Recent Work on Radar Velocity Data QC and Error Covariance Estimation at NSSL

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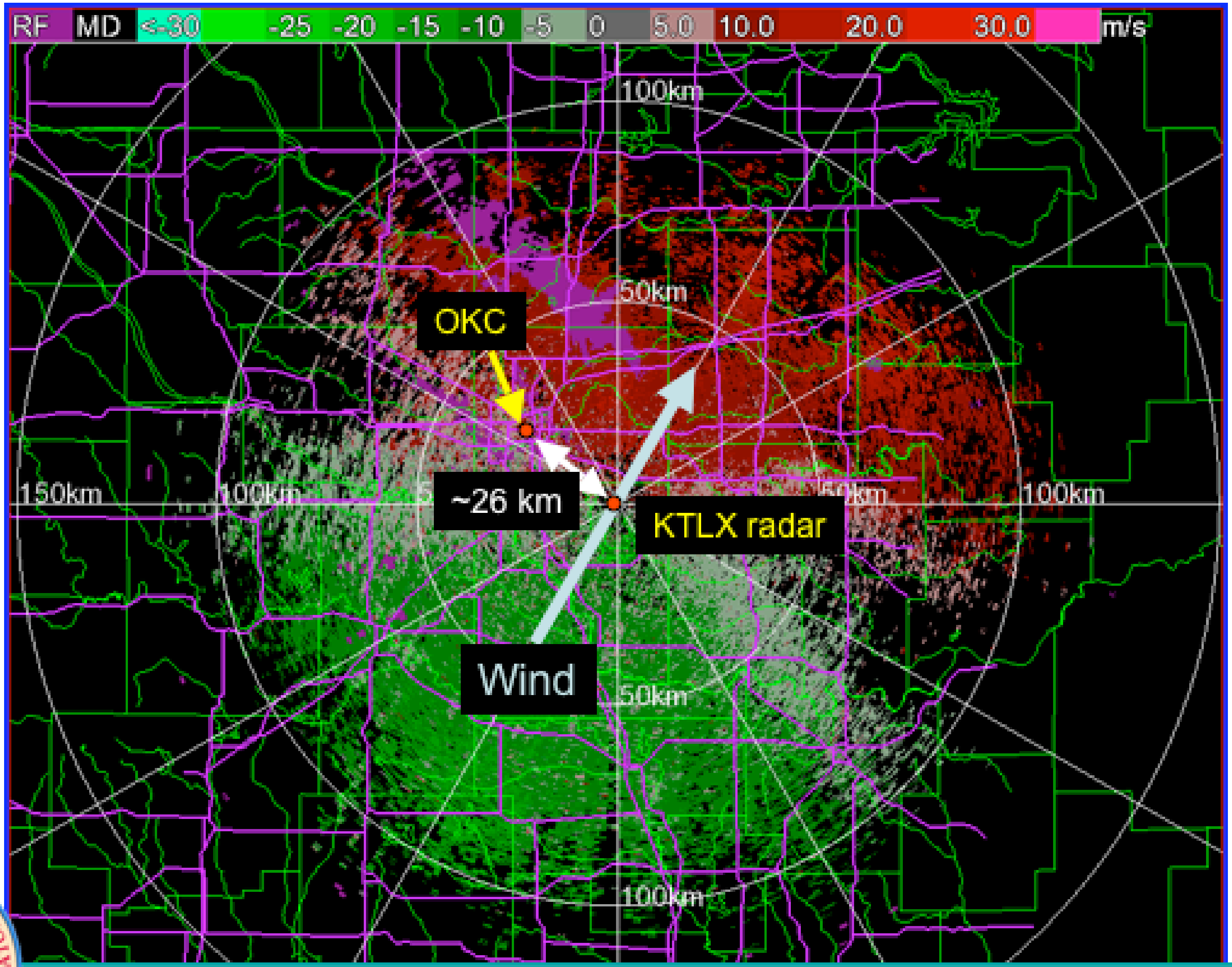
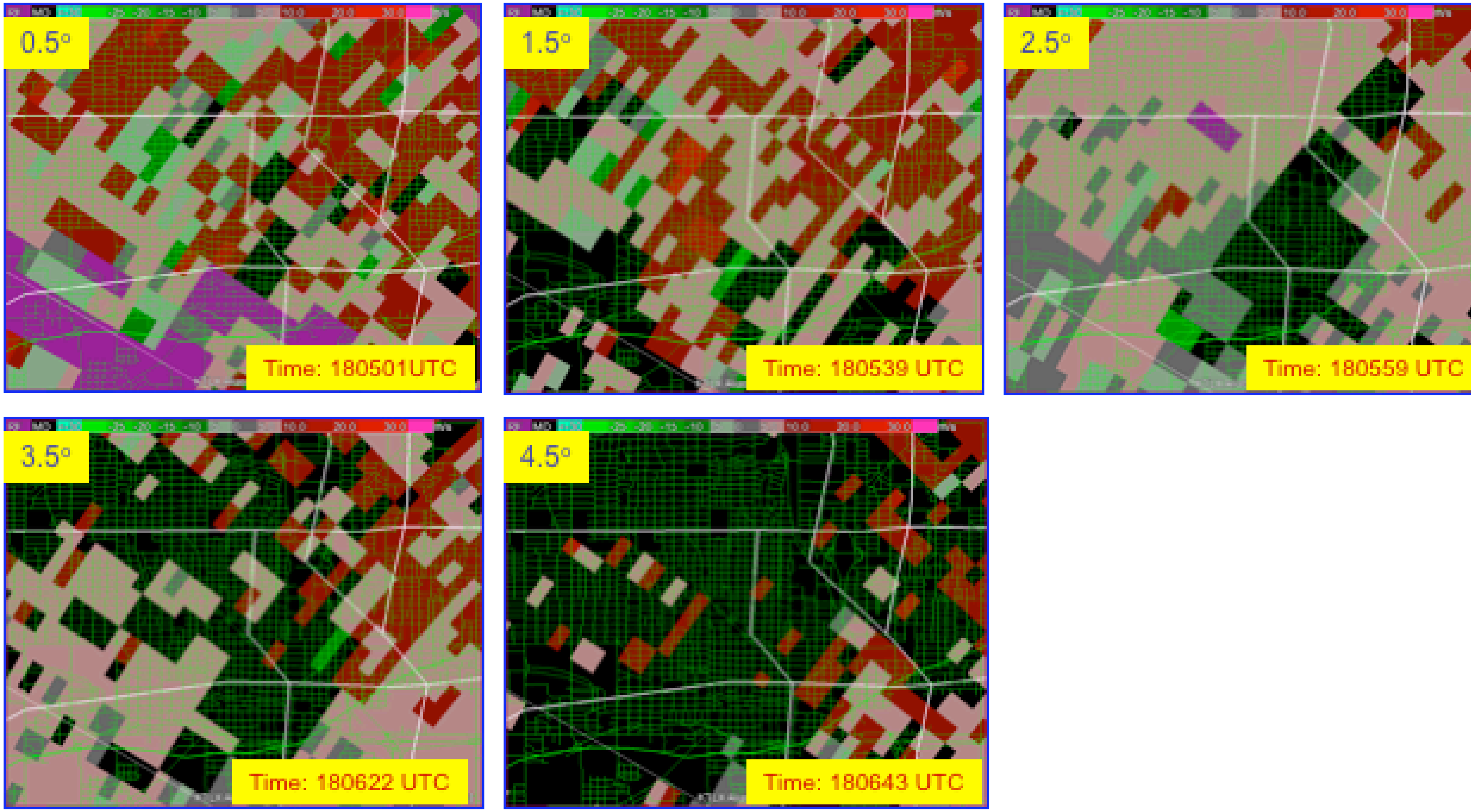
Doppler Velocity Data Quality Problems

1. Noisy fields (due to small Nyquist velocity)
2. Irregular variations due to scan mode switches
3. Alias ($|v_r^{ob}| \leq$ Nyquist velocity)
4. Contamination by flying objects (migrating birds etc.)
5. Ground clutters due to anomalous propagation (AP)
6. Large velocities caused by moving vehicles & AP
7. Sea Clutters

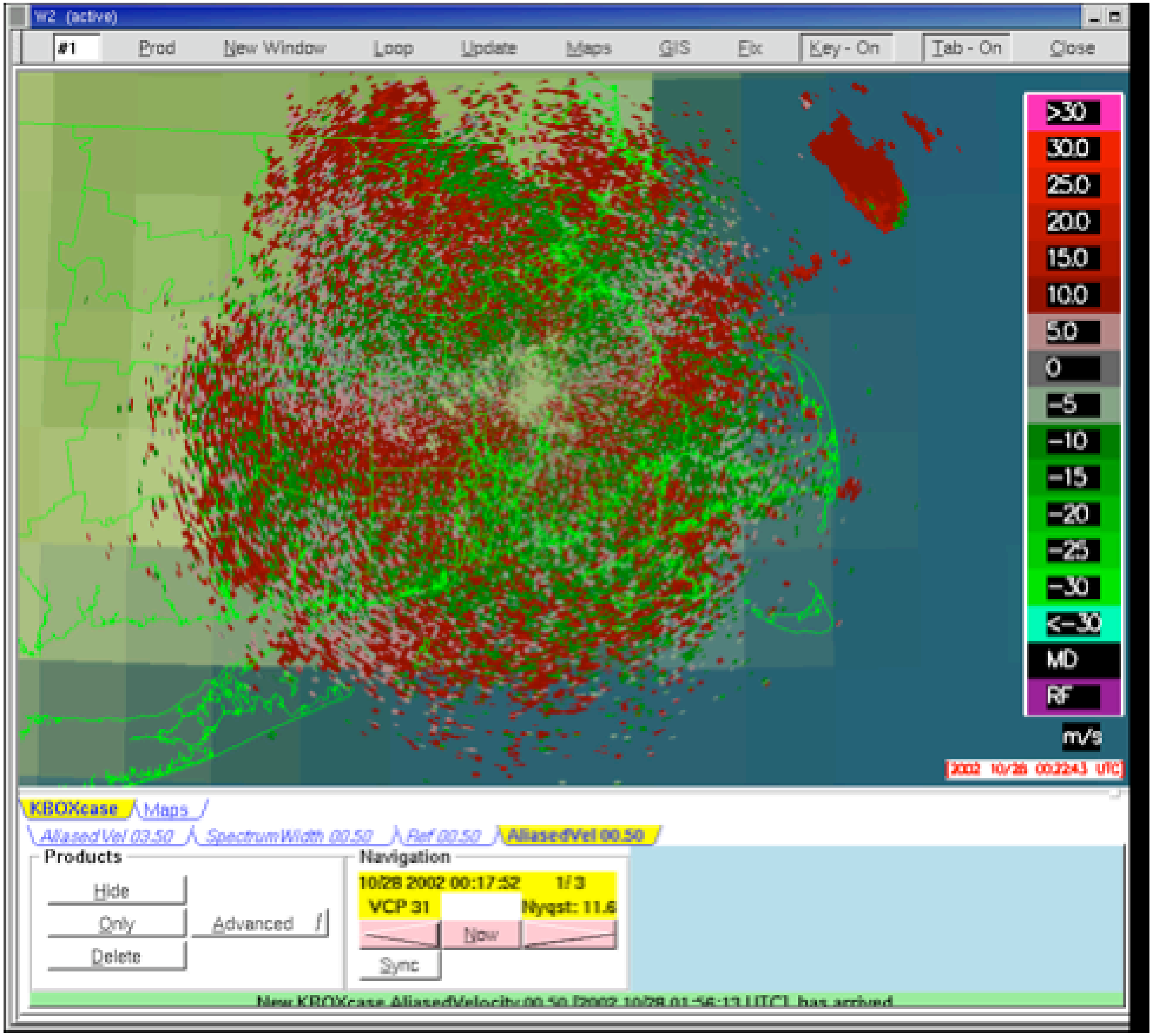
KTLX Doppler Velocity Observation: Oklahoma City experiment 2003



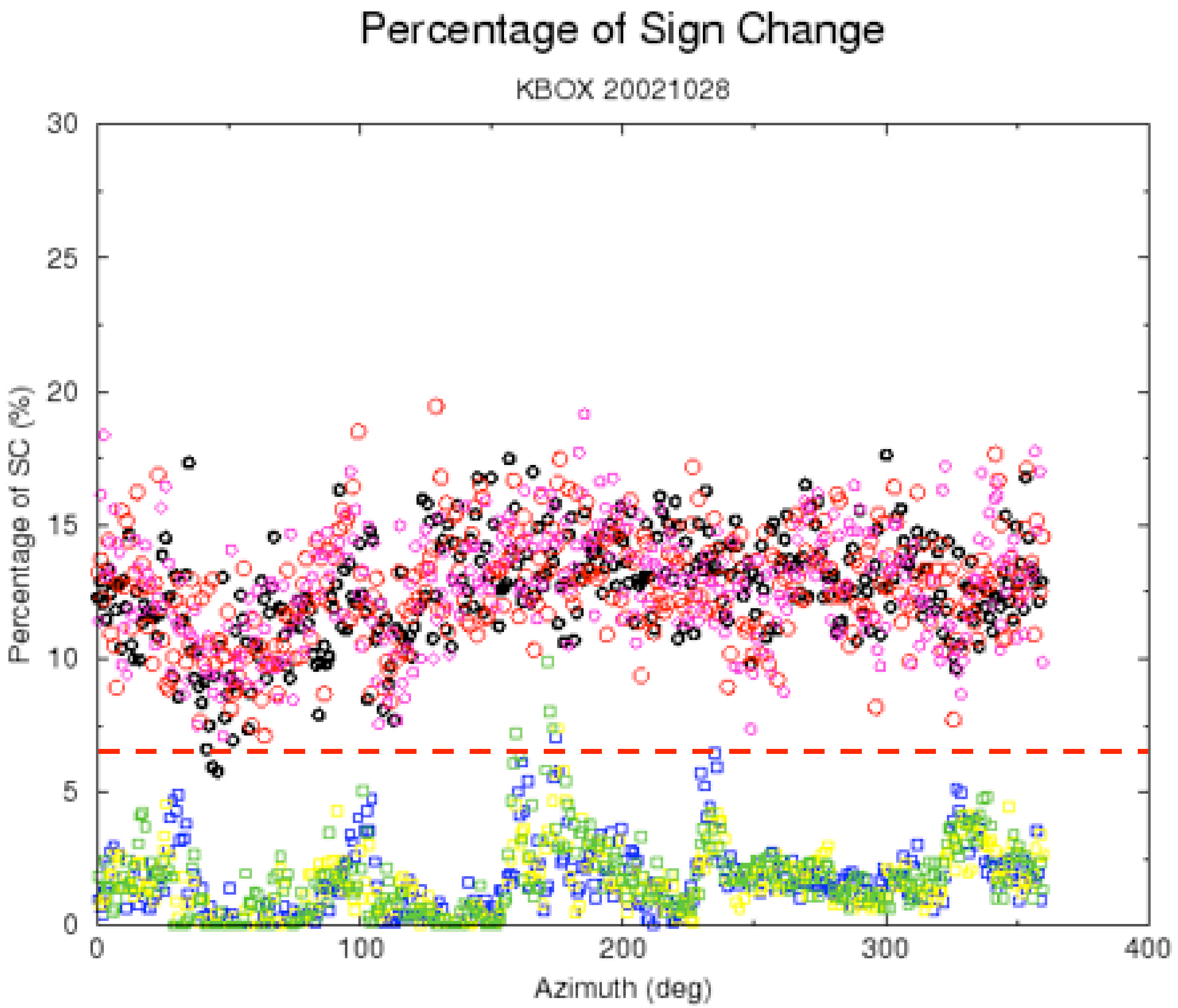
KTLX Doppler Velocity Observation: Oklahoma City experiment 2003



