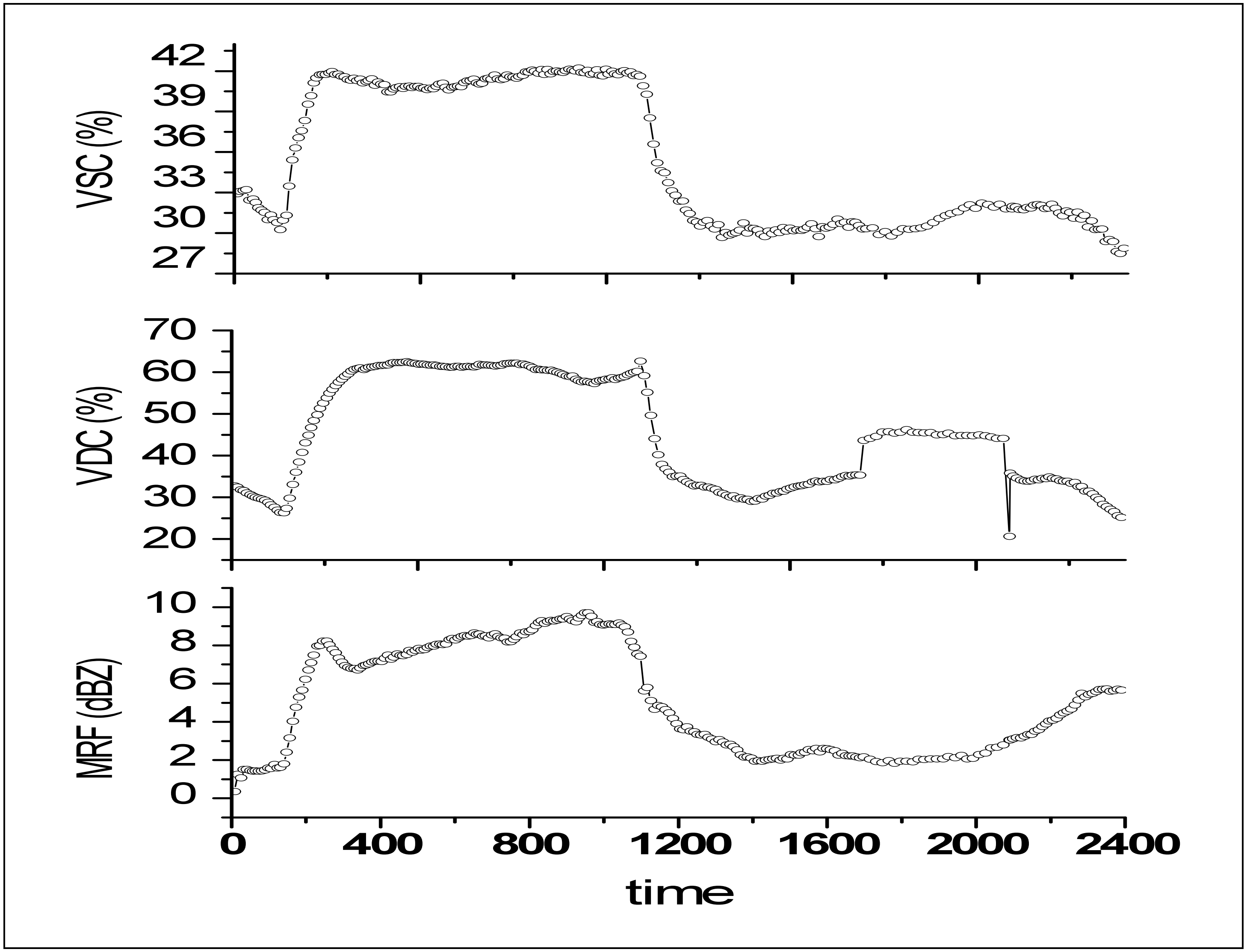
Along-beam perturbation velocity sign changes (VSC)

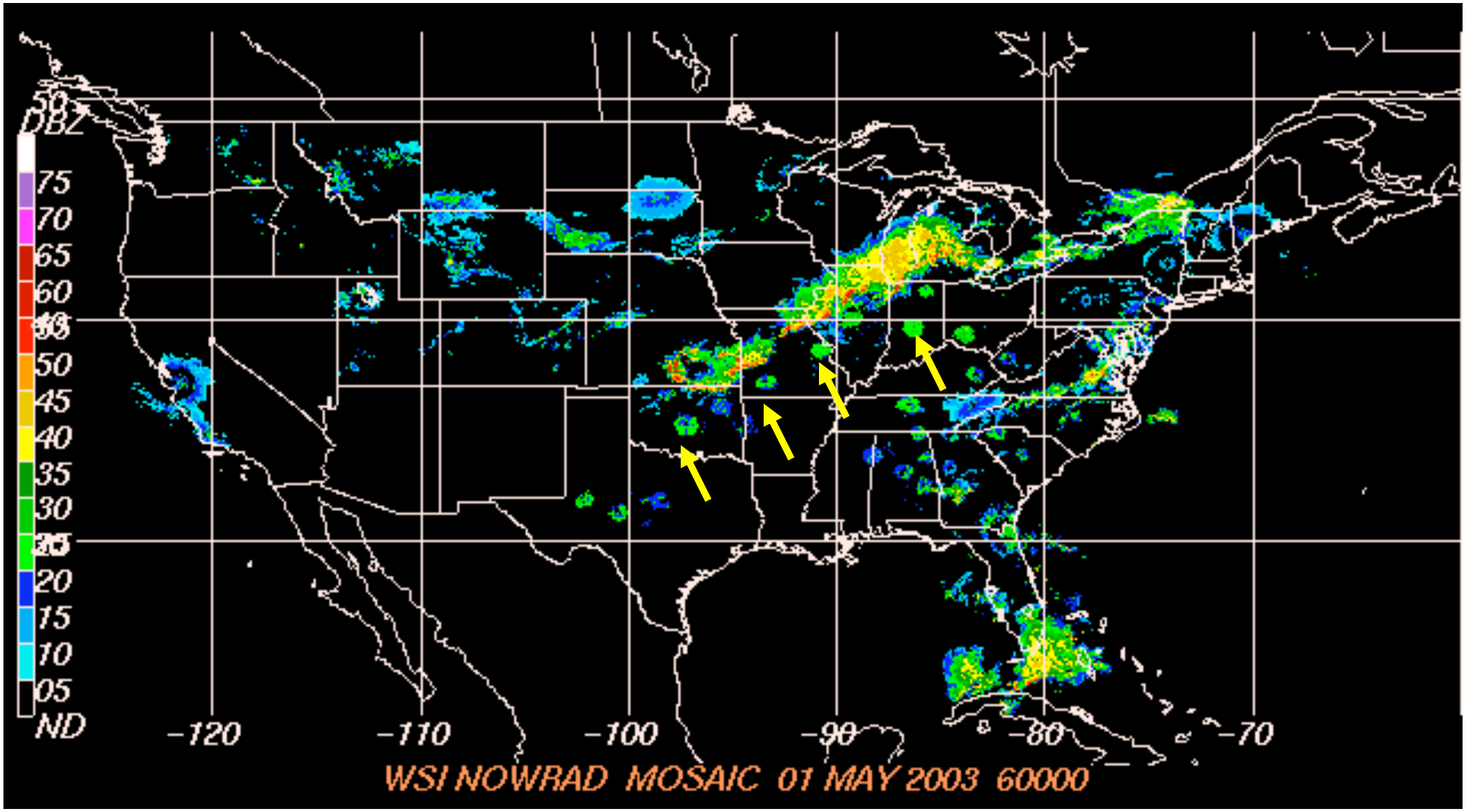
$$VSC = [\sum I_{psc}(j) / I_{vr}(j)] / J_{bm}$$

Along-beam velocity sign changes(SC)

Standard deviation of radial wind (STD)