Noisy Vr field (0022UTC)



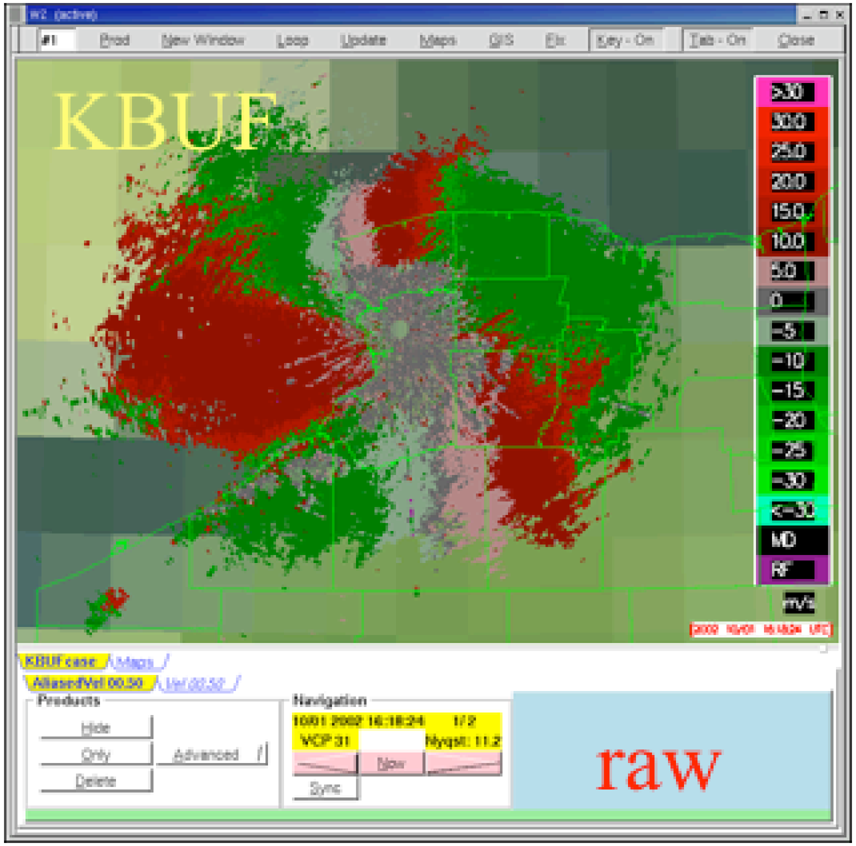
Percentage of Sign Change(Combined)

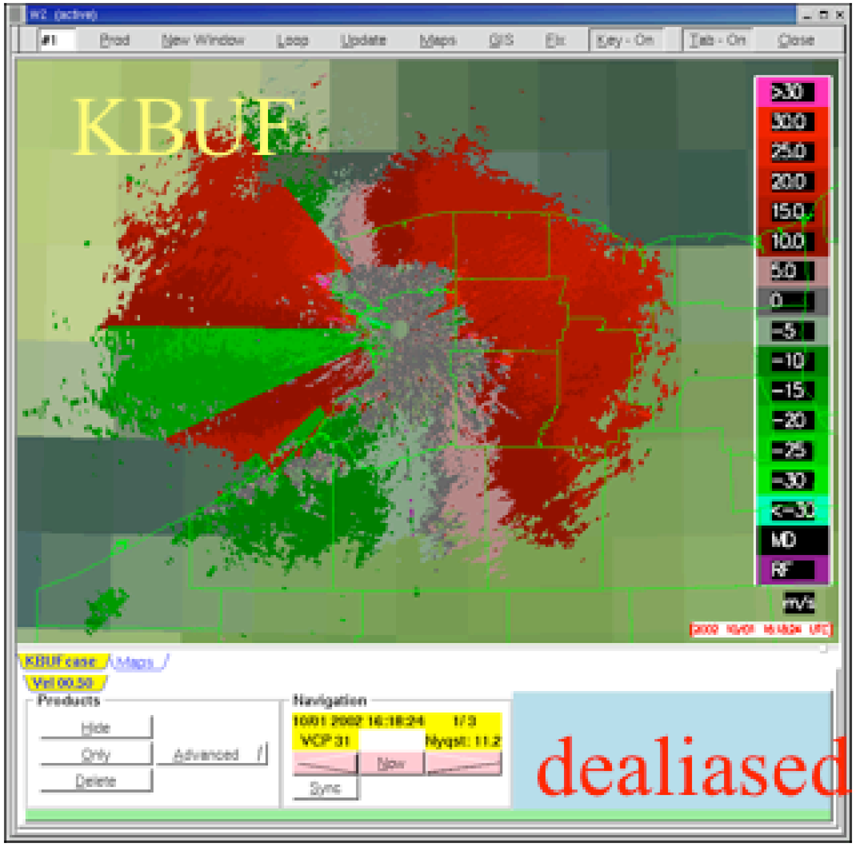


Problems in Operational Dealiasing

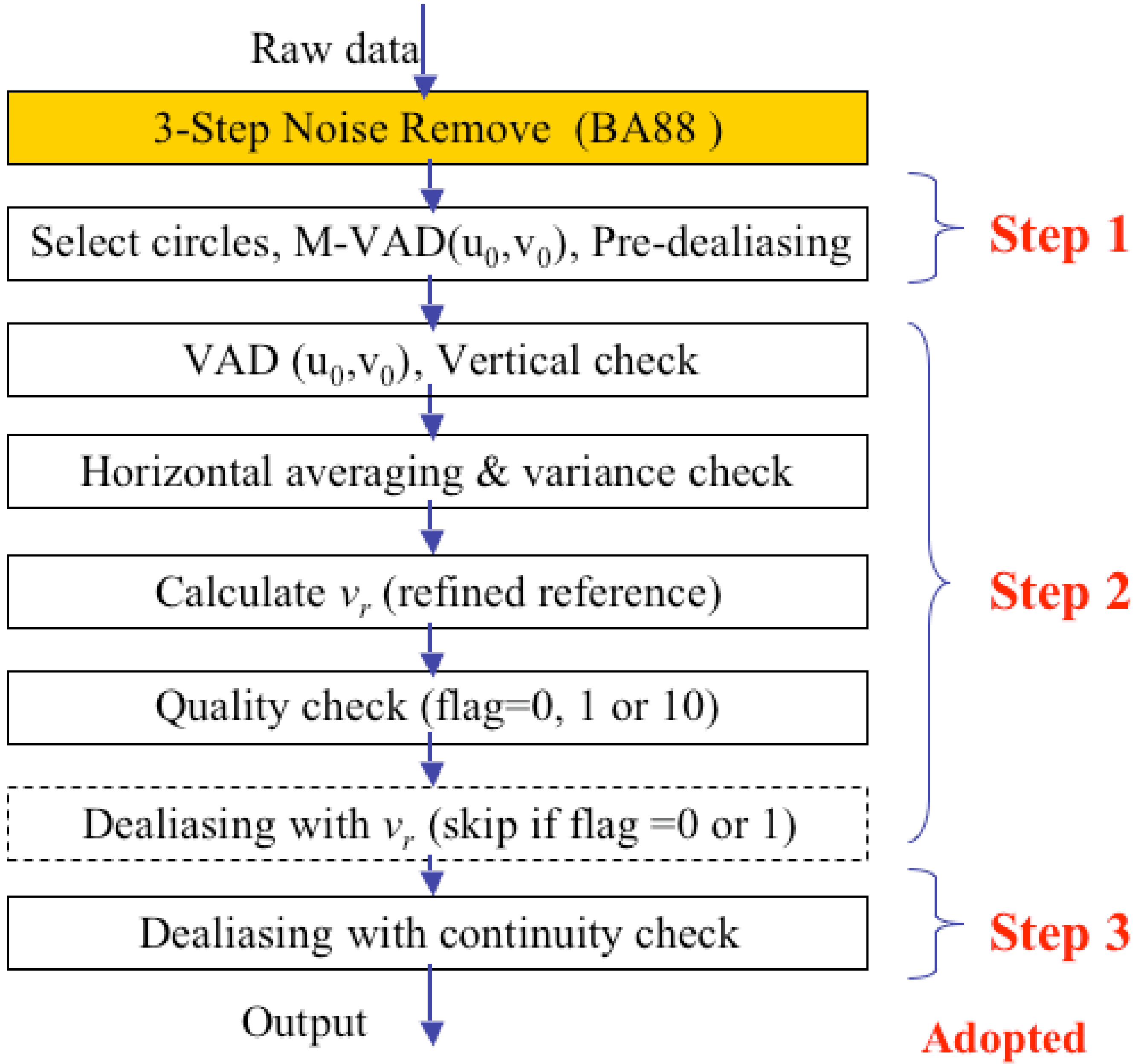
Level-II raw data

Level-III NIDS





Three-step Dealiasing for Level-II Velocities

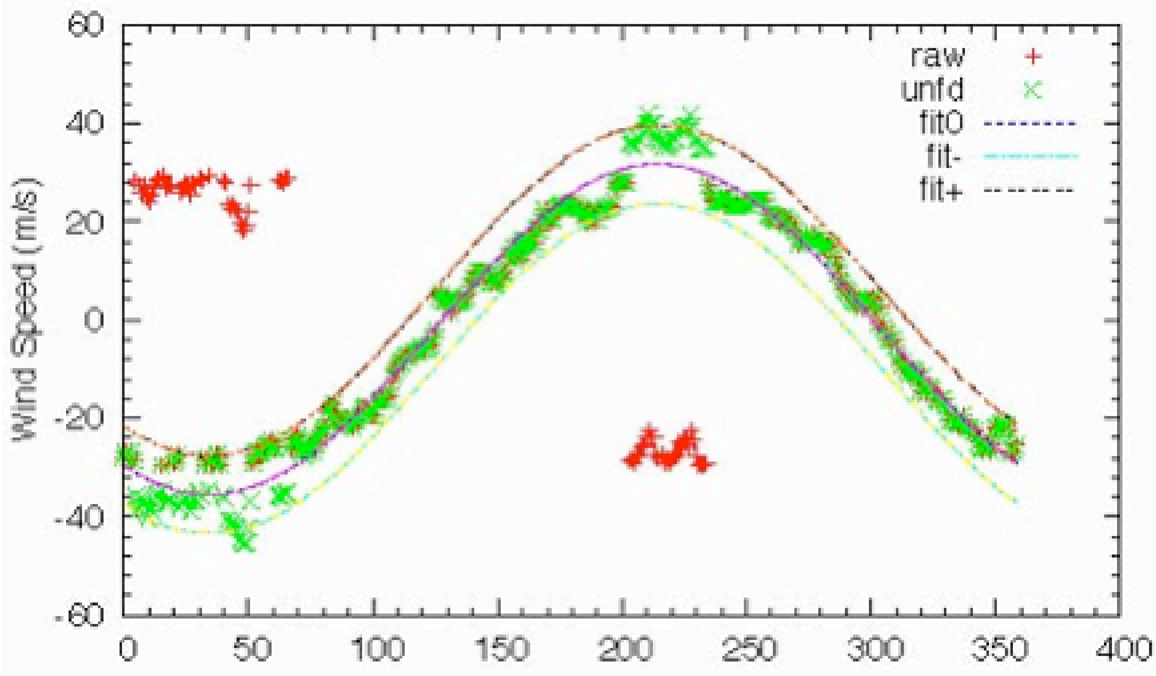


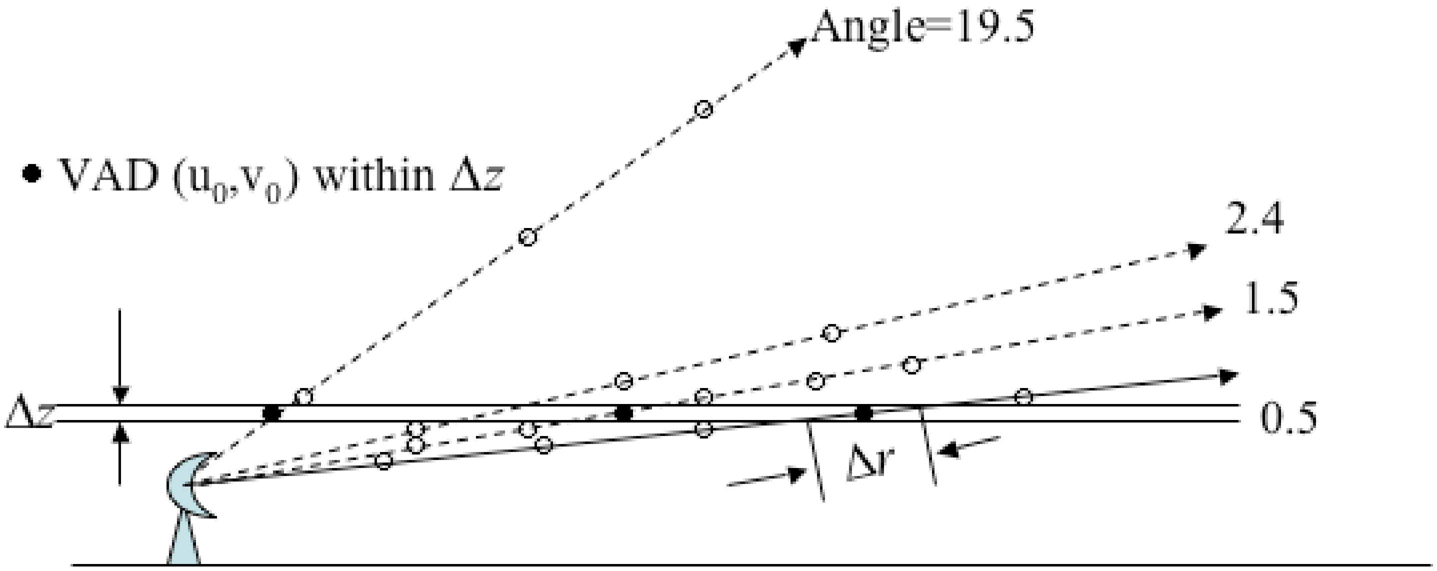
VAD

$$v_r = a + \cos\alpha(u_o \sin\theta + v_o \cos\theta)$$

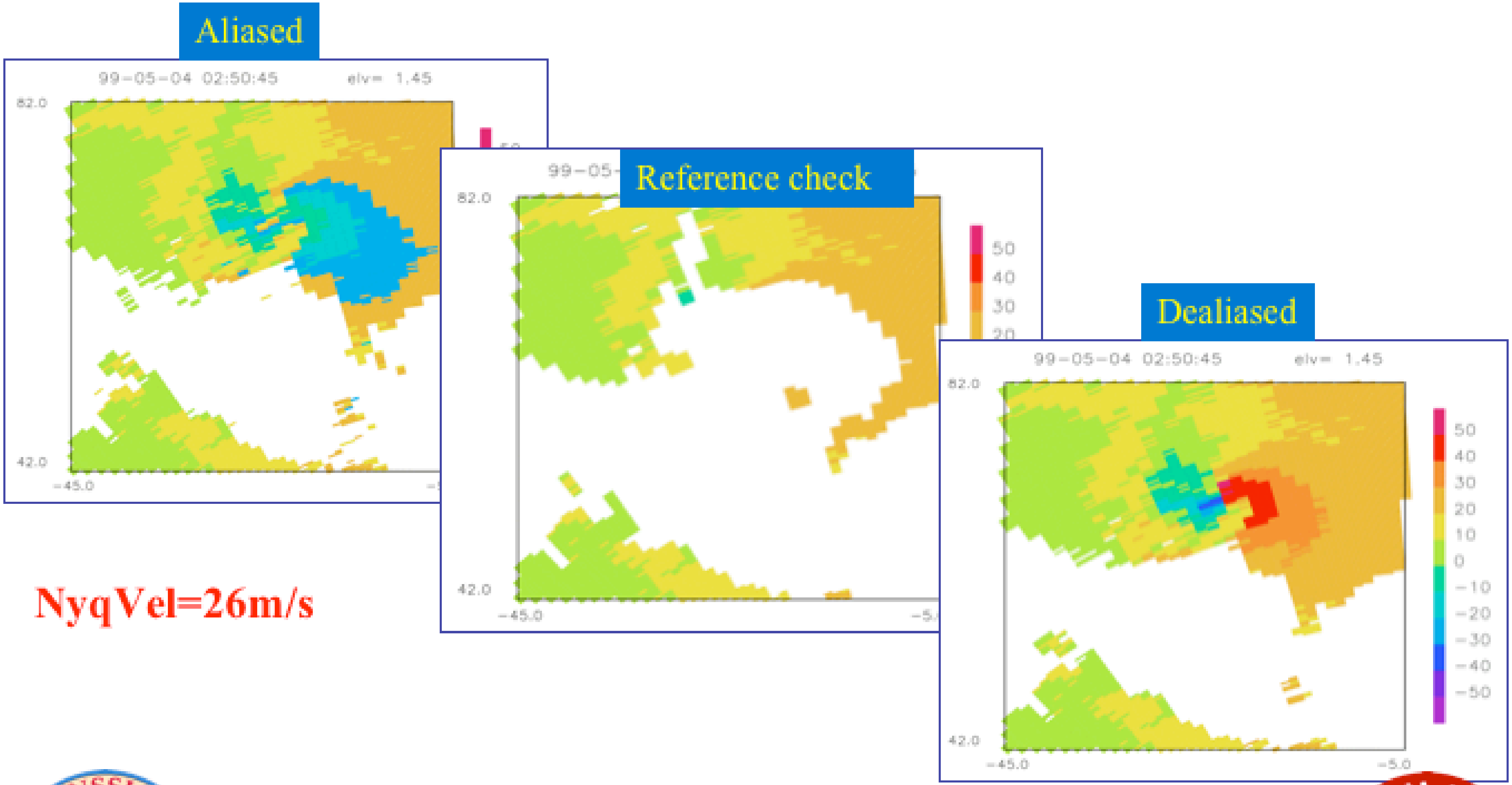
Modified VAD

$$\partial_\theta v_r = \cos\alpha(u_o \cos\theta - v_o \sin\theta)$$





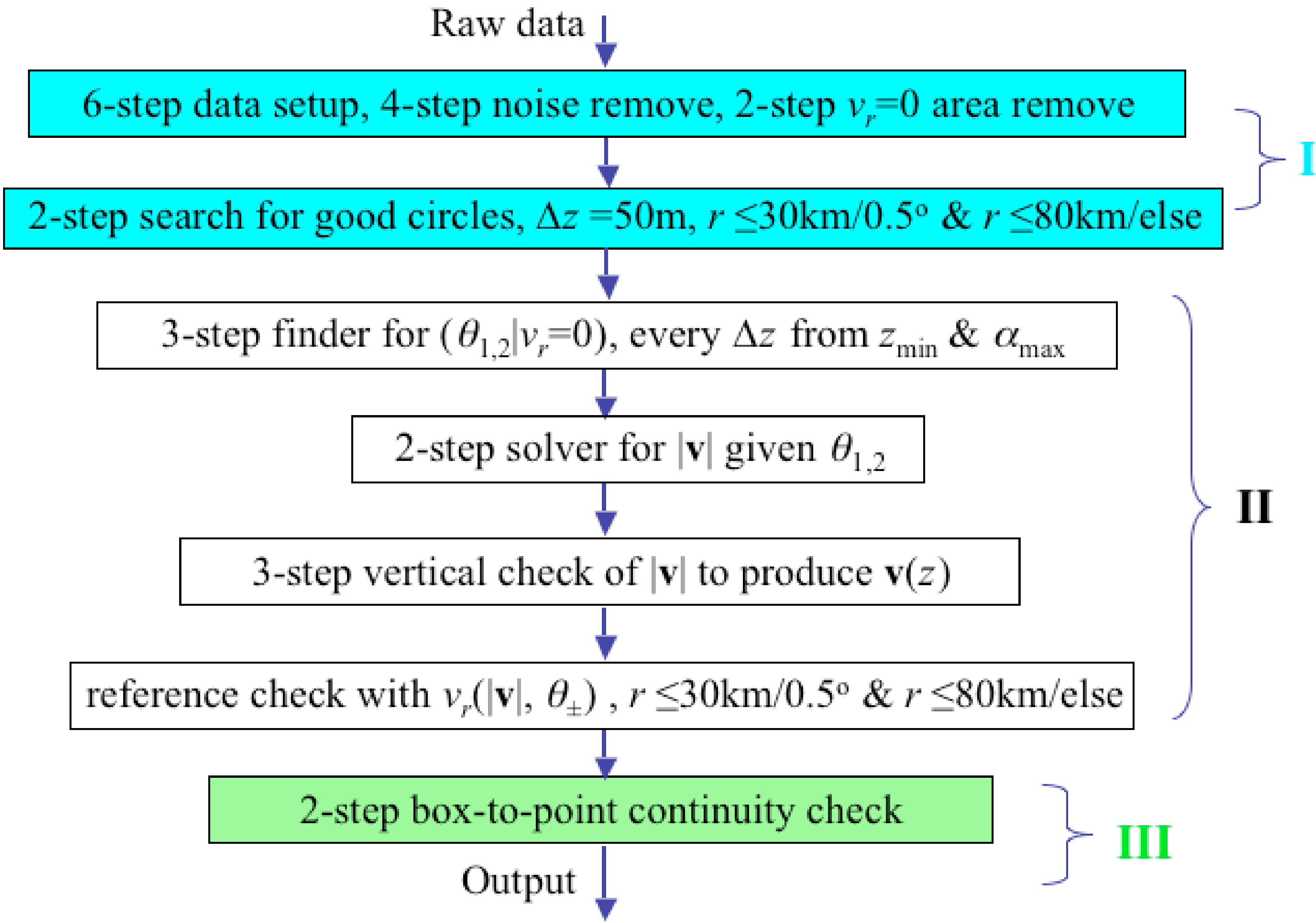
Examples



NyqVel=26m/s

KTLX 02:51 UTC, 4 May 1999

Dealiasing Algorithm Flow Chart

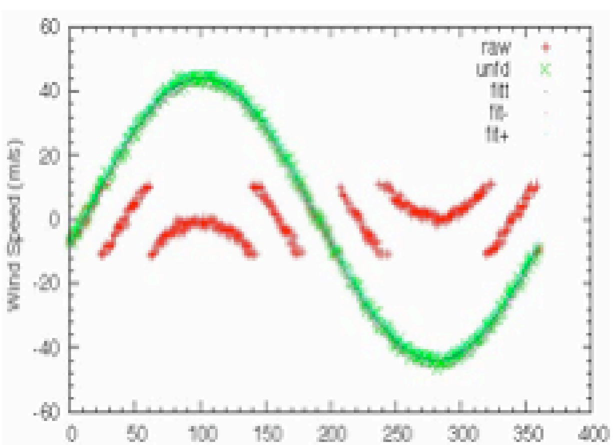


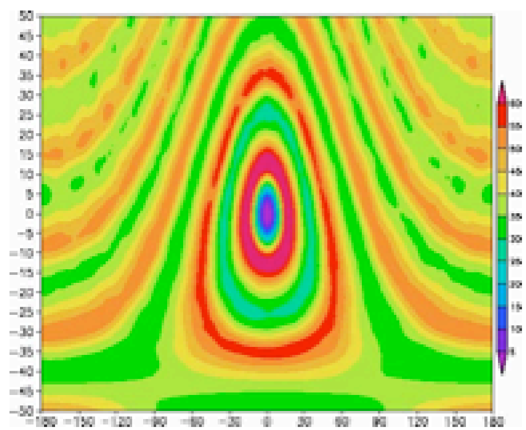
New VAD using aliased v_r

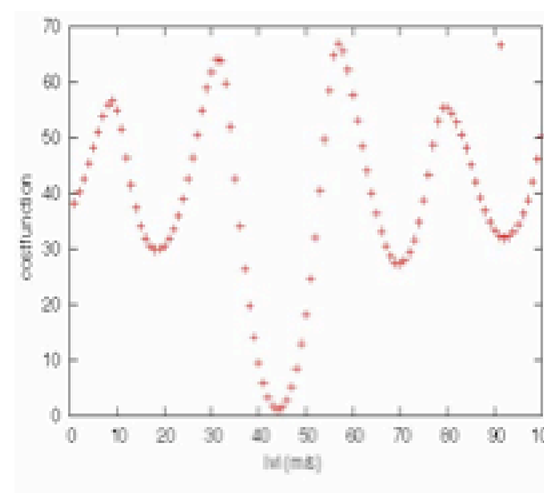
Raw obs $v_r^{ob} = Z[v_r^{true}]$, modeled obs $v_r = a + \cos\alpha(u_0 \sin\theta + v_0 \cos\theta) = |\mathbf{v}|\cos\alpha[\cos(\theta-\theta_+) - \cos\theta_-]$ where $\theta_+ = (\theta_1+\theta_2)/2$ & $\theta_- = (\theta_1-\theta_2)/2$.

3-steps search for $(\theta_{1,2}|v_r=0)$ for every Δz=50m from z_{min} & α_{max}.

Coarse+fine search for $|\mathbf{v}|$ to minimize the aliased rms difference between v_r and v_r^{ob} given $\theta_{1,2}$.

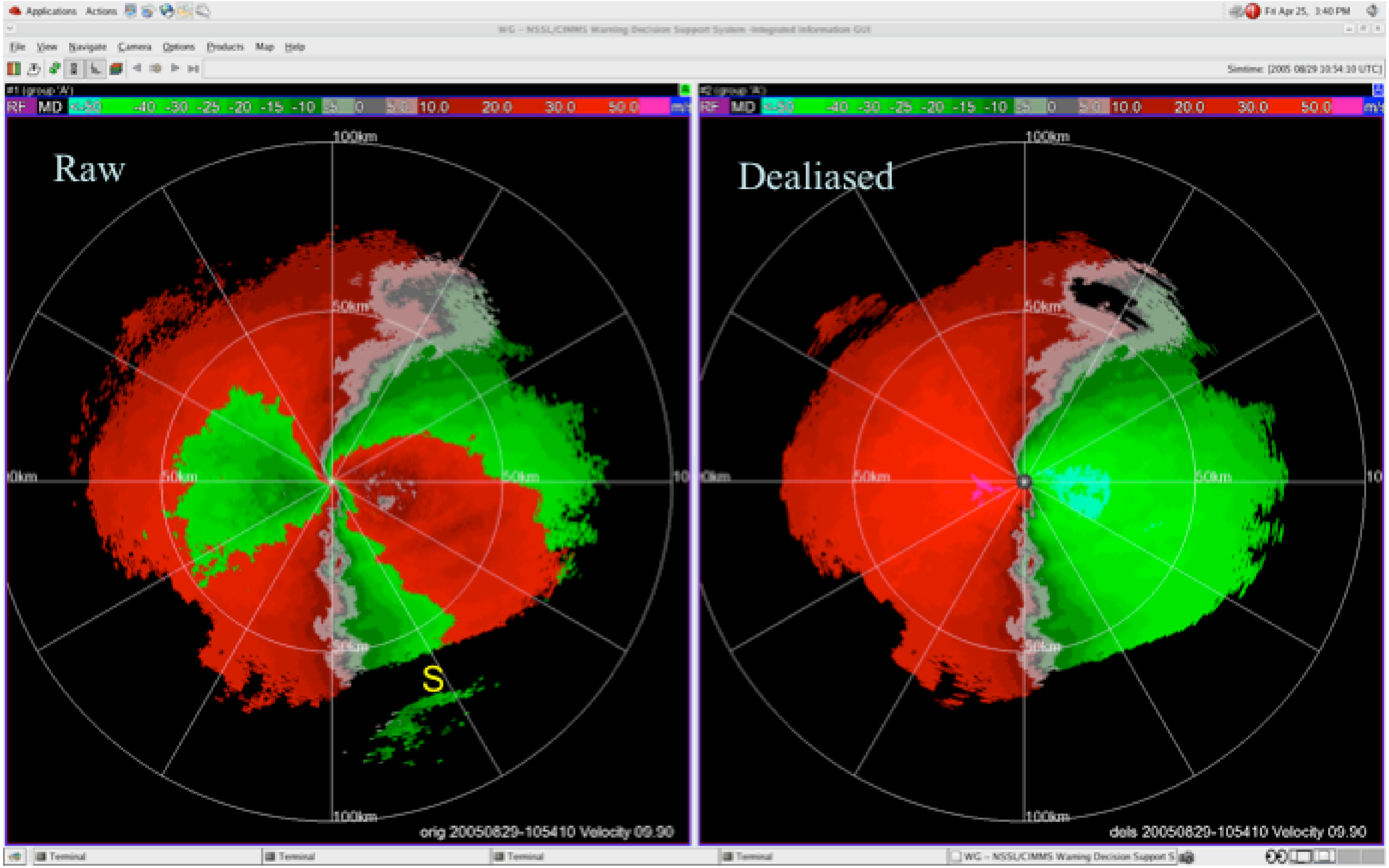




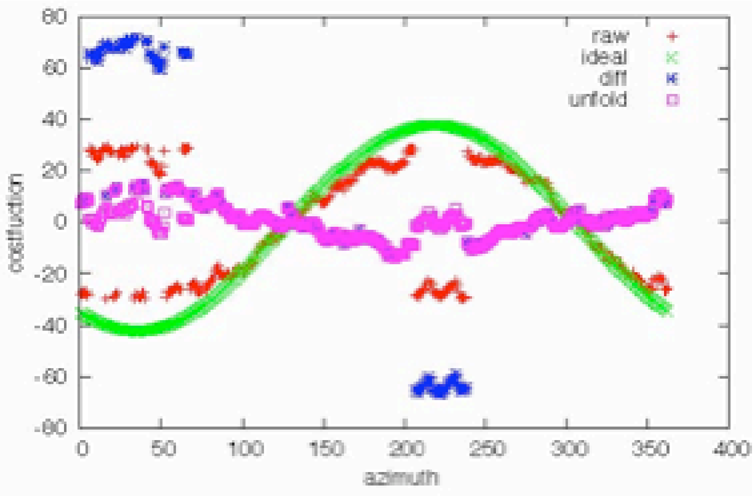


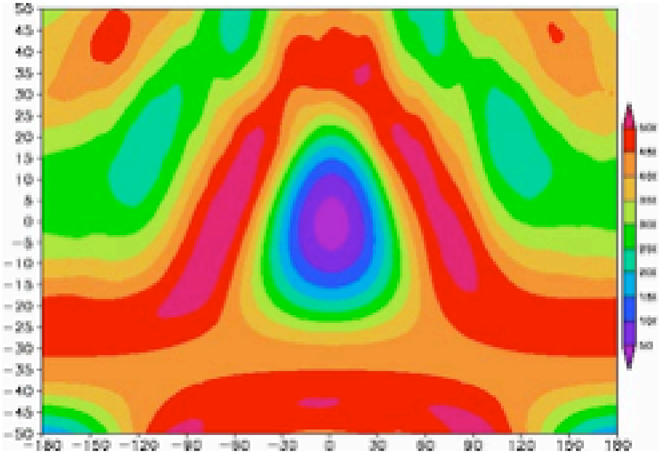
Test Example with Katrina High-wind Case