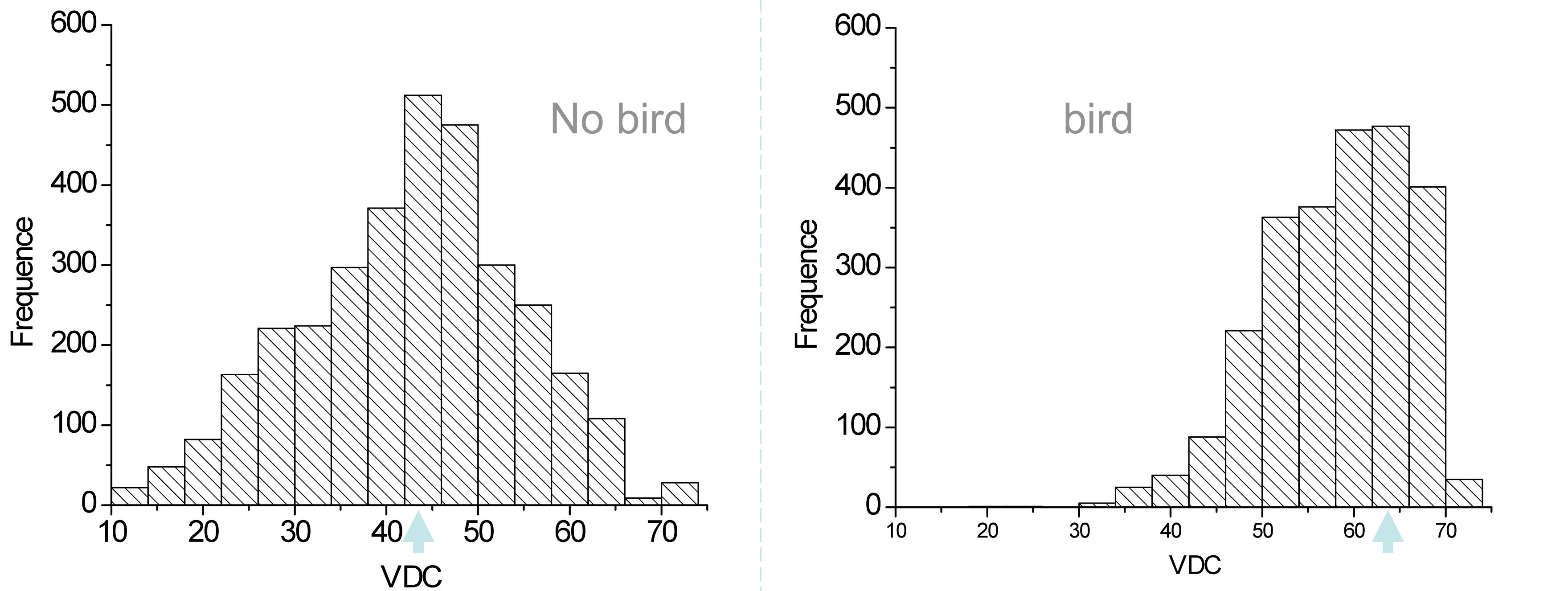
# Recorded QC parameters






Migrating Bird Contamination reflectivity Mosaic

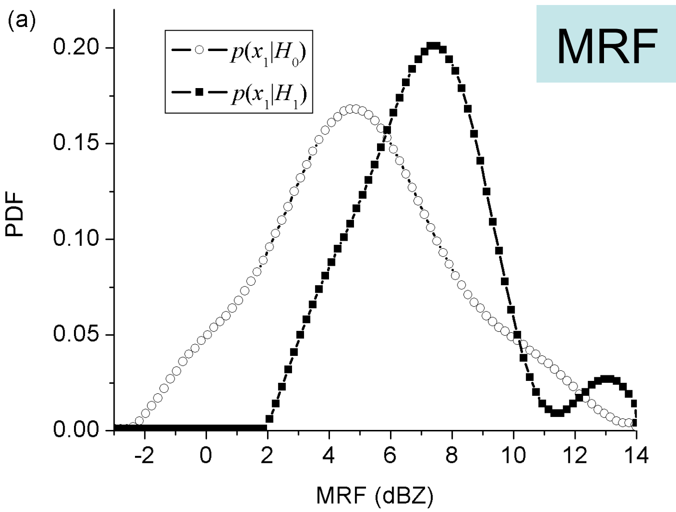
# Velocity Data Coverage

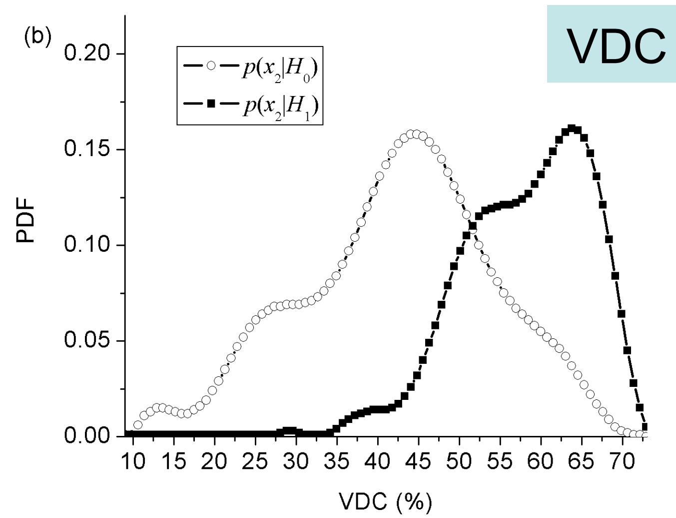


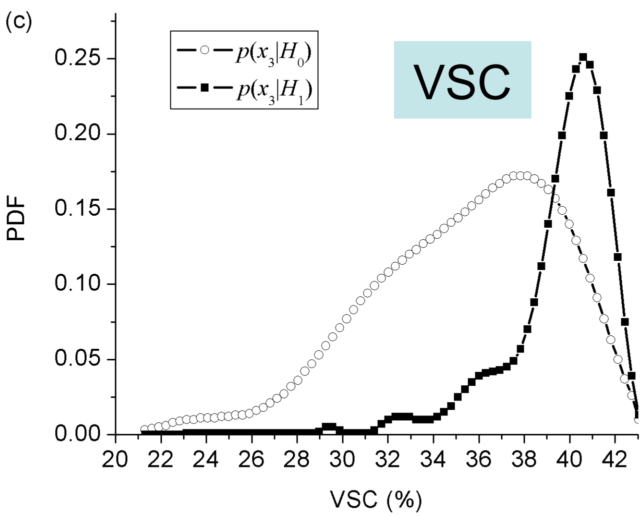

Histogram of VDC for (a) non-contaminated and (b) bird-contaminated sweeps.

KTLX (From April 15 to June 15 2003) night Observation

# Probability Density Function




**Prior probability density functions of MRF (a), VDC (b) and VSC (c).**

# Bayes Identification

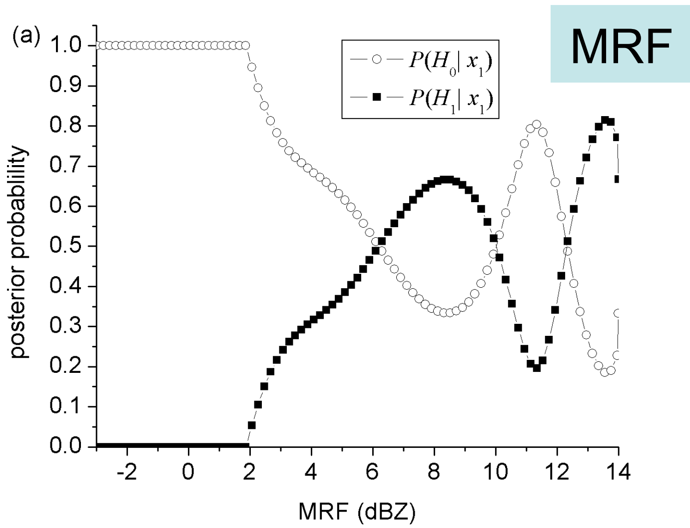
Denote the weather event by $H_0$.
Denote the bird event by $H_1$.

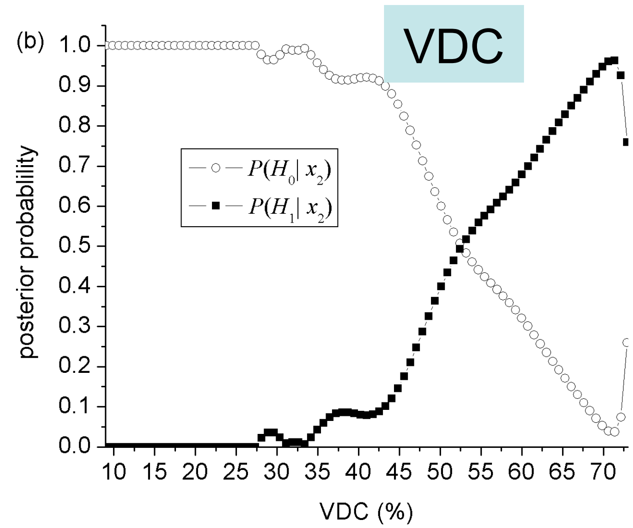
Denote the i-th QC parameter by $X_{i.}$

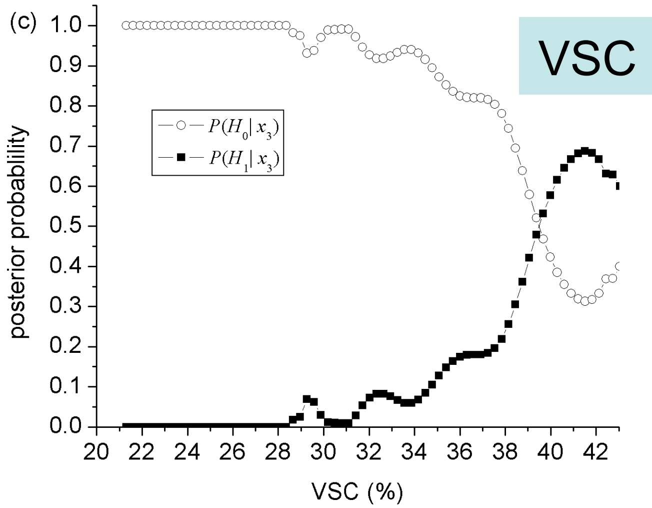
$$P(H_0 \,|x_i) = p(x_i \,|H_0)P(H_0)/p(x_i),$$
$$P(H_1 \,|x_i) = p(x_i \,|H_1)P(H_1)/p(x_i).$$
$$p(x_i)= p(x_i \,|H_0)P(H_0)+p(x_i \,|H1)P(H1)$$