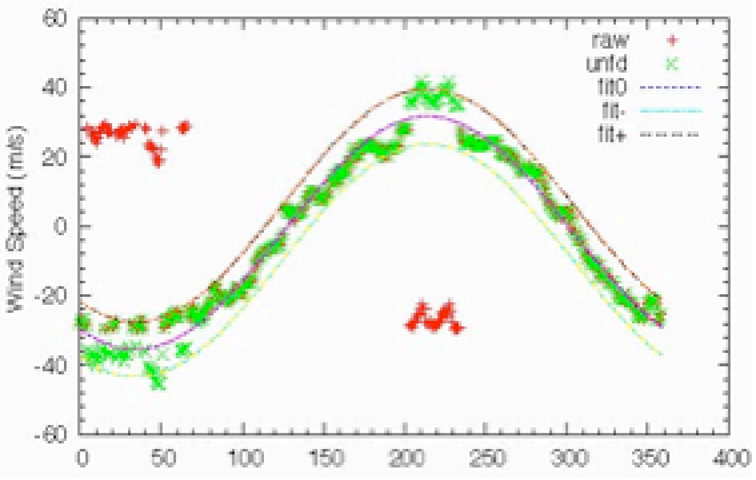
v_r from New Orland KLIX at 9.9º 10:54UTC 8/29/05



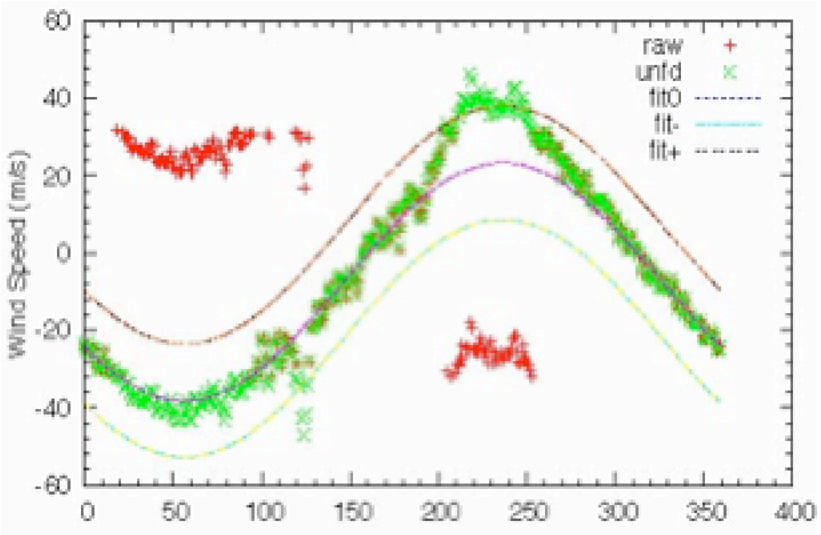
Obs and Fit on $\alpha = 9.9^{o}$ at z = 250m

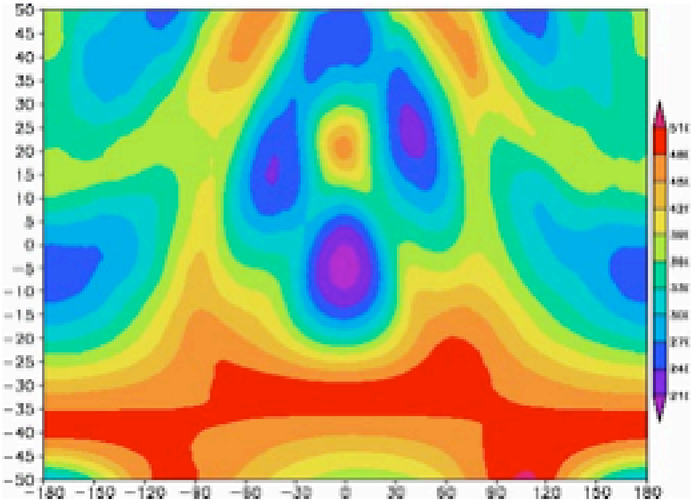






Obs and Fit on $\alpha = 0.15^o$ at $z = 500$m

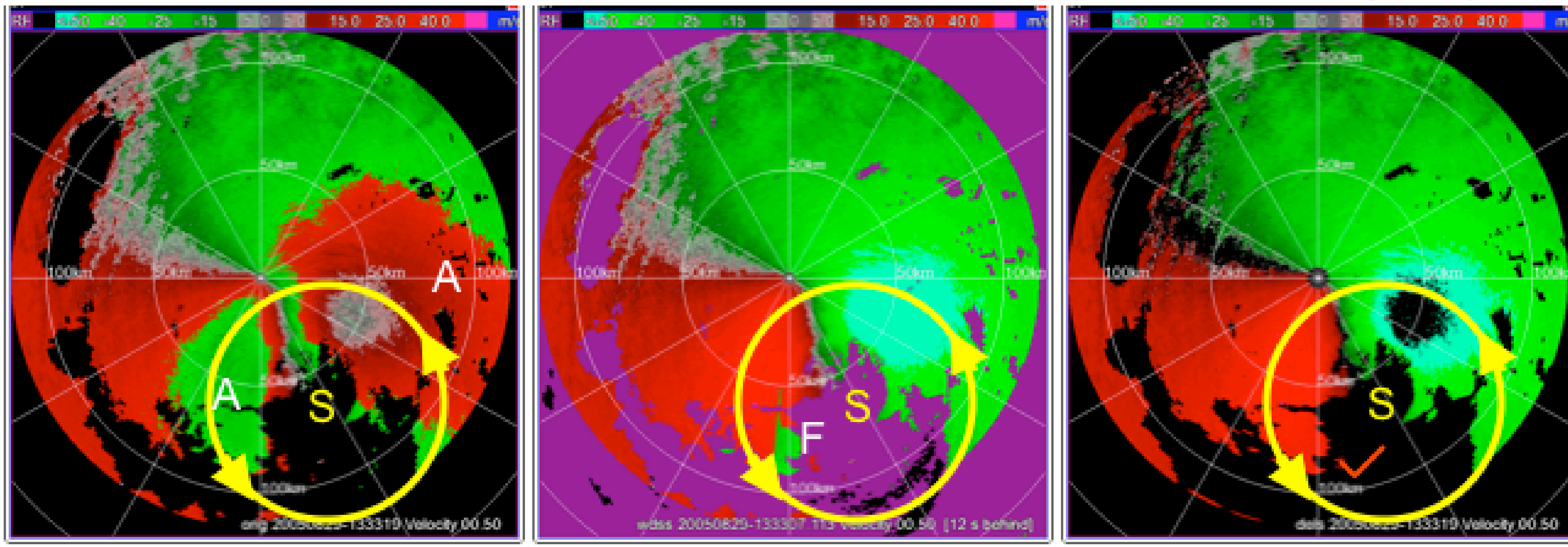




NSSL QC for NCEP: Improved dealiasing technique for radial-velocity Vr data

An example for challenging hurricane Katrina case

Raw Vr | dealiased Vr (WDSS-II) | dealiased Vr (new)



S : Center of Katrina 8/29/05

A : Aliased Vr from KLIX

F : Failed dealiasing area

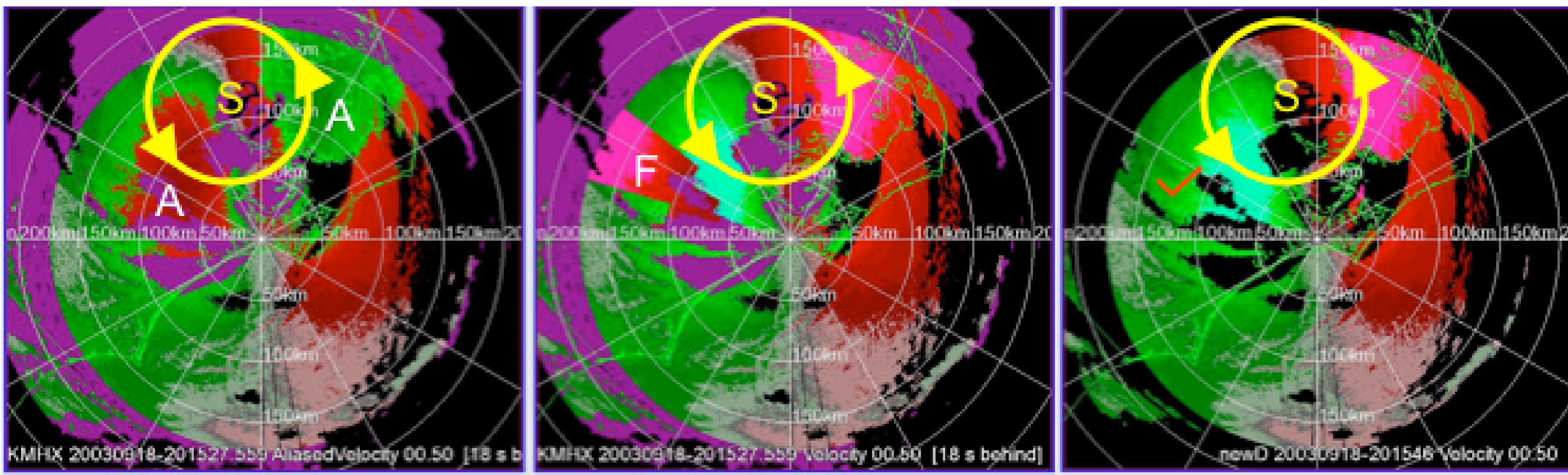
Green: toward the radar

***Red*:** away from the radar

NSSL QC for NCEP: Improved dealiasing technique for radial-velocity Vr data

An example for challenging hurricane high-wind cases

Raw V_r | dealiased V_r (WDSS-II) | dealiased V_r (new)



S : Center of Hurricane Isabel 9/18/03

A : Aliased Vr from KMHX (Morehead)

F : Failed dealiasing area

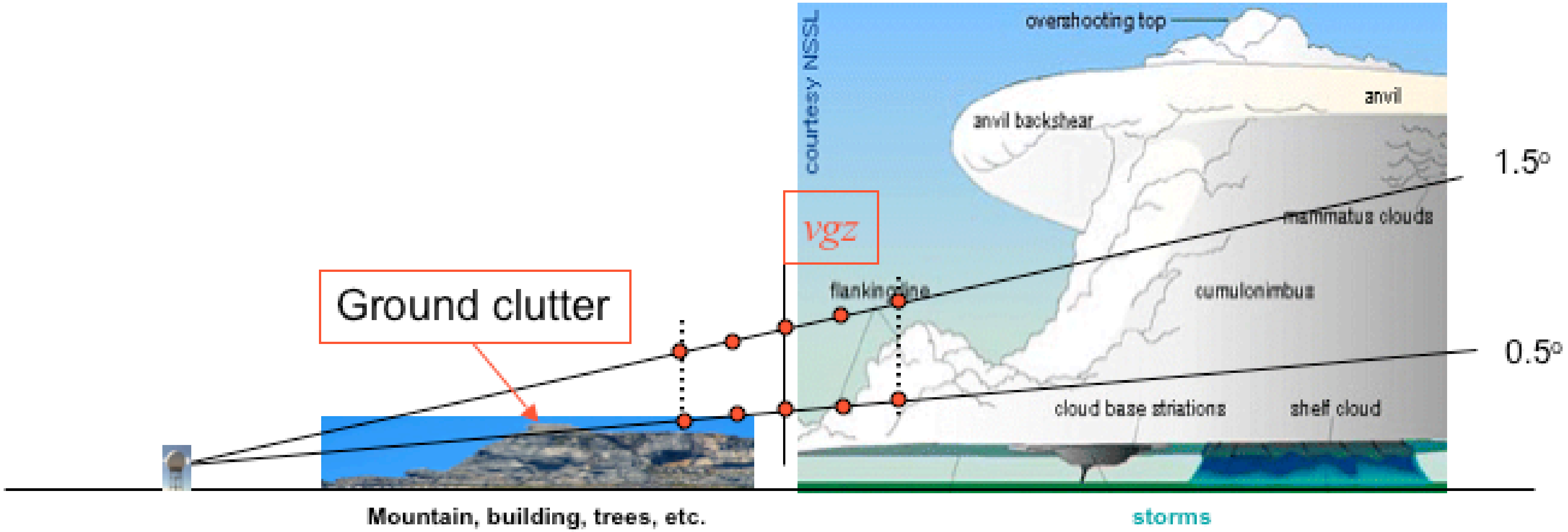
Green: toward the radar

Red: away from the radar

Simplified fussy logic method

3 parameters are selected:

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

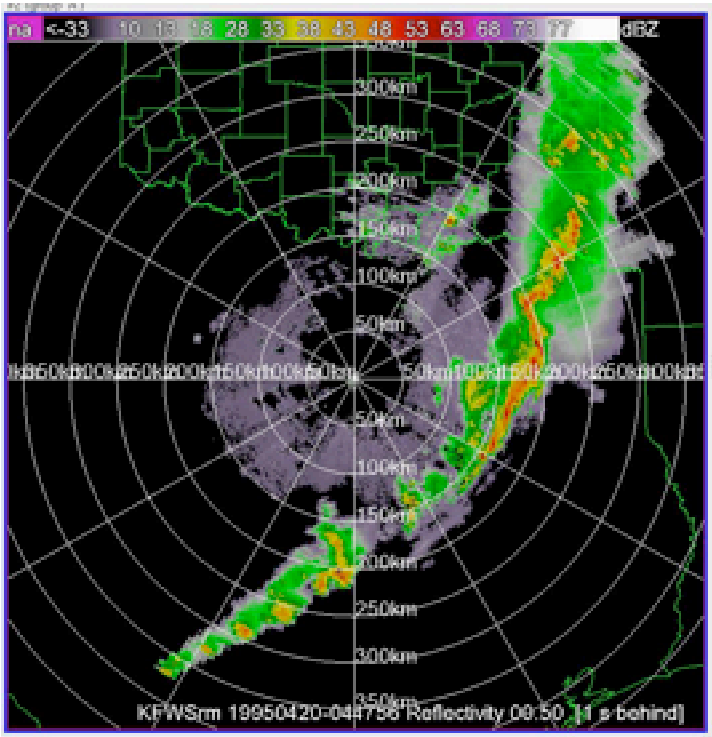


If 2 of 3 parameters are over the thresholds, then the gate at 0.5° elve. angle is marked as ground/sea clutter.