$$P(H_0)=N_0/(N_0+N_1)$$
$$P(H_1)=N_1/(N_0+N_1)$$

# Posterior Probability

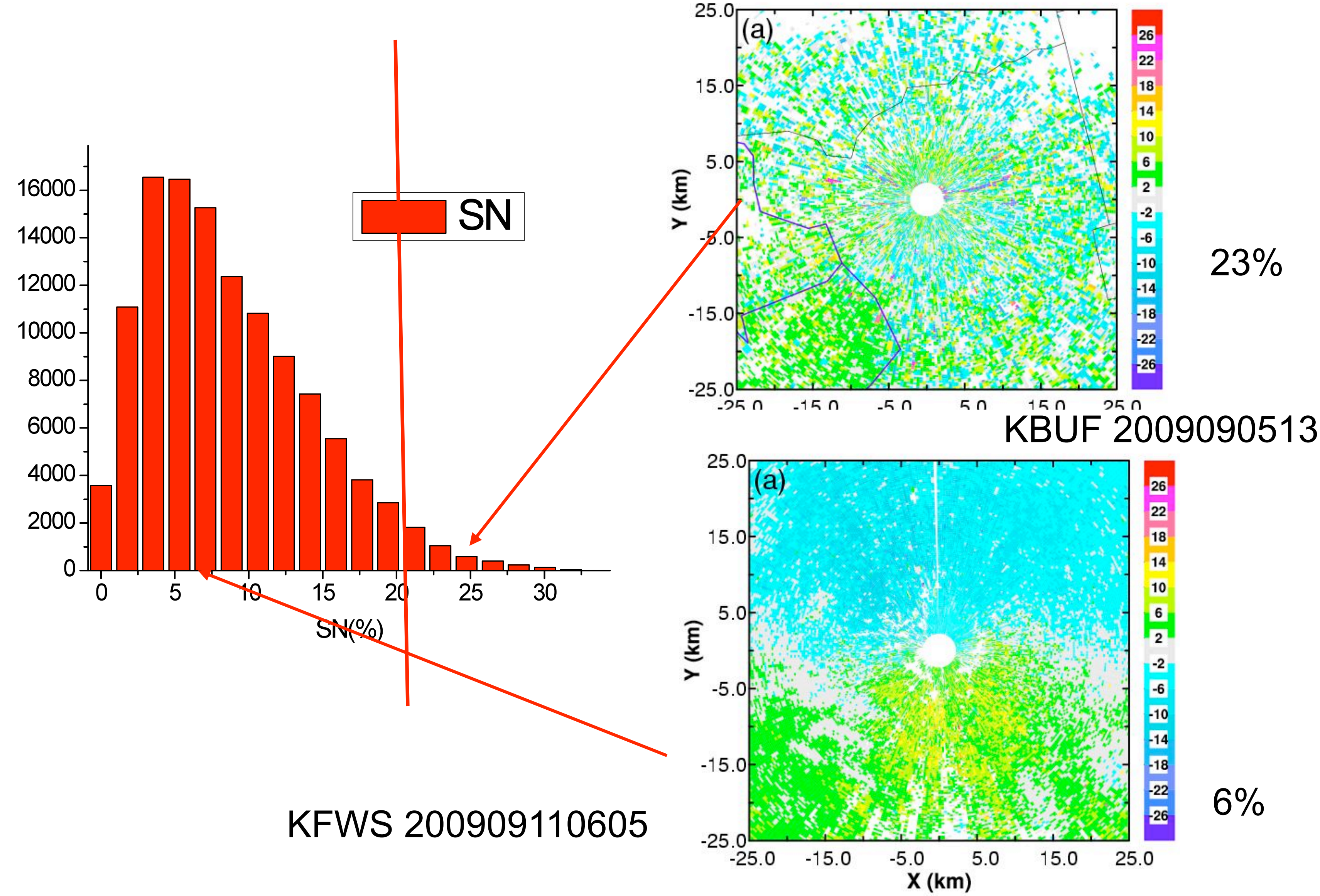


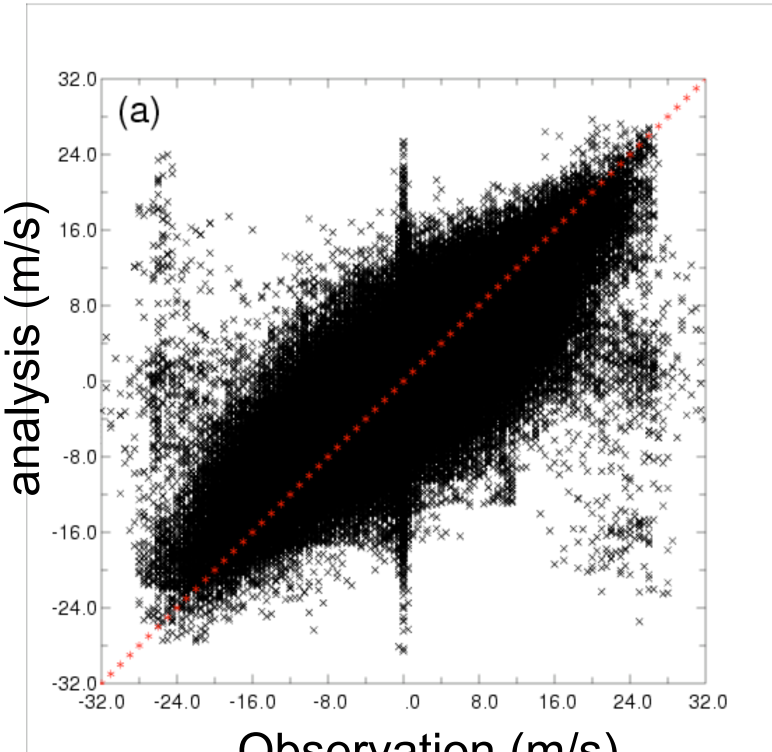




Posterior probability distributions of MRF (a), VDC (b) and VSC (c)