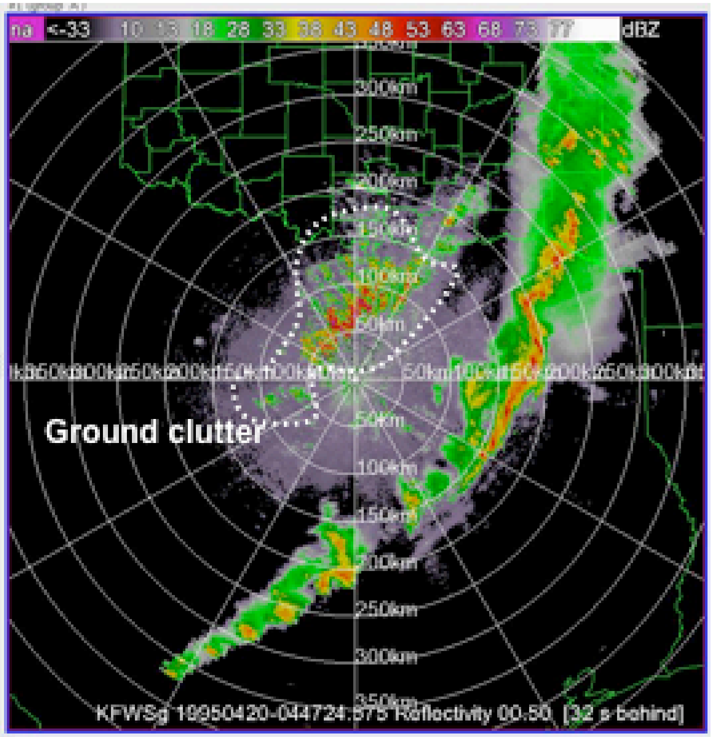
A typical ground clutter case

KFWS @ 19950420 0447 UTC

Z after QC



Z Raw



A typical ground clutter case

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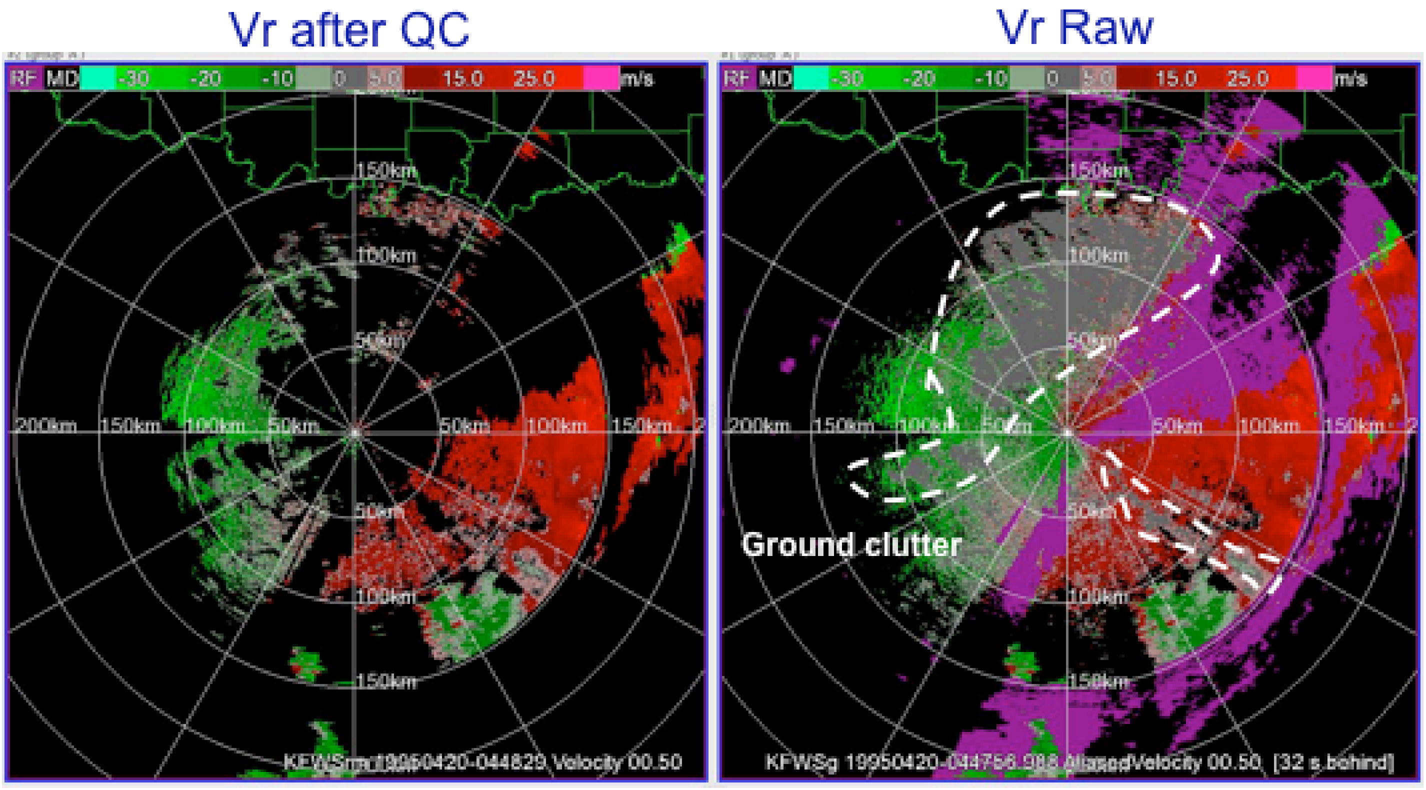
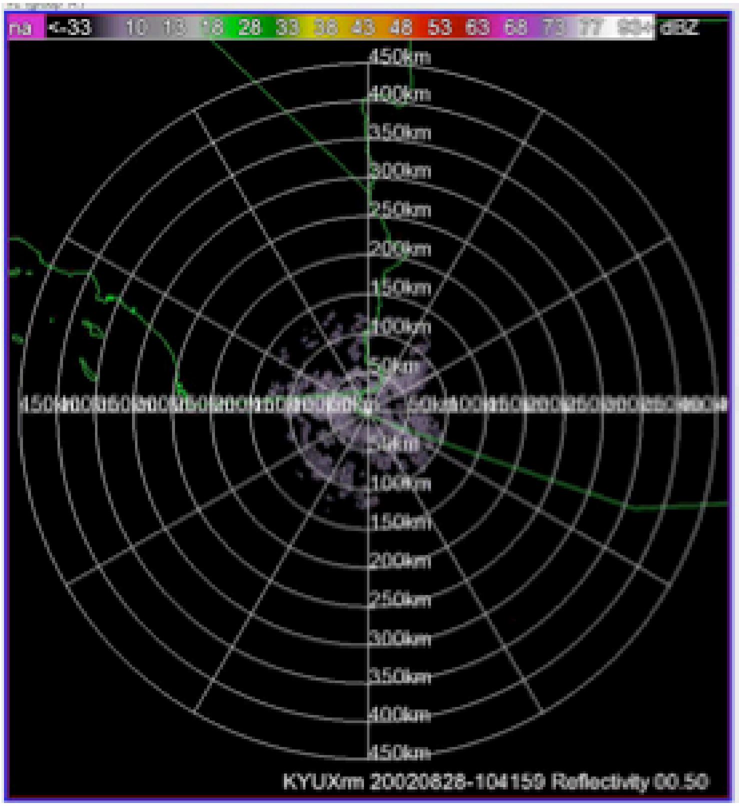