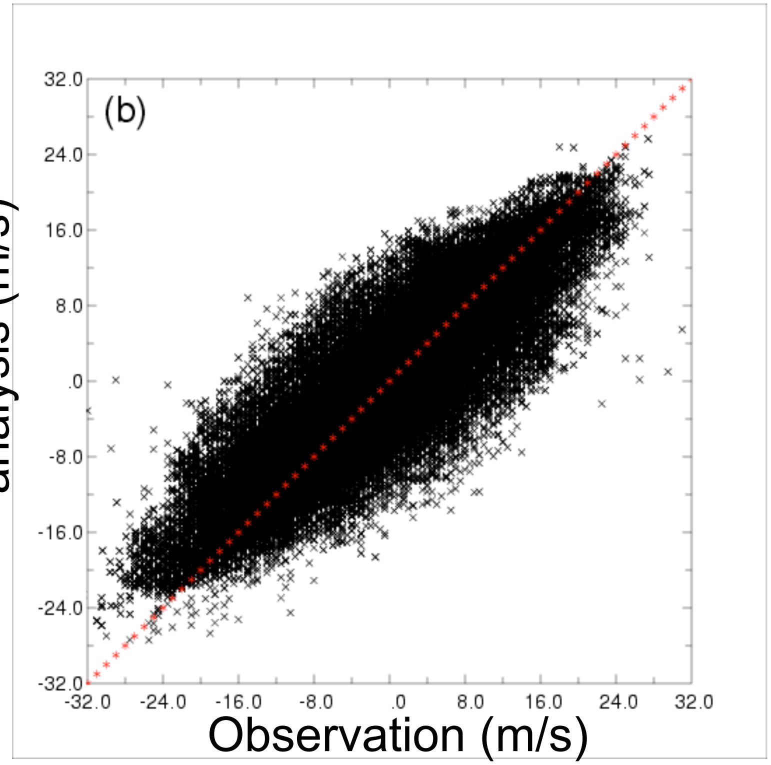
# Statistics-based QC



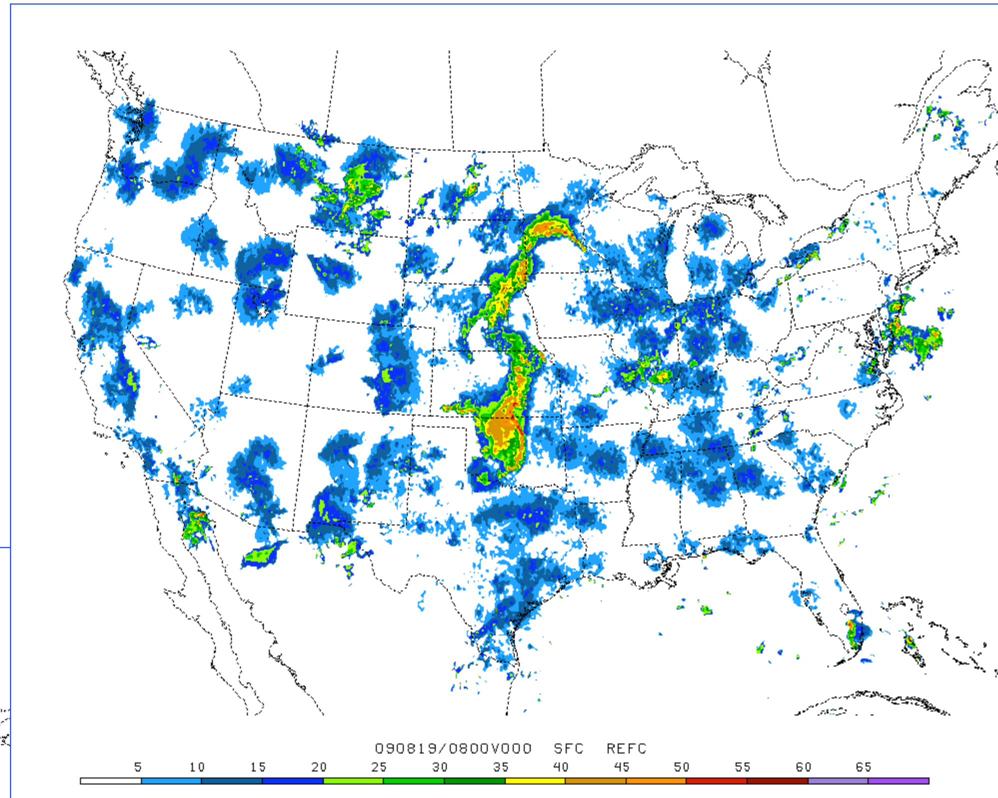
# Performance of radar data QC

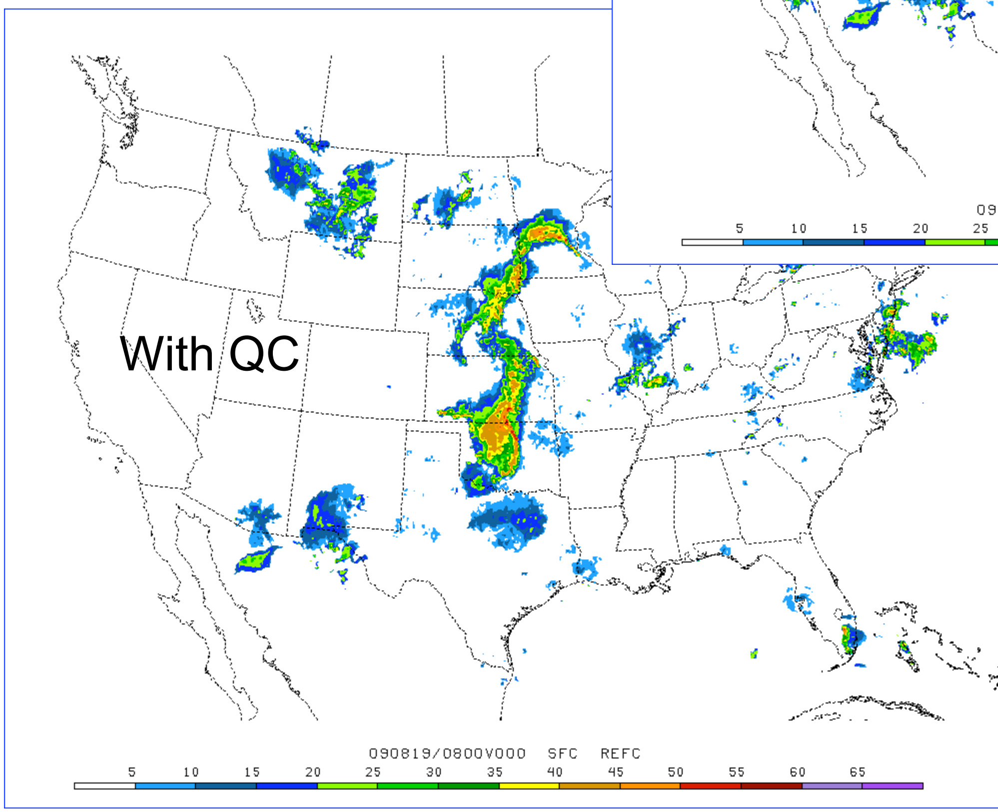


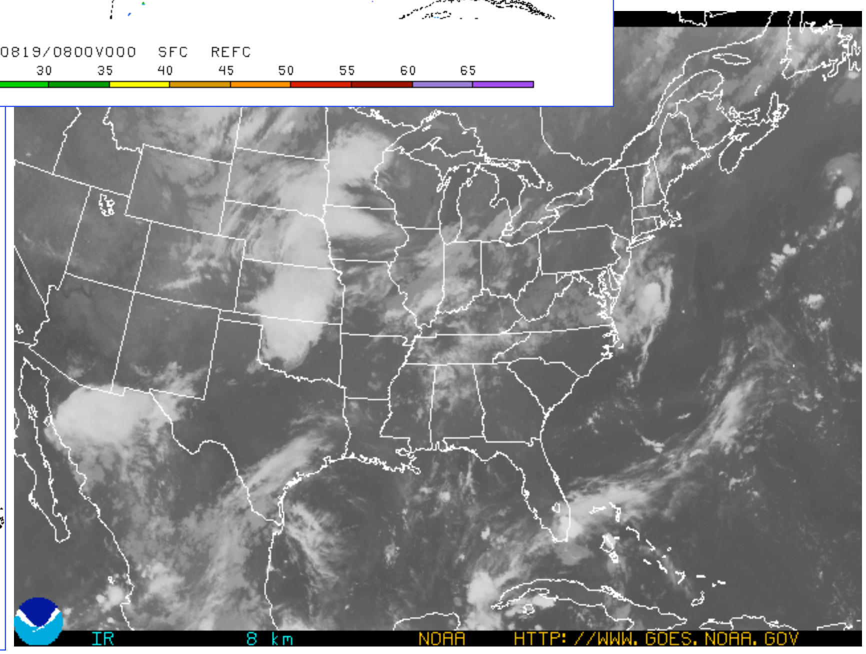

**before QC**



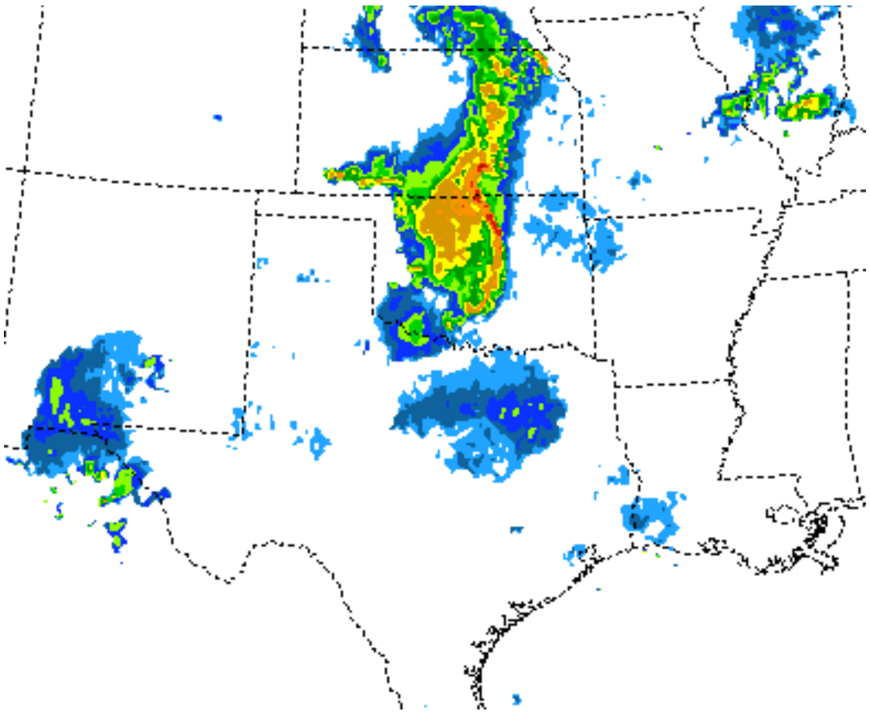

**after QC**

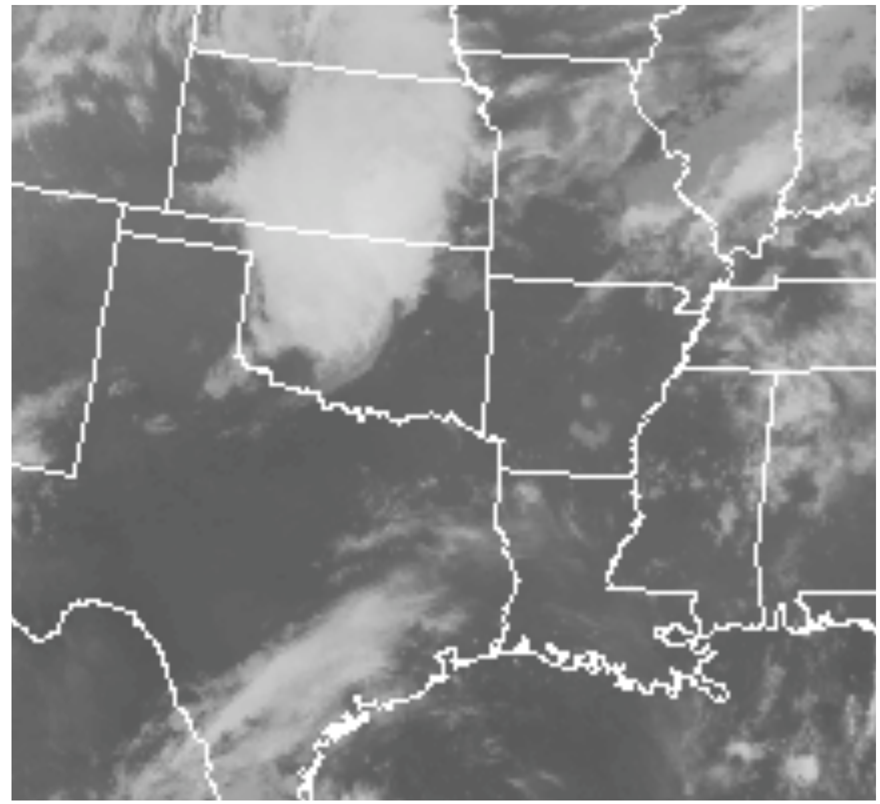

090819/0800V000 SFC REFC
5 10 15 20 25 30 35 40 45 50 55 60 65


With QC
090819/0800V000 SFC REFC
5 10 15 20 25 30 35 40 45 50 55 60 65


IR 8 km NOAA HTTP://WWW.GOES.NOAA.GOV

Goes image

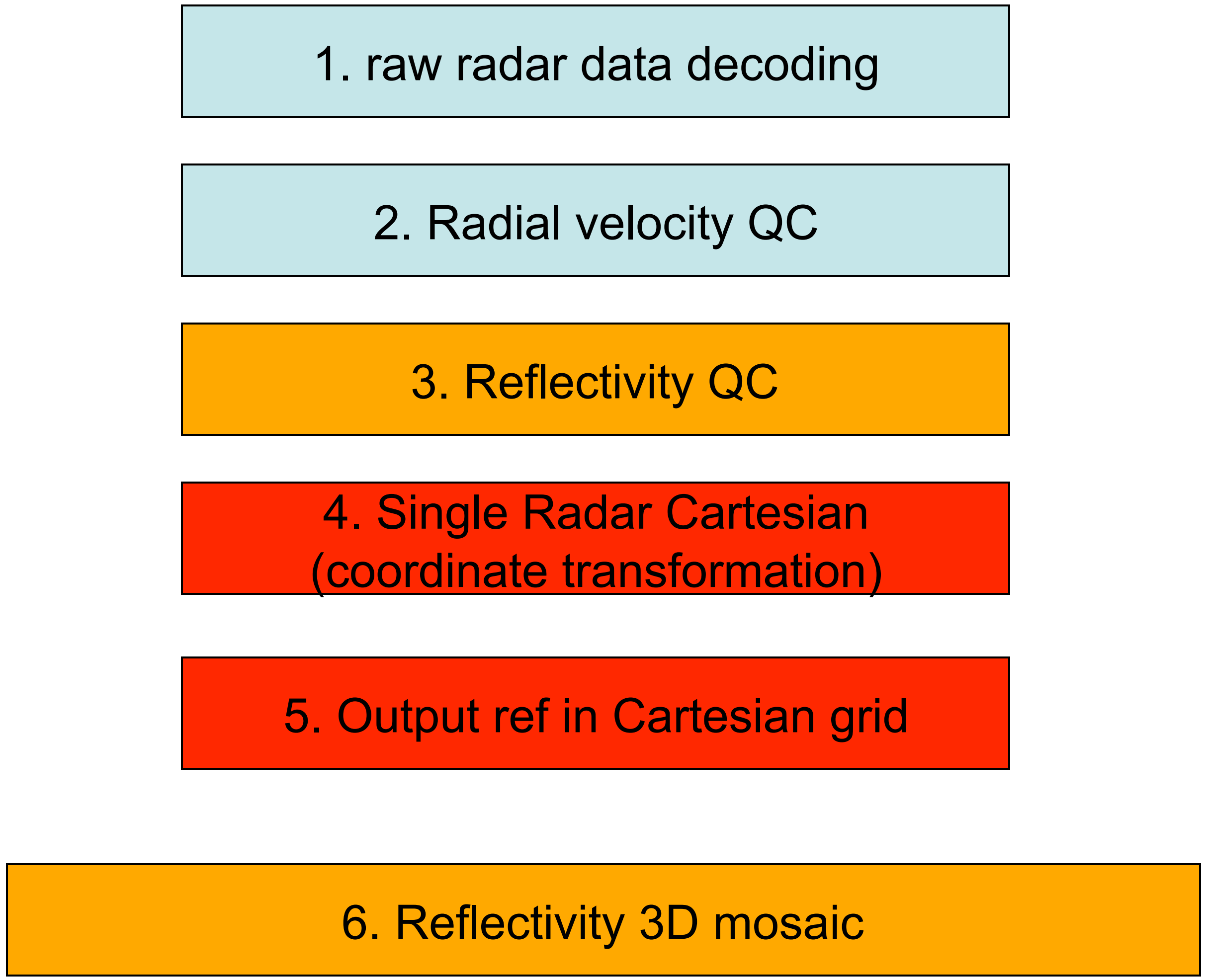




Zoom-in area

# Radar Reflectivity Mosaic

# Flowchart of reflectivity data processing



# Reflectivity in radar coordinate

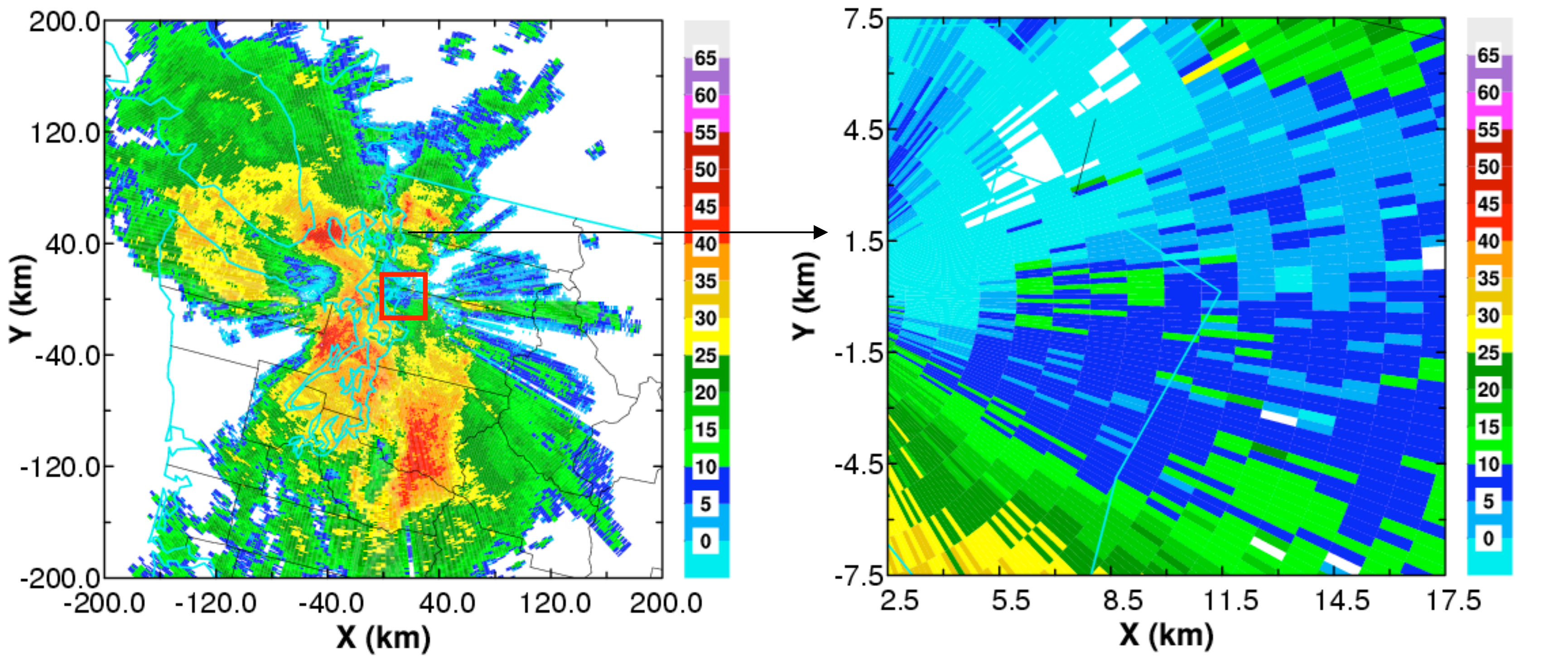



Fig. 1. Raw reflectivity from KATX radar at 0.5 deg elevation at radar coordinate and zoom-in area