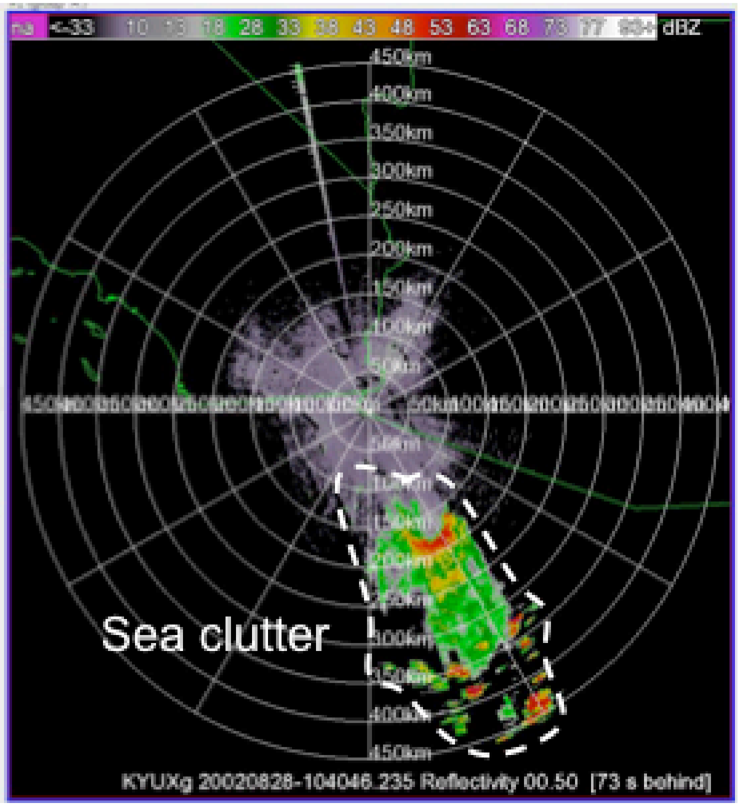
An extreme sea clutter case

KYUX @20020828 1041 UTC

Z after QC

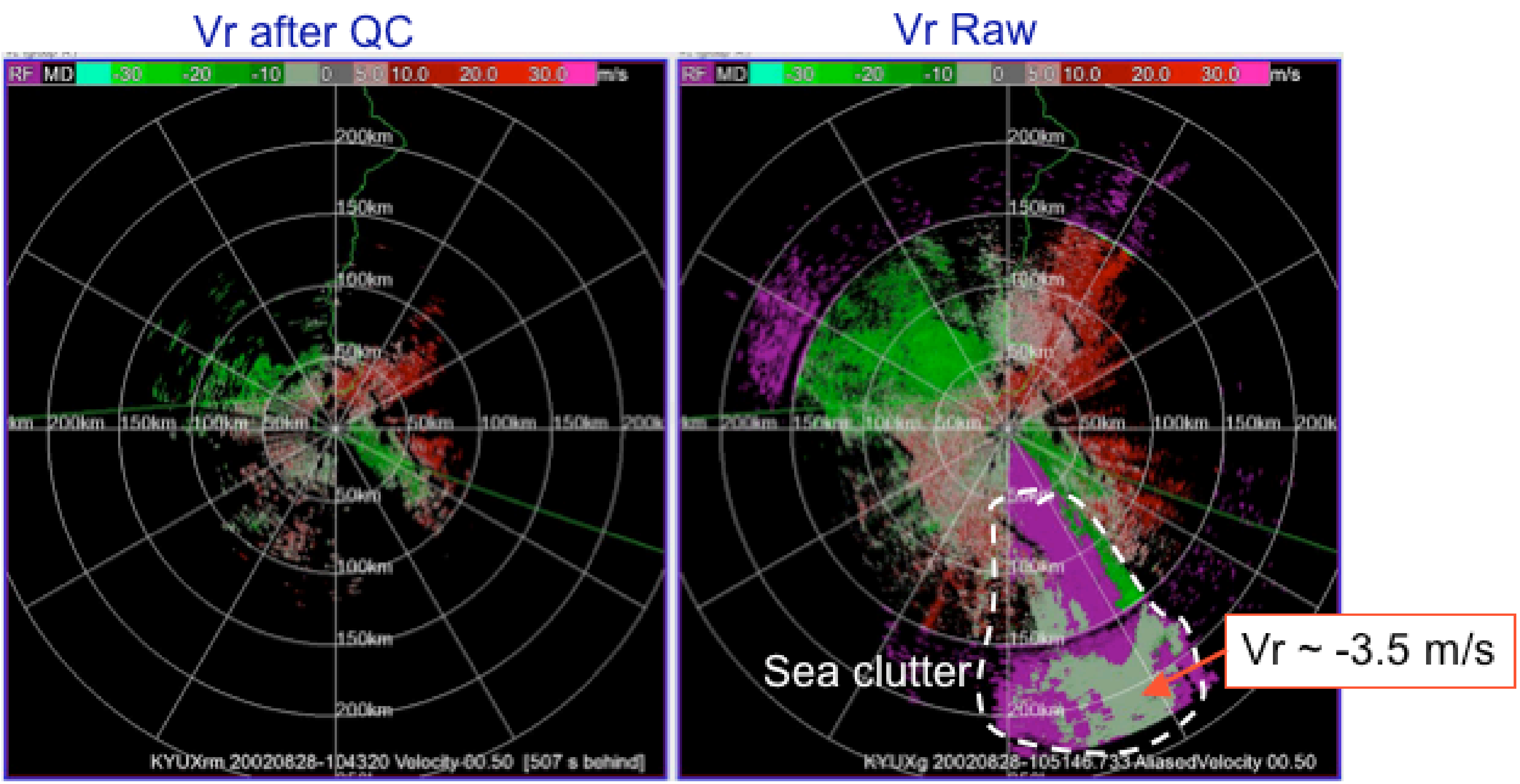


Z Raw



An extreme sea clutter case

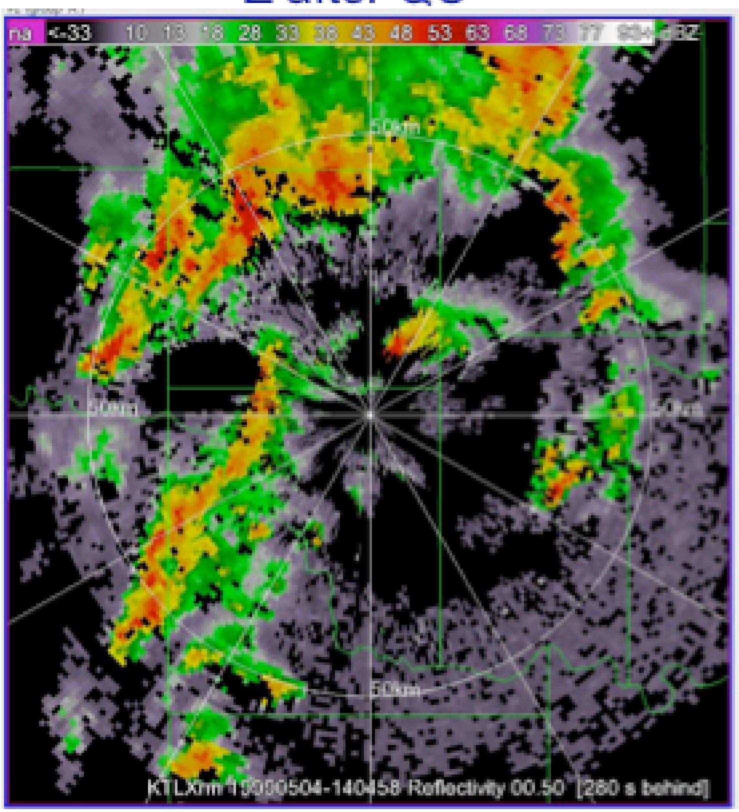
KYUX @20020828 1041 UTC



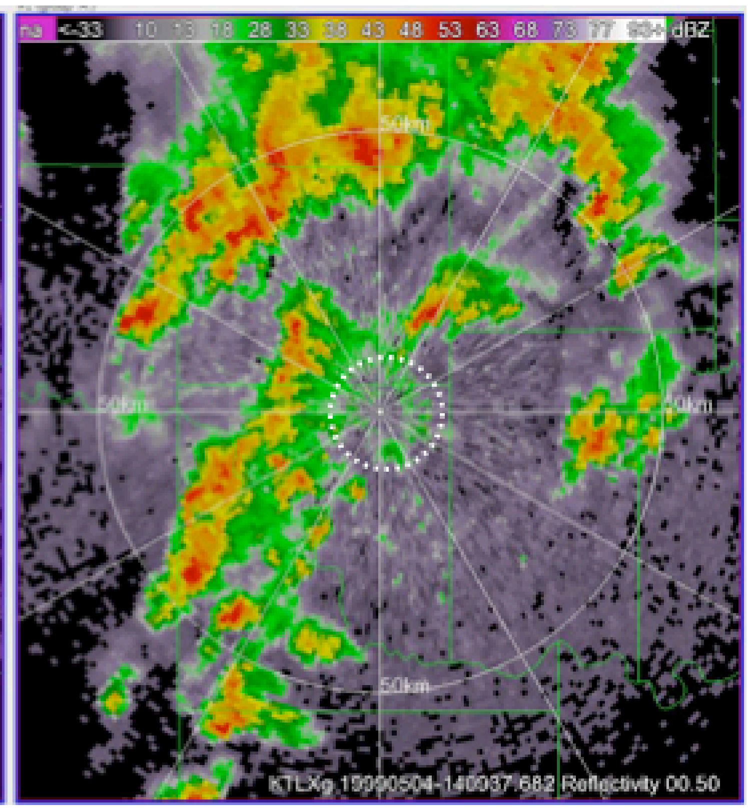
A normal ground clutter near radar case

KTLX @ 19990504 1404 UTC

Z after QC



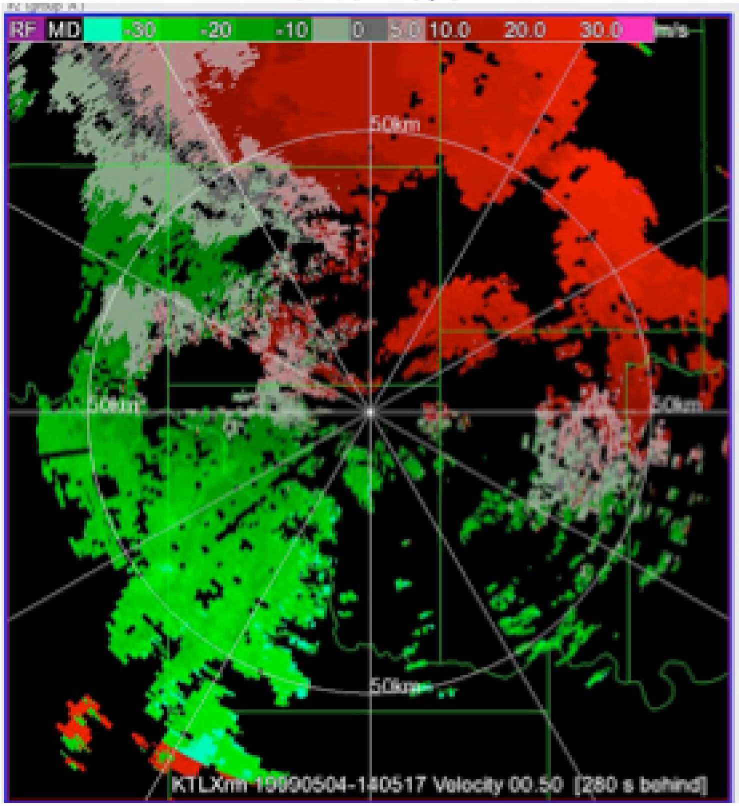
Z Raw



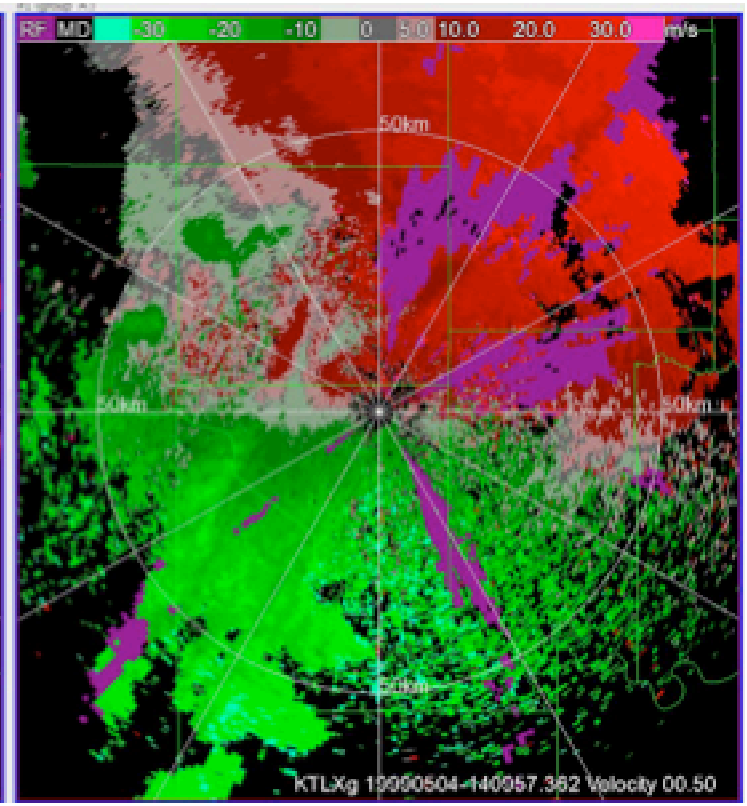
A normal ground clutter near radar case

KTLX @ 19990504 1405 UTC

Vr after QC



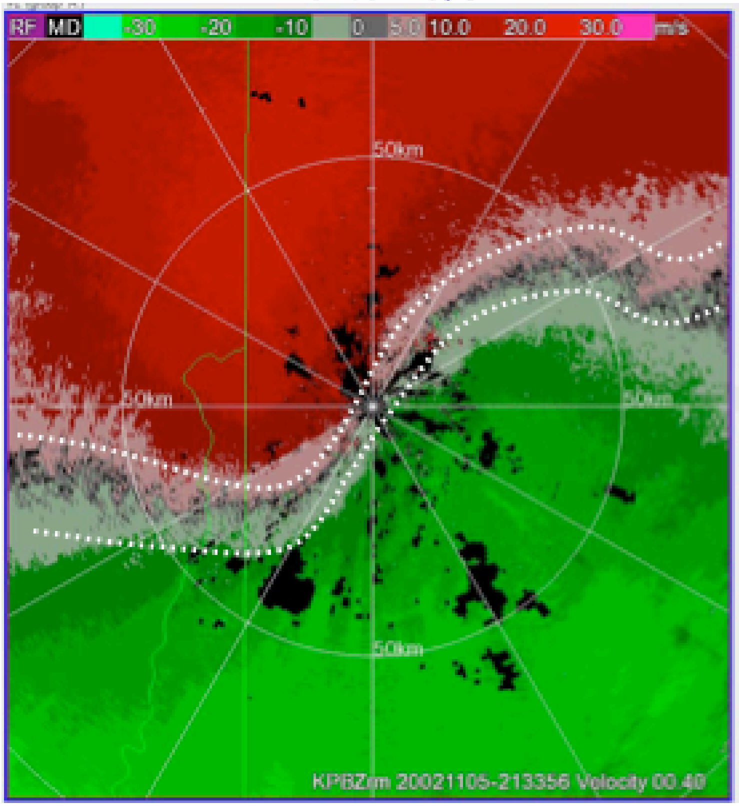
Vr Raw



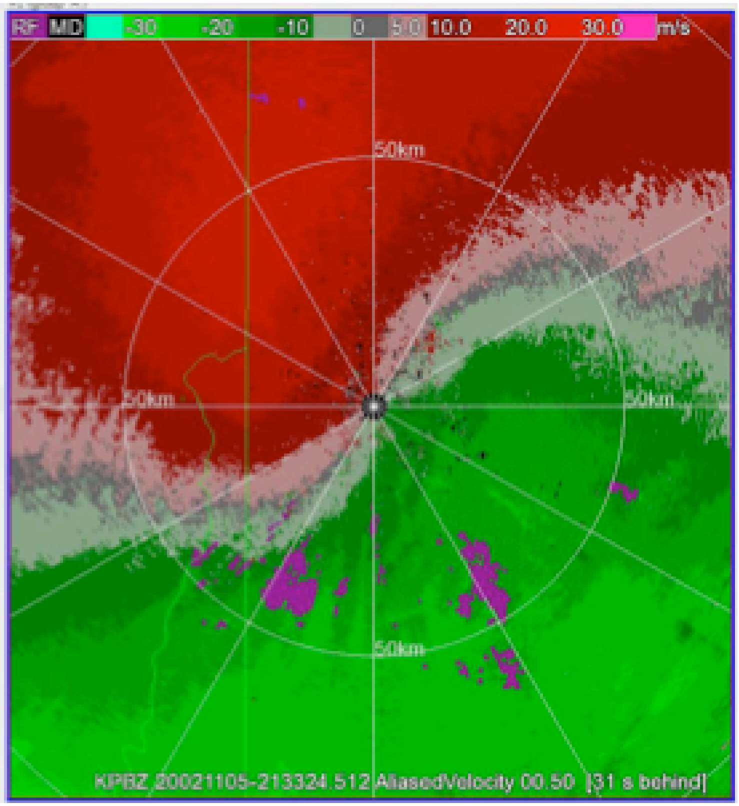
Overkill on zero Doppler velocity isoline

KPBZ @20021105 2133 UTC

Vr after QC



Vr Raw

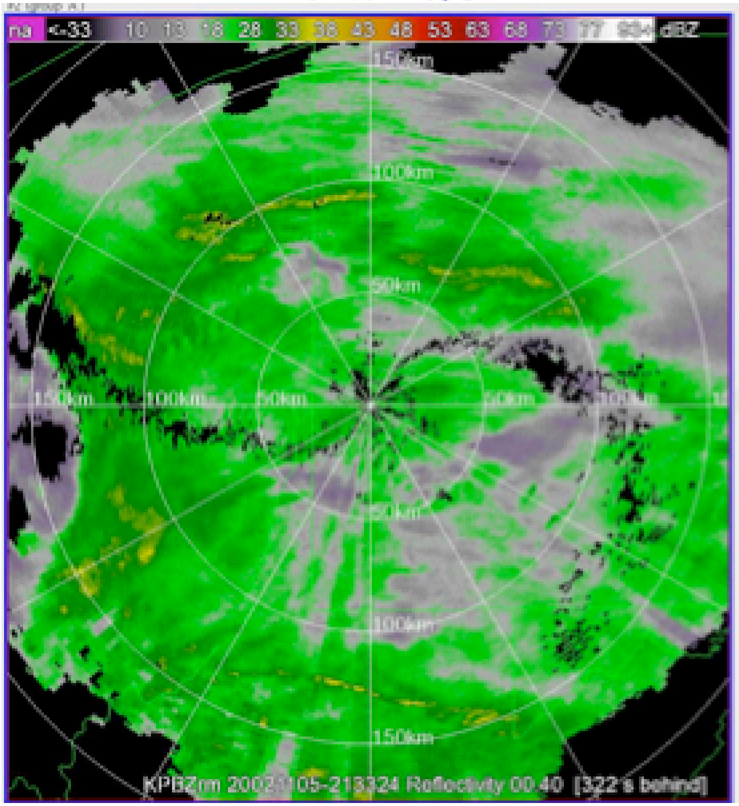


Beware: the scale of this image is different from the following one.

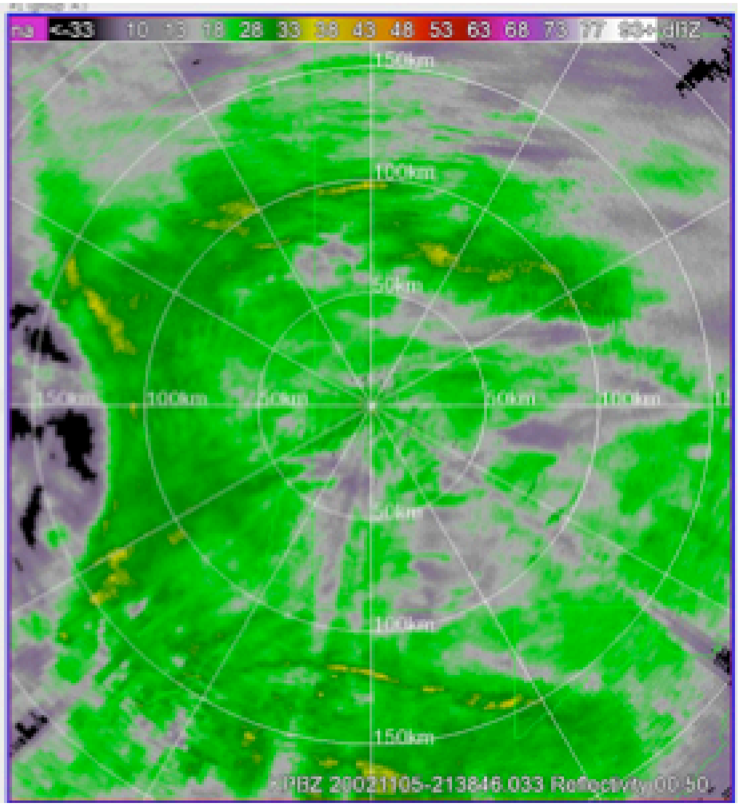
Overkill on zero Doppler velocity isoline

KPBZ @20021105 2133 UTC

Z after QC



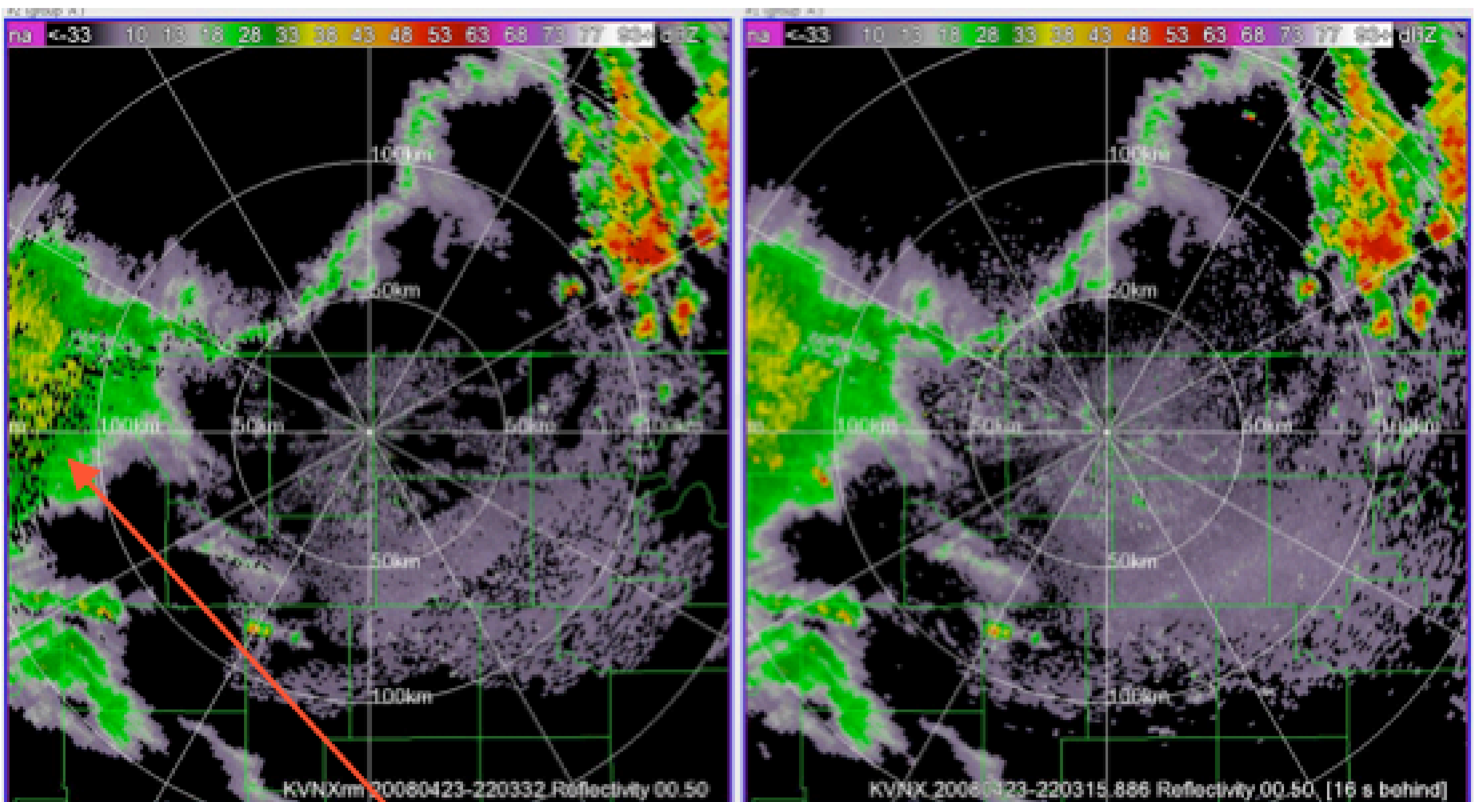
Z Raw



A normal observation in precipitation mode

KVNX @20080423-2203 UTC

Z after QC | Z Raw

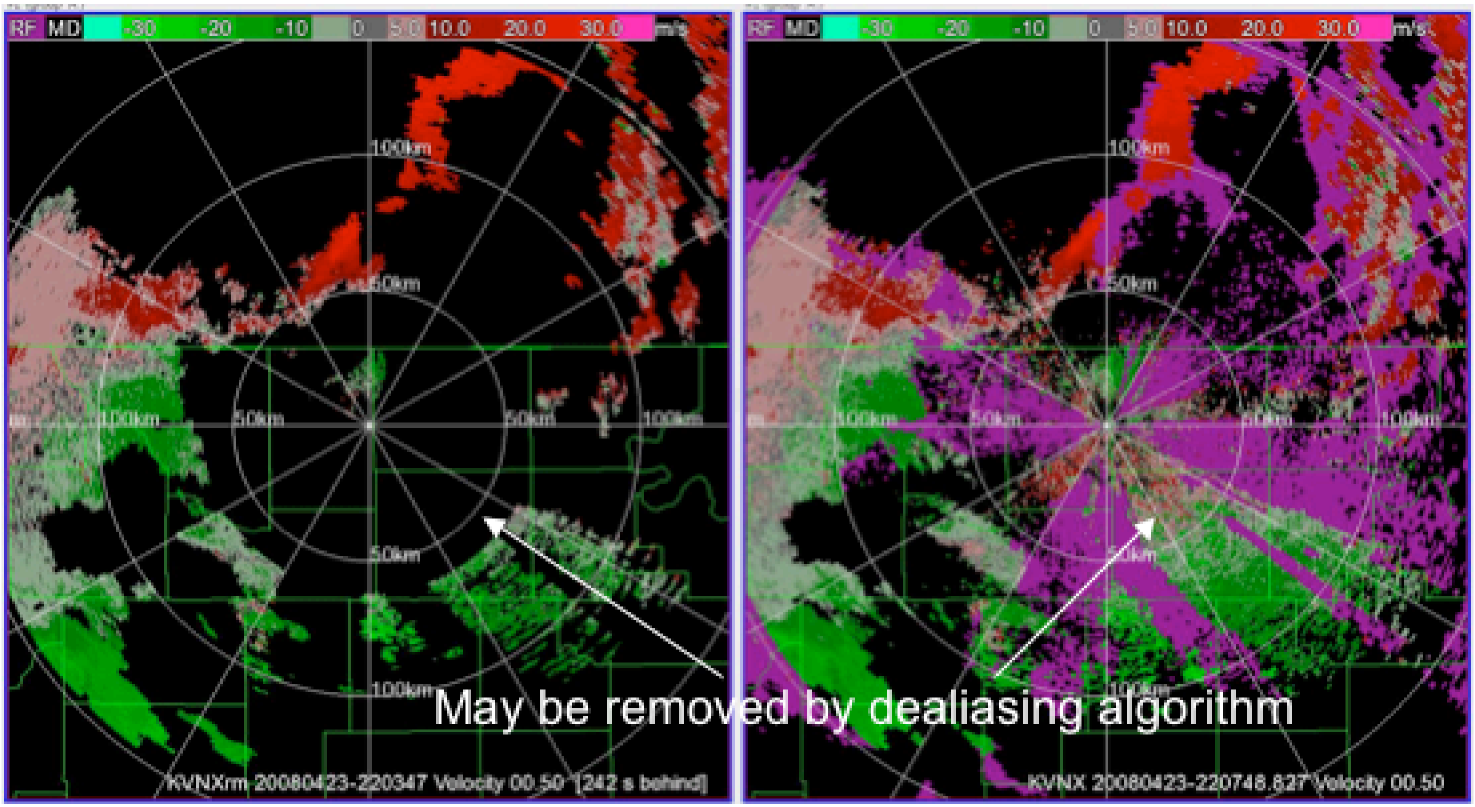


Overkill in the precipitation region

A normal observation in precipitation mode

KVNX @20080423-2203 UTC

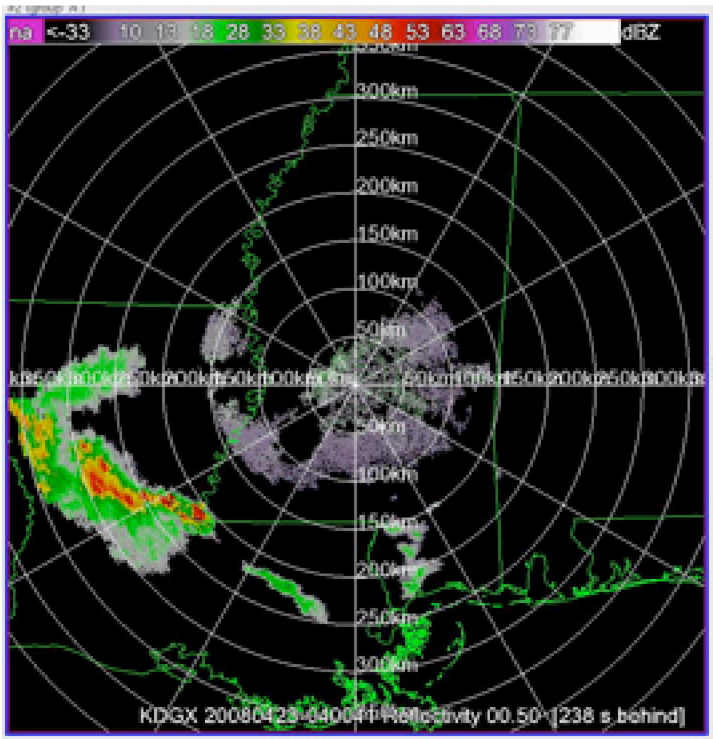
Vr after QC | Vr Raw



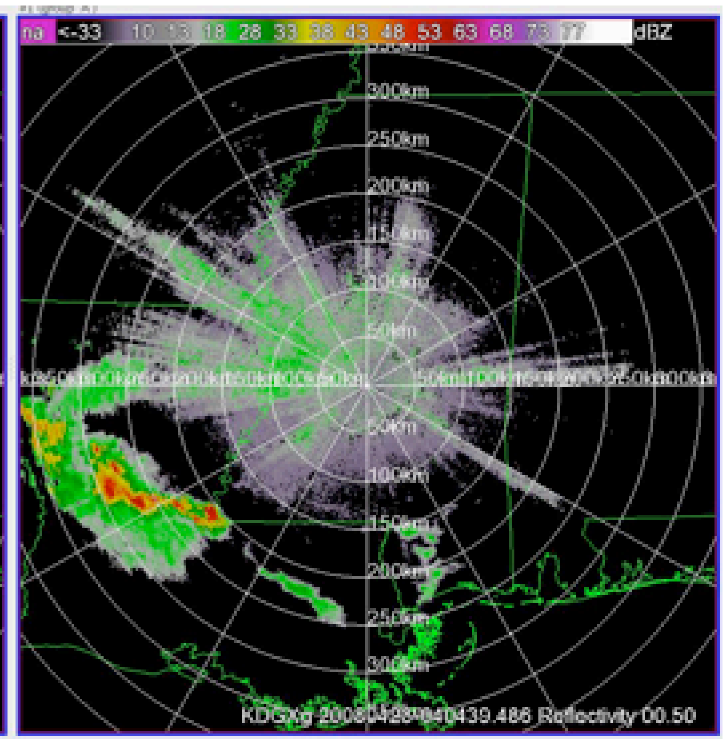
A weak AP case

KDGX @20080423 0400 UTC

Z after QC



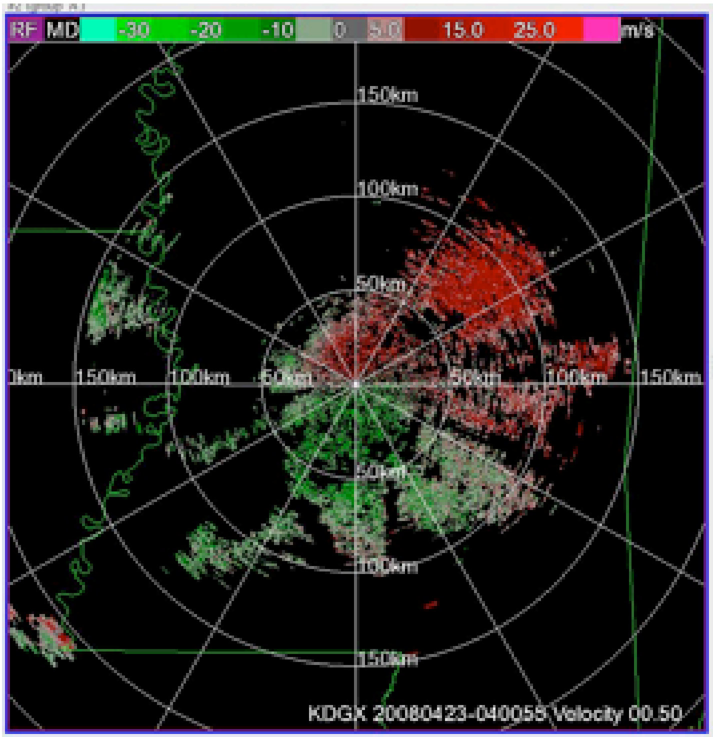
Z Raw



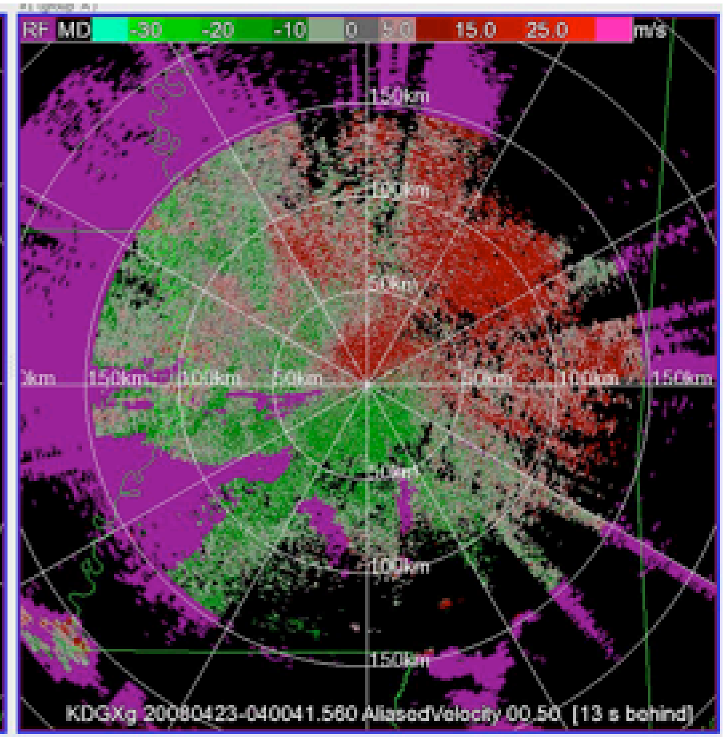
A weak AP case

KDGX @20080423 0400 UTC

Vr after QC



Vr Raw

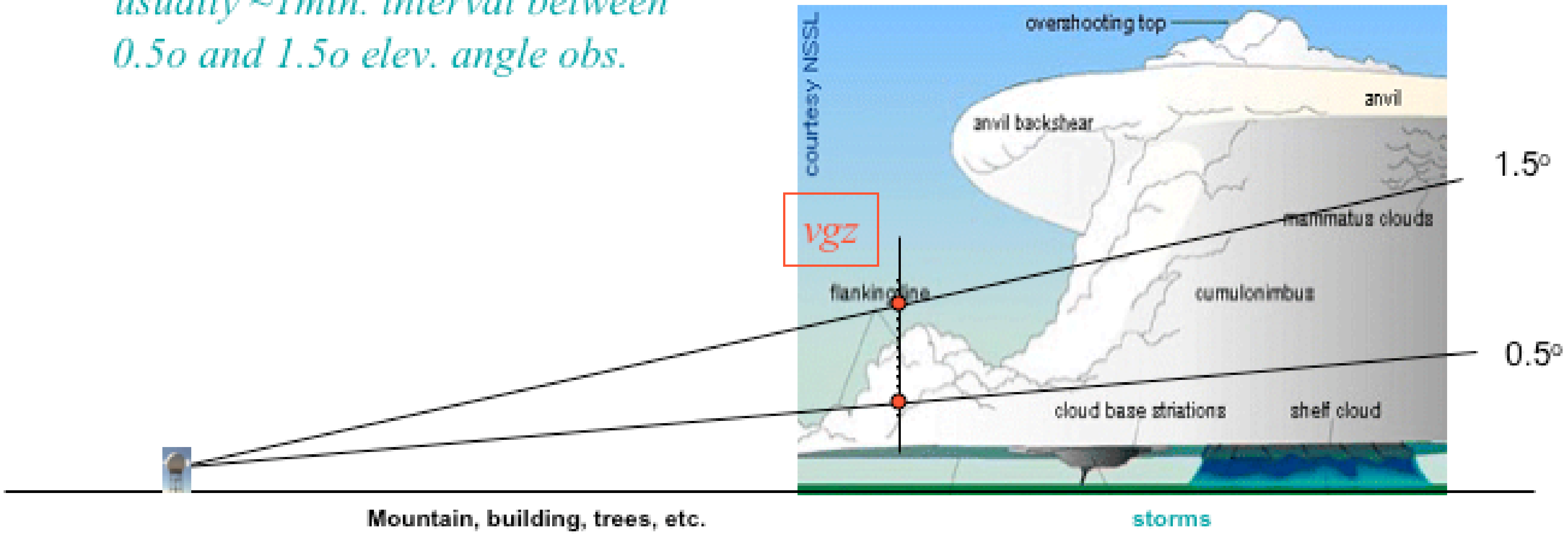