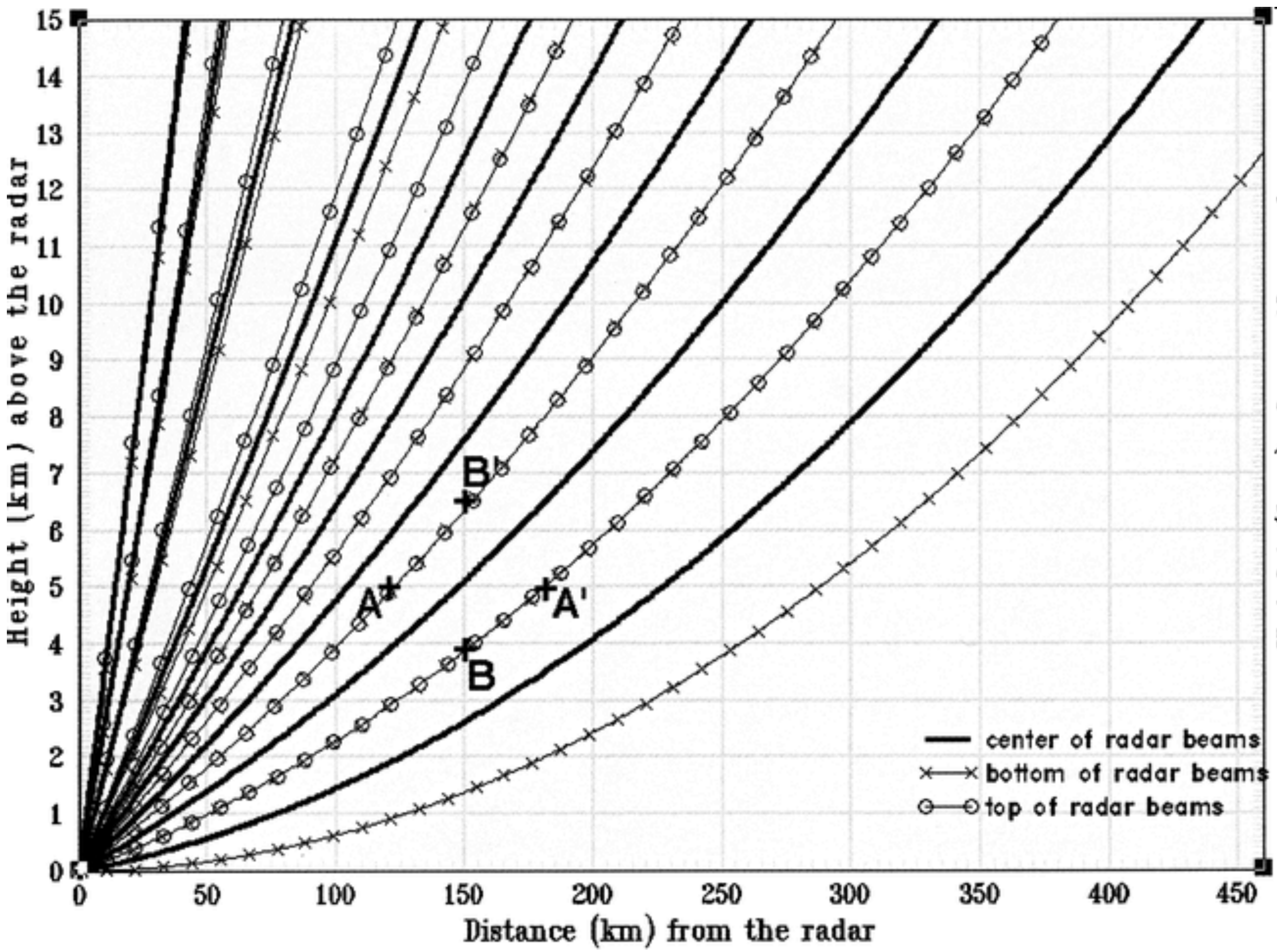



Figure is from NSSL

# Reflectivity after SRC at 1500m

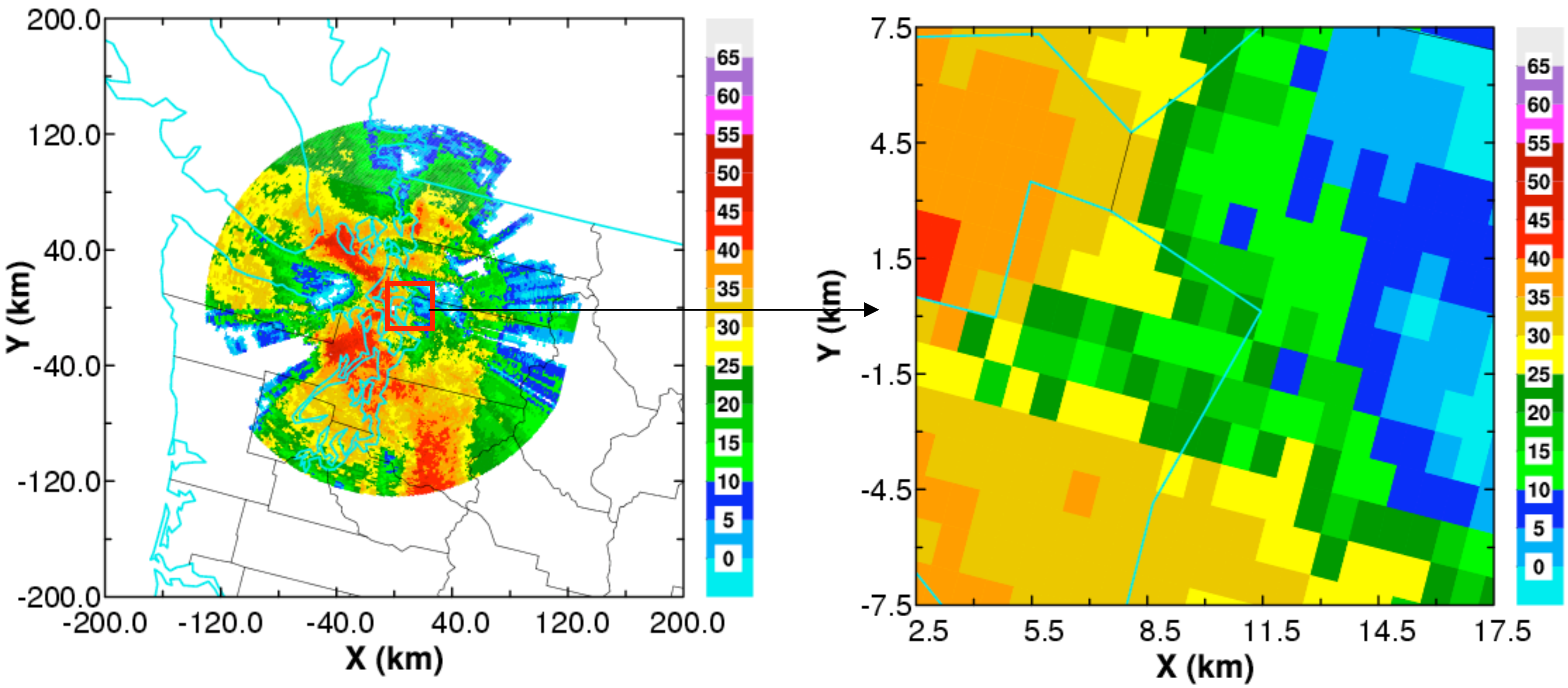



Fig. 2. Reflectivity after SRC at Cartesian grid at 1500 m and zoom in area

# Domain setup

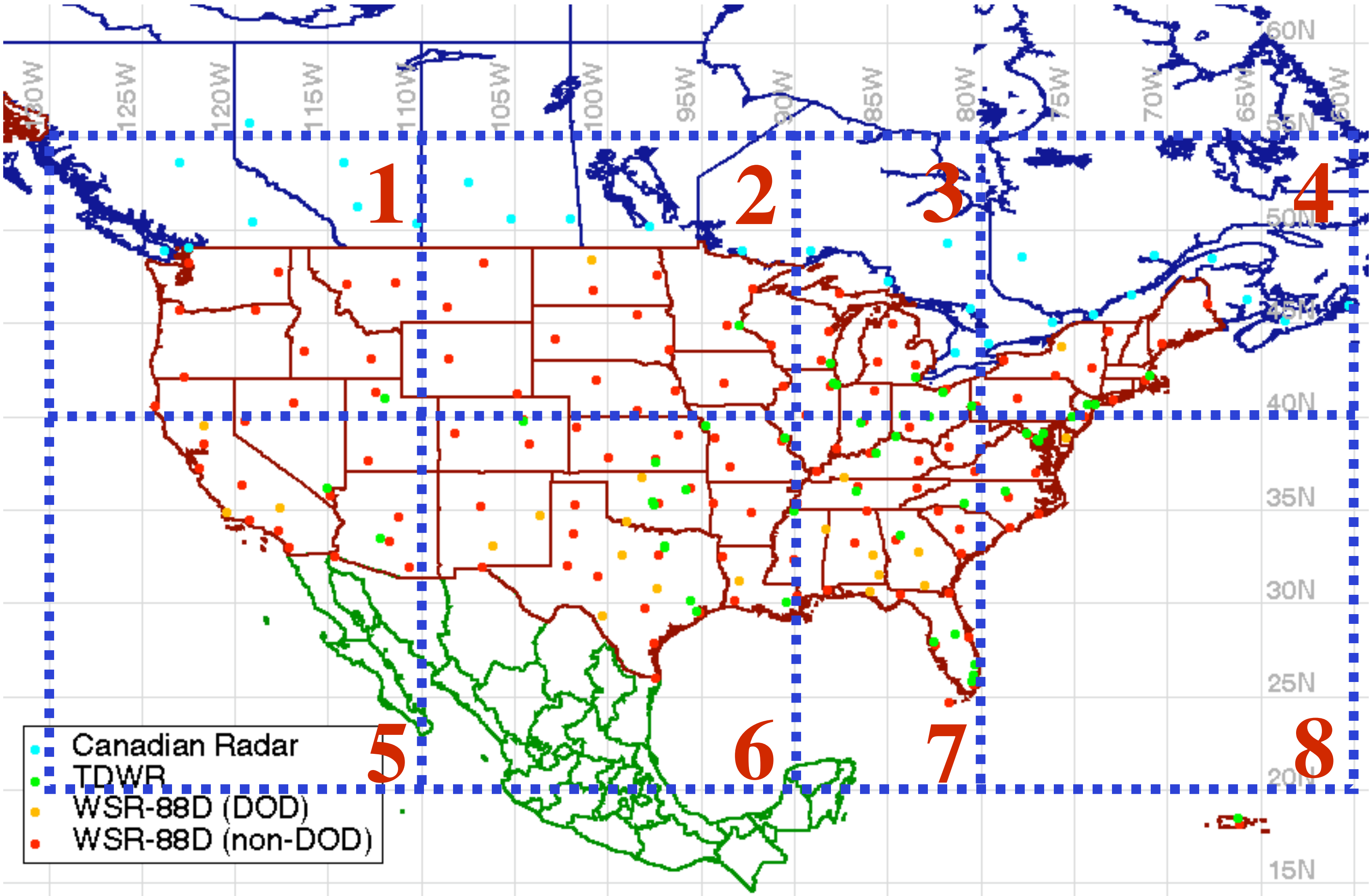


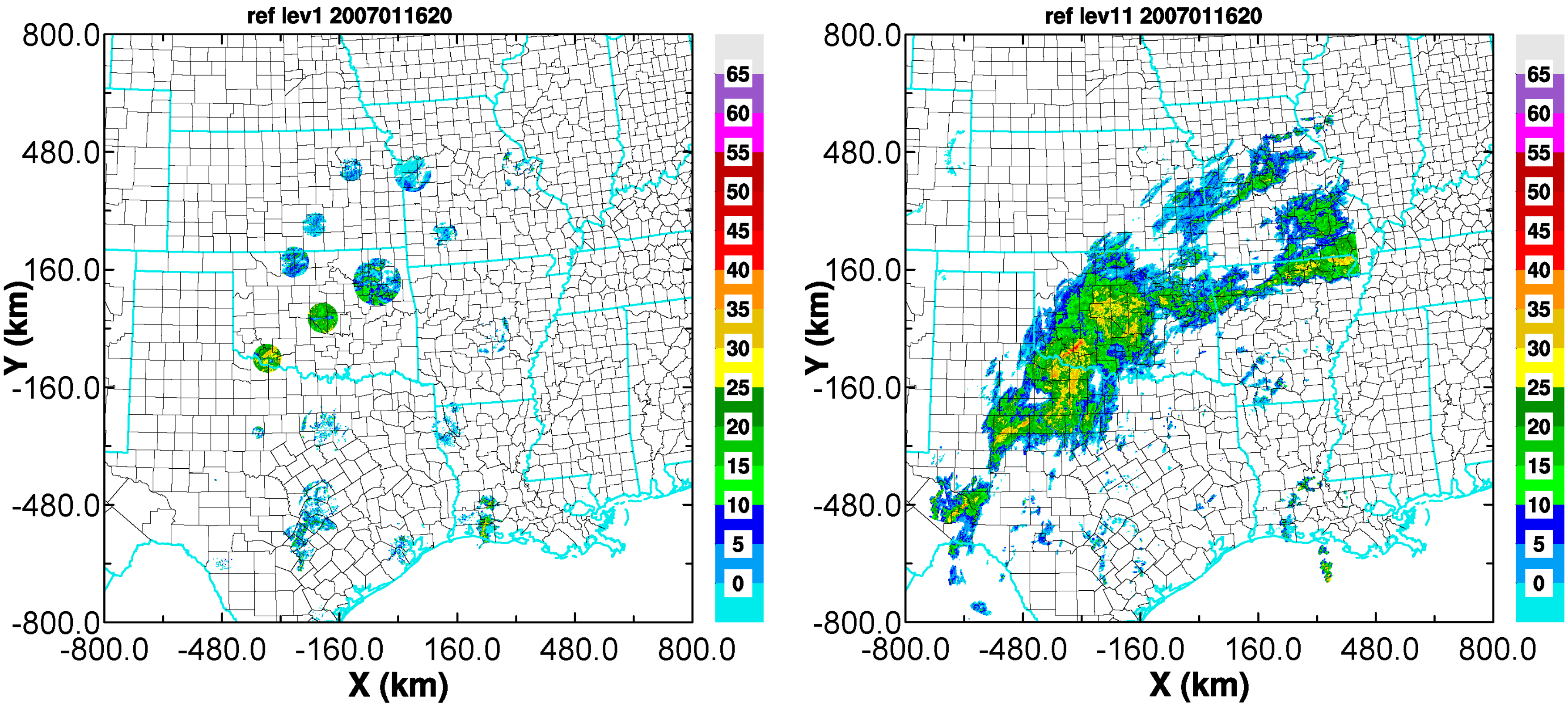

Figure is from NSSL

# Domain Specifications

| Tile ID | ctrlat (ºN) | ctrlon (ºW) | nx | ny | nz | SW corner | NE corner |
|---|---|---|---|---|---|---|---|
| 1 | 47.5 | 120 | 2001 | 1501 | 31 | 40, -130 | 55, -110 |
| 2 | 47.5 | 100 | 2001 | 1501 | 31 | 40, -110 | 55, -90 |
| 3 | 47.5 | 85 | 1001 | 1501 | 31 | 40, -90 | 55, -80 |
| 4 | 47.5 | 70 | 2001 | 1501 | 31 | 40, -80 | 55, -60 |
| 5 | 30 | 120 | 2001 | 2001 | 31 | 20, -130 | 40, -110 |
| 6 | 30 | 100 | 2001 | 2001 | 31 | 20, -110 | 40, -90 |
| 7 | 30 | 85 | 1001 | 2001 | 31 | 20, -90 | 40, -80 |
| 8 | 30 | 70 | 2001 | 2001 | 31 | 20, -80 | 40, -60 |

Table from NSSL

# Reflectivity at different vertical levels in domain 6




Reflectivity mosaic fields at 500 and 2500 m

# Radar wind assimilation in GSI

# Radar wind assimilation in GSI

- 3D variational (3DVAR) algorithm (Wu et al. 2002).
- The cost function is defined by

$$J = 1/2[\mathbf{x}^T \mathbf{B}^{-1}\mathbf{x} + (H\mathbf{x} - \mathbf{y})\mathbf{R}^{-1}(H\mathbf{x} - \mathbf{y})]$$

- Forward model

$$\mathrm{V}_r(\theta,\alpha) = \mathrm{u}\cos\alpha\cos\theta + \mathrm{v}\cos\alpha\sin\theta + \left[\mathrm{w}\sin\alpha\right]$$

# GSI namelist and scripts for radial wind assimilation

```
&OBS_INPUT
dfile(06)='radarbufr', dtype(06)='rw',       dplat(06)=' ',        dsis(06)='rw',                 dval(06)=1.0,
dthin(06)=0,
```

```
&SUPEROB_RADAR
del_azimuth=5.,del_elev=.25,del_range=5000.,del_time=.
5,elev_angle_max=5.,minnum=50,range_max=100000.,
  l2superob_only=.false.,
/
```

```
$ncp $dataobs/${prefixo}.prepbufr.tm12 ./prepbufr
$ncp $dataobs/${prefixo}.radwnd.tm12 ./radarbufr
$ncp $dataobs/${prefixo}.nexrad.tm12 ./l2rwbufr
```

# Radar data flow in GSI

Outer loop:

a. read-in radar data

b. Compute O-B

c. Call Inner loop

   1). Compute cost function and gradient

   2). Update analysis increment

read_l2bufr_mod.f90
read_radar.f90

setuprw.f90

intrw.f90
stprw.f90

update_guess.f90

# Radial wind data

WSR-88D radar wind observations
VAD, level-III, level-2.5 data and level-II data.

- read_l2bufr_mod.f90

read in level-II radial wind data and generate super-obs.

- read_radar.f90

read in VAD (from prepbufr), level-III, level-2.5 (from radarbufr) and super-obs from level-II.

# Level-II radar wind bufr

Radial wind bufr:

- SSTN | 001018 | RADAR STATION IDENTIFIER (SHORT) |
- | RPID | 001198 | RADAR STATION IDENTIFIER |
- | VOID | 001212 | RADAR VOLUME ID (IN THE FORM DDHHMM) |
- | SCID | 001213 | RADAR SCAN ID (RANGE 1-21) |
- | ANAZ | 002134 | ANTENNA AZIMUTH ANGLE |
- | ANEL | 002135 | ANTENNA ELEVATION ANGLE |
- | YEAR | 004001 | YEAR |
- | MNTH | 004002 | MONTH |
- | DAYS | 004003 | DAY |
- | HOUR | 004004 | HOUR |
- | MINU | 004005 | MINUTE |
- | SECO | 004006 | SECOND |
- | STDM | 004075 | TIME DISPLACEMENT IN MINUTES FROM BASE TIME (SHORT) |
- | CLAT | 005002 | LATITUDE (COARSE ACCURACY) |
- | SUPLAT | 005197 | LATITUDE OF RADIAL WIND SUPEROB(COARSE ACCURACY) |
- | CLON | 006002 | LONGITUDE (COARSE ACCURACY) |
- | DIST | 006021 | DISTANCE (FROM ANTENNA TO GATE CENTER) |
- | SUPLON | 006197 | LONGITUDE OF RADIAL WIND SUPEROB(COARSE ACCURACY) |
- | DIST125M | 006210 | DISTANCE (FROM ANTENNA TO GATE CENTER) IN UNITS OF 125M |
- | SELV | 007001 | HEIGHT OF STATION |
- | HEIT | 007007 | HEIGHT OF RADIAL WIND SUPEROB |
- | HSMSL | 007030 | HEIGHT OF STATION GROUND ABOVE MSL |
- | HSALG | 007032 | HEIGHT OF ANTENNA ABOVE GROUND |
- | HREF | 021001 | HORIZONTAL REFLECTIVITY |
- | DMVR | 021014 | DOPPLER MEAN RADIAL VELOCITY |
- | DVSW | 021017 | DOPPLER VELOCITY SPECTRAL WIDTH |
- | HNQV | 021019 | HIGH NYQUIST VELOCITY |
- | RWND | 021194 | RADIAL WIND RADIAL WIND SUPEROB |
- | RWAZ | 021195 | AZIMUTH OF RADIAL WIND SUPEROB |
- | RSTD | 021196 | STANDARD DEVIATION OF RADIAL WIND SUPEROB |
- | VOCP | 021197 | VOLUME COVERAGE PATTERN |
- | QCRF | 033250 | QUALITY MARK FOR REFLECTIVITIES ALONG RADIAL LINE |
- | QCRW | 033251 | QUALITY MARK FOR WINDS ALONG RADIAL LINE |
- | MGPT | 050004 | BUFR MESSAGE NUMBER |

# Radial wind QC in GSI

setuprw.f90:

a. Increase error if model and observation topography too different
b. Increase error for observation over high topography
c. Gross error check

# Background Error

- The default decorrelation length of the background errors used in GSI is estimated using the NMC method. It  may not be suitable for analyzing radar data representing convective scales.

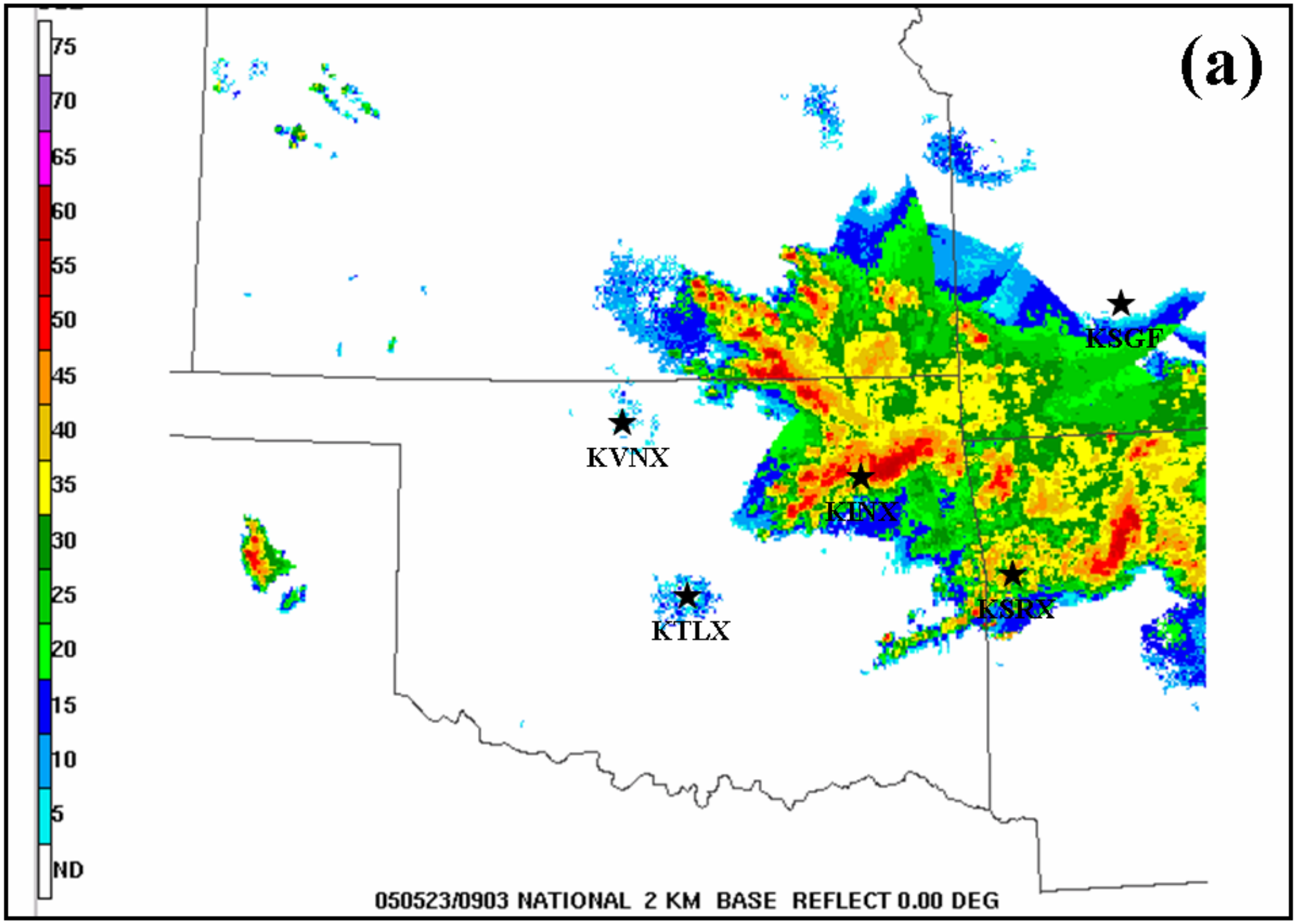
- Decorrelation length of background errors can be set in namelist. For high-resolution and convective scales analysis, the use of shorter decorrelation length may keep more details of storm.

In namelist, tuning hzscl to set suitable background decorrelation length.

&BKGERR

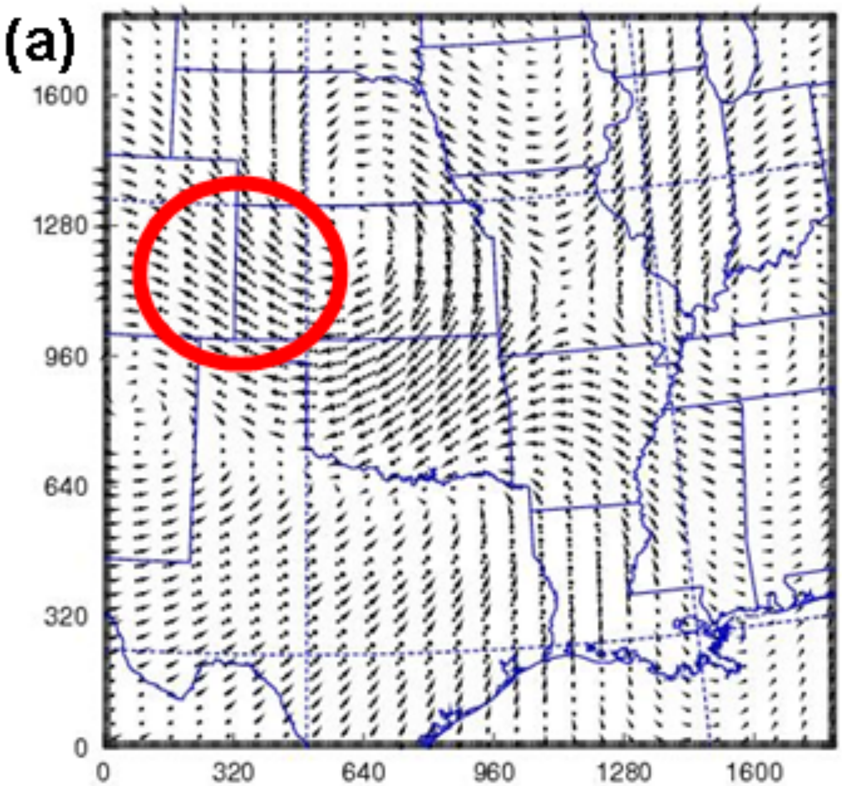
hzscl=0.373, 0.746, 1.50,

# Radar reflectivity at 0900 UTC on 23 May 2005

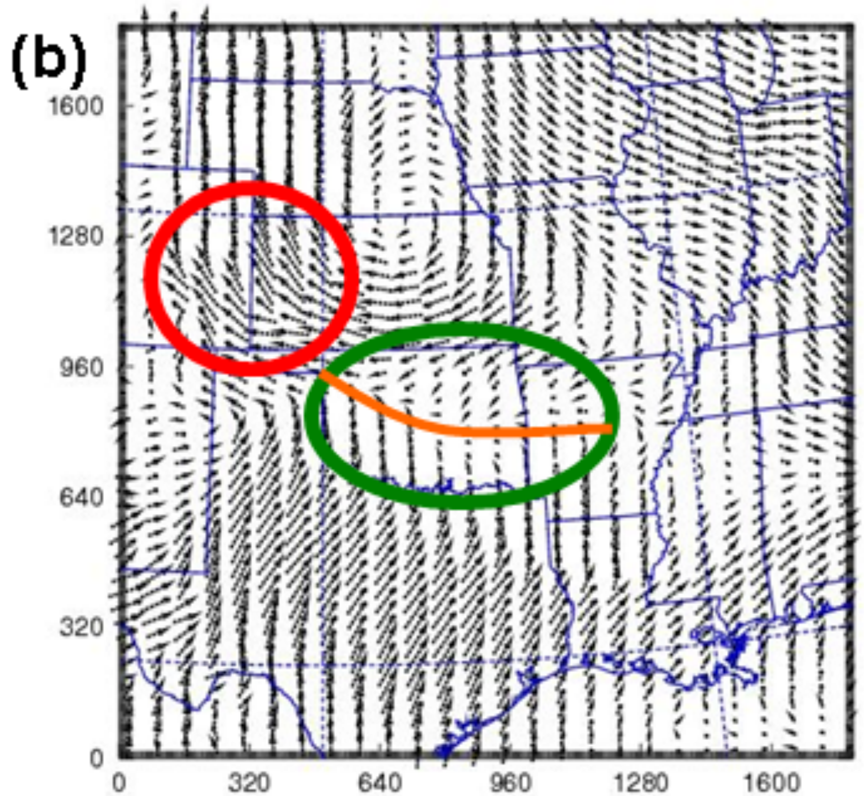


# *Analysis using default decorrelation length*

*Increment of the analyzed winds*

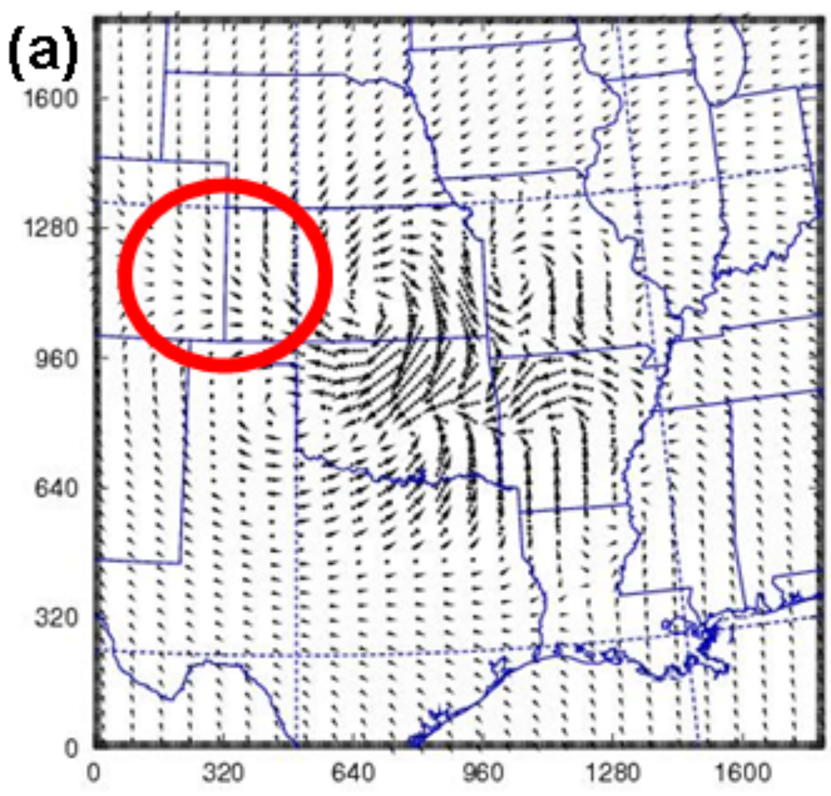



*Full wind vectors*

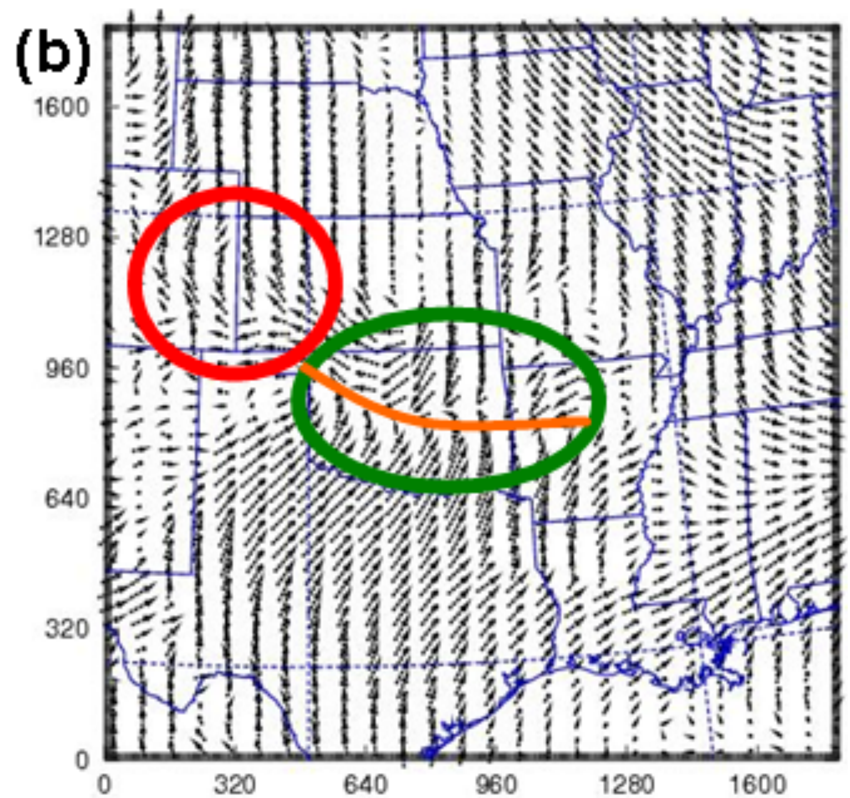


# *Analysis using 0.25 times the default decorrelation length*

*Increment of the analyzed winds*




*Full wind vectors*



# Check Result

STDOUT:

## read_l2bufr_mod.f90

### Summary of radar stations in BUFR file

```
0: RADAR_BUFR_READ_ALL:  num_radars_0,loops_total =  74 355200
  0: master list radar   1 stn id,lat,lon,hgt = KAKQ     36.98    -77.01
  0: master list radar   2 stn id,lat,lon,hgt = KDVN     41.61    -90.58
  0: master list radar   3 stn id,lat,lon,hgt = KEPZ     31.87   -106.70
  0: master list radar   4 stn id,lat,lon,hgt = KFDR     34.36    -98.98
```

### Summary of input data

```
 0:  nradials_in= 2815600
0:  nradials_fail_angmax= 668391
0:  nradials_fail_time= 1403832
0:  nradials_fail_elb= 0
0:  nobs_in= 127634068
0:  nobs_badvr= 7264458
0:  nobs_badsr= 12975
0:  nobs_lrbin= 199
```

### Summary of super-obs for each staion

```
0:  for radar KAKQ nsuper= 4241
  0:   vrmin,max= -24.39374924 24.13636398
  0:  errmin,max= 0.2636067569 25.28617668
```

### Summary of data used in assimilation

```
4:READ_RADAR   : file=radarbufr  type=rw         sis=rw
nread=    536549 ithin= 0 rmesh=120.000 isfcalc= 0 ndata=
42425 ntask=  1
```

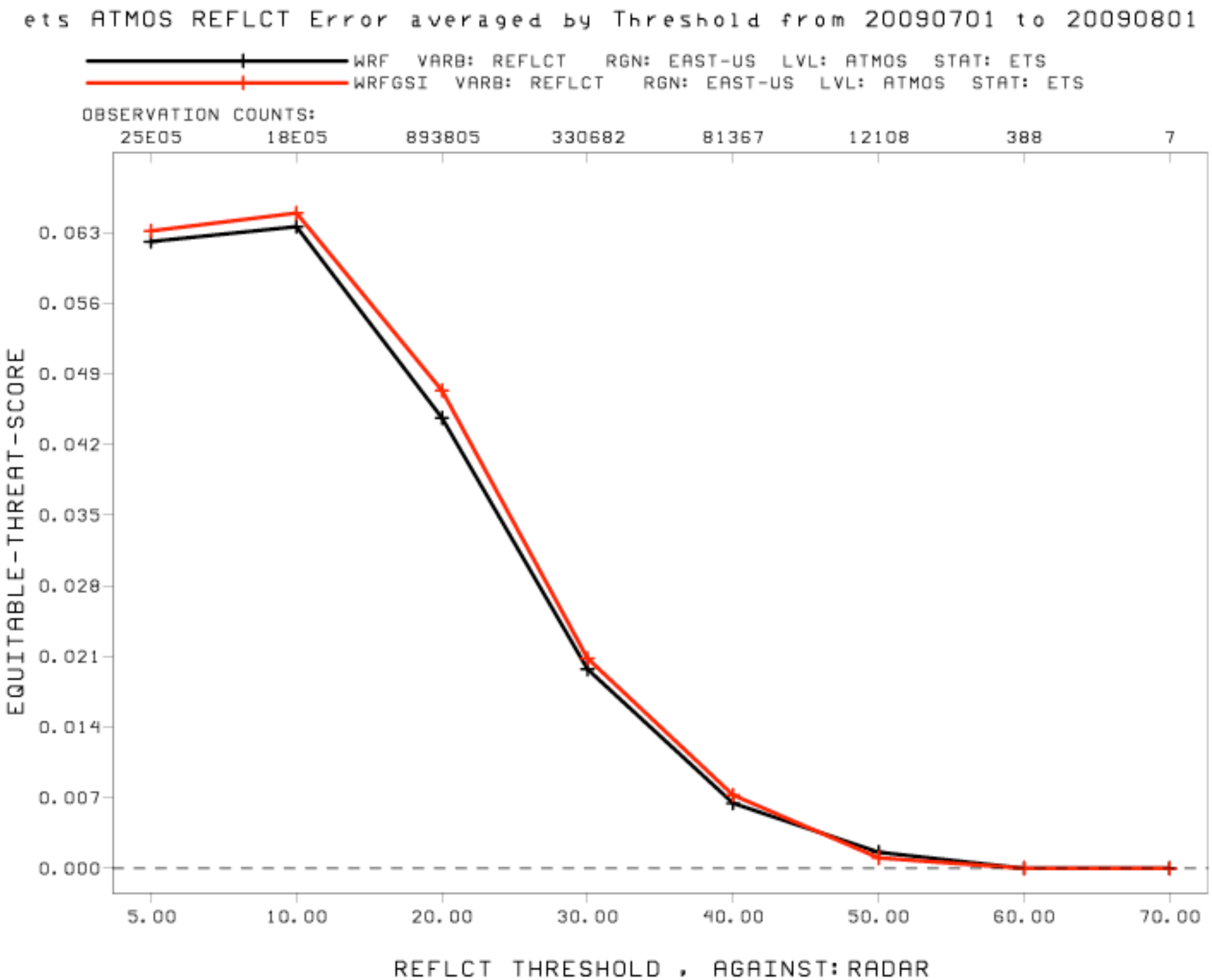
# Check Result

## Fort.209

```
current vfit of radar wind data, ranges in m/s
                         ptop  1000.0  900.0  800.0  600.0  400.0  300.0  250.0  200.0  150.0  100.0   50.0     0.0
   it    obs    type styp  pbot  1200.0  999.9  899.9  799.9  599.9  399.9  299.9  249.9  199.9  149.9   99.9  2000.0
------------------------------------------------------------------------------------------------------------------------------
 o-g 01     rw     999 0000 count      6   2898  12526  22872   4094      3      0      0      0      0      0  42424
 o-g 01     rw     999 0000  bias   1.37   0.03  -0.00  -0.02  -0.05  -1.33   0.00   0.00   0.00   0.00   0.00   -0.01
 o-g 01     rw     999 0000   rms   3.32   1.74   1.32   1.53   2.03   4.96   0.00   0.00   0.00   0.00   0.00    1.54
 o-g 01     rw     999 0000  cpen   0.33   1.84   1.59   1.98   2.98  35.16   0.00   0.00   0.00   0.00   0.00    1.96
 o-g 01     rw     999 0000 qcpen   0.33   1.84   1.59   1.98   2.98  35.16   0.00   0.00   0.00   0.00   0.00    1.96
 o-g 01           all      count      6   2898  12526  22872   4094      3      0      0      0      0      0  42424
 o-g 01           all       bias   1.37   0.03  -0.00  -0.02  -0.05  -1.33   0.00   0.00   0.00   0.00   0.00   -0.01
 o-g 01           all        rms   3.32   1.74   1.32   1.53   2.03   4.96   0.00   0.00   0.00   0.00   0.00    1.54
 o-g 01           all       cpen   0.33   1.84   1.59   1.98   2.98  35.16   0.00   0.00   0.00   0.00   0.00    1.96
 o-g 01           all      qcpen   0.33   1.84   1.59   1.98   2.98  35.16   0.00   0.00   0.00   0.00   0.00    1.96
 o-g 01     rw rej 999 0000 count      0      0      0      0      1      0      0      0      0      0      0      1
 o-g 01     rw rej 999 0000  bias   0.00   0.00   0.00   0.00 -13.72   0.00   0.00   0.00   0.00   0.00   0.00  -13.72
 o-g 01     rw rej 999 0000   rms   0.00   0.00   0.00   0.00  13.72   0.00   0.00   0.00   0.00   0.00   0.00   13.72
 o-g 01     rw rej 999 0000  cpen   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00    0.00
 o-g 01     rw rej 999 0000 qcpen   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00    0.00
 o-g 01        rej all     count      0      0      0      0      1      0      0      0      0      0      0      1
 o-g 01        rej all      bias   0.00   0.00   0.00   0.00 -13.72   0.00   0.00   0.00   0.00   0.00   0.00  -13.72
 o-g 01        rej all       rms   0.00   0.00   0.00   0.00  13.72   0.00   0.00   0.00   0.00   0.00   0.00   13.72
 o-g 01        rej all      cpen   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00    0.00
 o-g 01        rej all     qcpen   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00    0.00
 num(r) =    58 at lev    1 pen,qcpen,cpen,cqcpen =  60.728     60.728     1.0470     1.0470
 num(r) =    55 at lev    2 pen,qcpen,cpen,cqcpen =  43.509     43.509    0.79107    0.79107
 num(r) =    61 at lev    3 pen,qcpen,cpen,cqcpen =  101.79     101.79     1.6687     1.6687
 num(r) =    80 at lev    4 pen,qcpen,cpen,cqcpen =  157.71     157.71     1.9714     1.9714
 num(r) =    75 at lev    5 pen,qcpen,cpen,cqcpen =  44.601     44.601    0.59469    0.59469
 num(r) =   205 at lev    6 pen,qcpen,cpen,cqcpen =  422.71     422.71     2.0620     2.0620
 num(r) =   249 at lev    7 pen,qcpen,cpen,cqcpen =  1449.6     1449.6     5.8219     5.8219
 num(r) =   275 at lev    8 pen,qcpen,cpen,cqcpen =  484.49     484.49     1.7618     1.7618
 num(r) =   303 at lev    9 pen,qcpen,cpen,cqcpen =  456.83     456.83     1.5077     1.5077
 num(r) =   340 at lev   10 pen,qcpen,cpen,cqcpen =  563.62     563.62     1.6577     1.6577
 num(r) =   381 at lev   11 pen,qcpen,cpen,cqcpen =  1565.3     1565.3     4.1084     4.1084
```

# HiRes Initialization with radial wind

- Background error de-correlation length
- HiRes assimilation with radar wind only.


ets ATMOS REFLCT Error averaged by Threshold from 20090701 to 20090801
WRF VARB: REFLCT RGN: EAST-US LVL: ATMOS STAT: ETS
WRFGSI VARB: REFLCT RGN: EAST-US LVL: ATMOS STAT: ETS
OBSERVATION COUNTS:
25E05
18E05
893805
330682
81367
12108
388
7
EQUITABLE-THREAT-SCORE
0.063
0.056
0.049
0.042
0.035
0.028
0.021
0.014
0.007
0.000
5.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
REFLCT THRESHOLD , AGAINST:RADAR

30 h

# Challenge

- Reflectivity assimilation
- Cross-covariance between wind and other control variables
- Data QC
- New radar data from TDWR, Dual-Pol and Canadian radar.