Portion of storm echoes may be removed

- Vertical gradient of Z

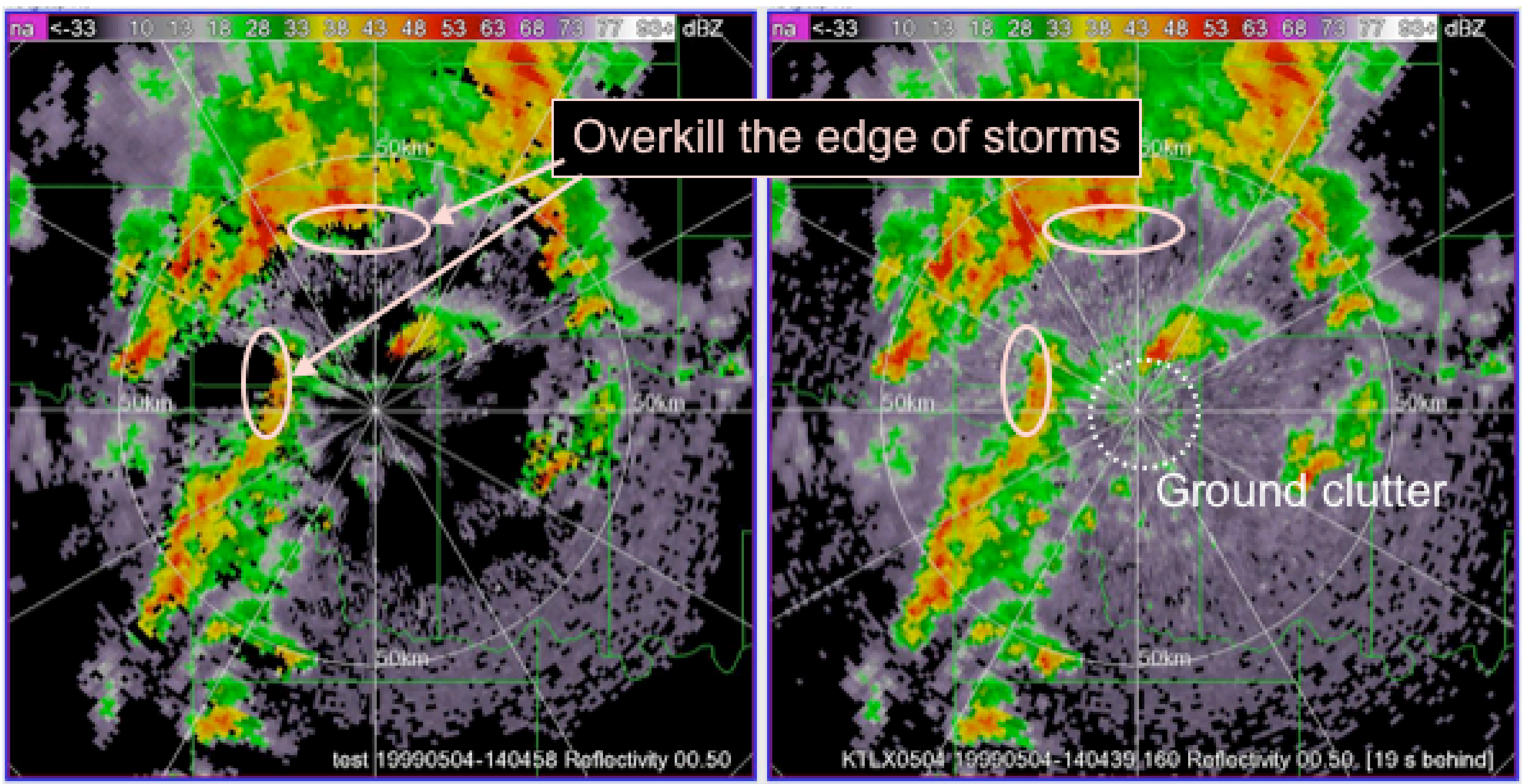
  storm is not a perfect vertical column
- Fast movement of storm

  usually ~1min. interval between 0.5o and 1.5o elev. angle obs.



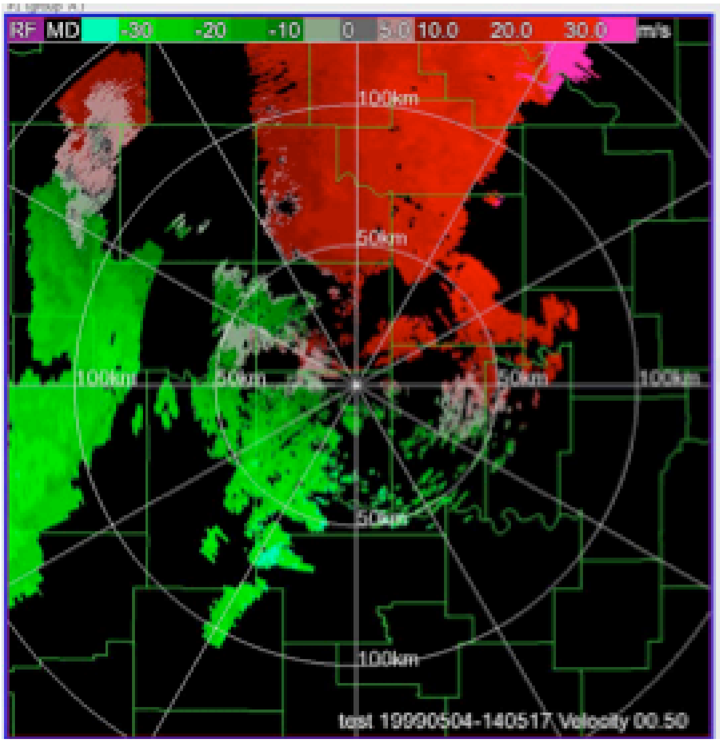
Portion of storm echoes removed

Z after QC | Z Raw

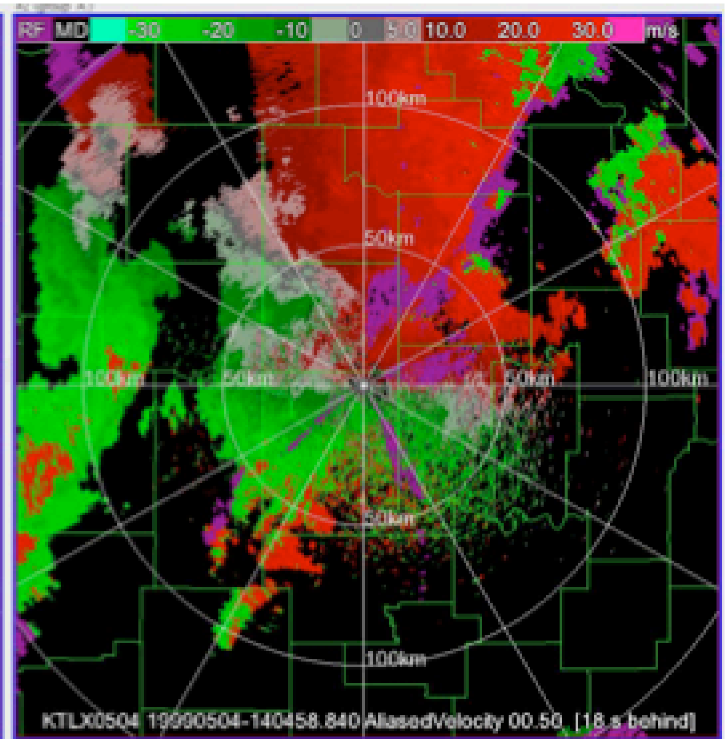


Portion of storm echoes removed

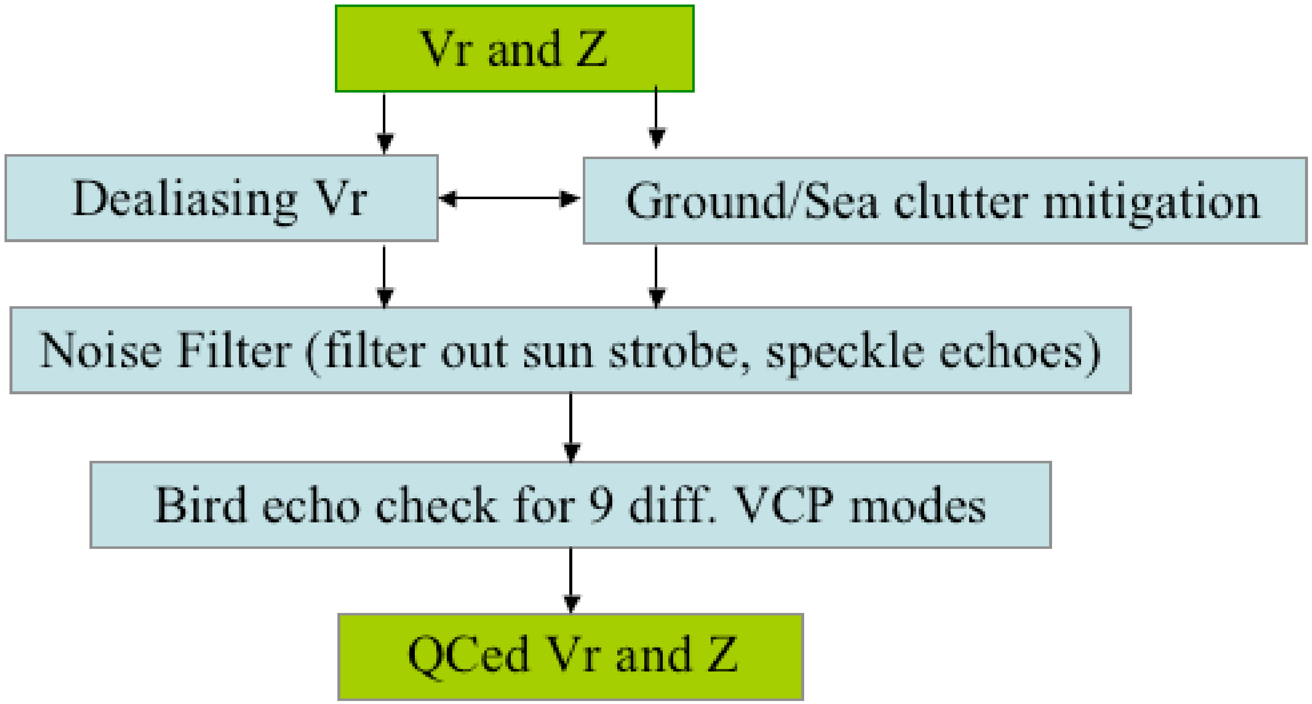
Vr after QC



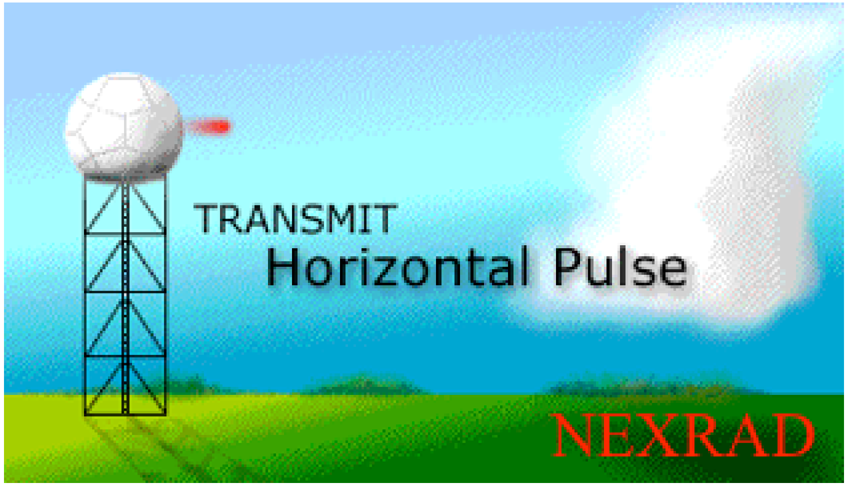
Vr Raw

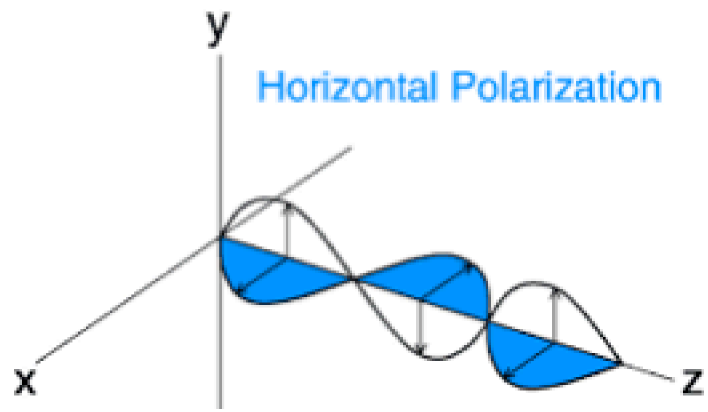


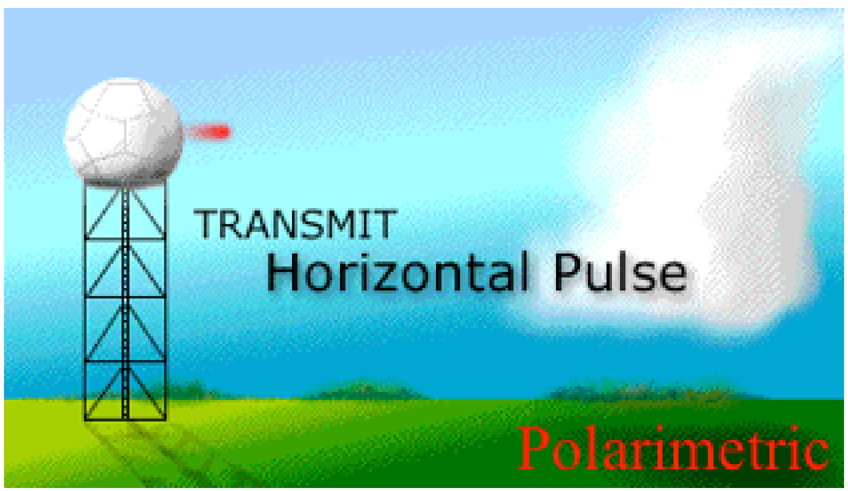
New Flow Chart of QC process

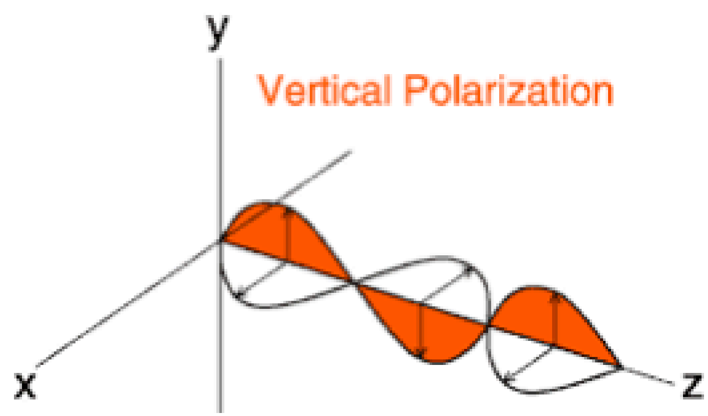


What is a polarimetric radar?





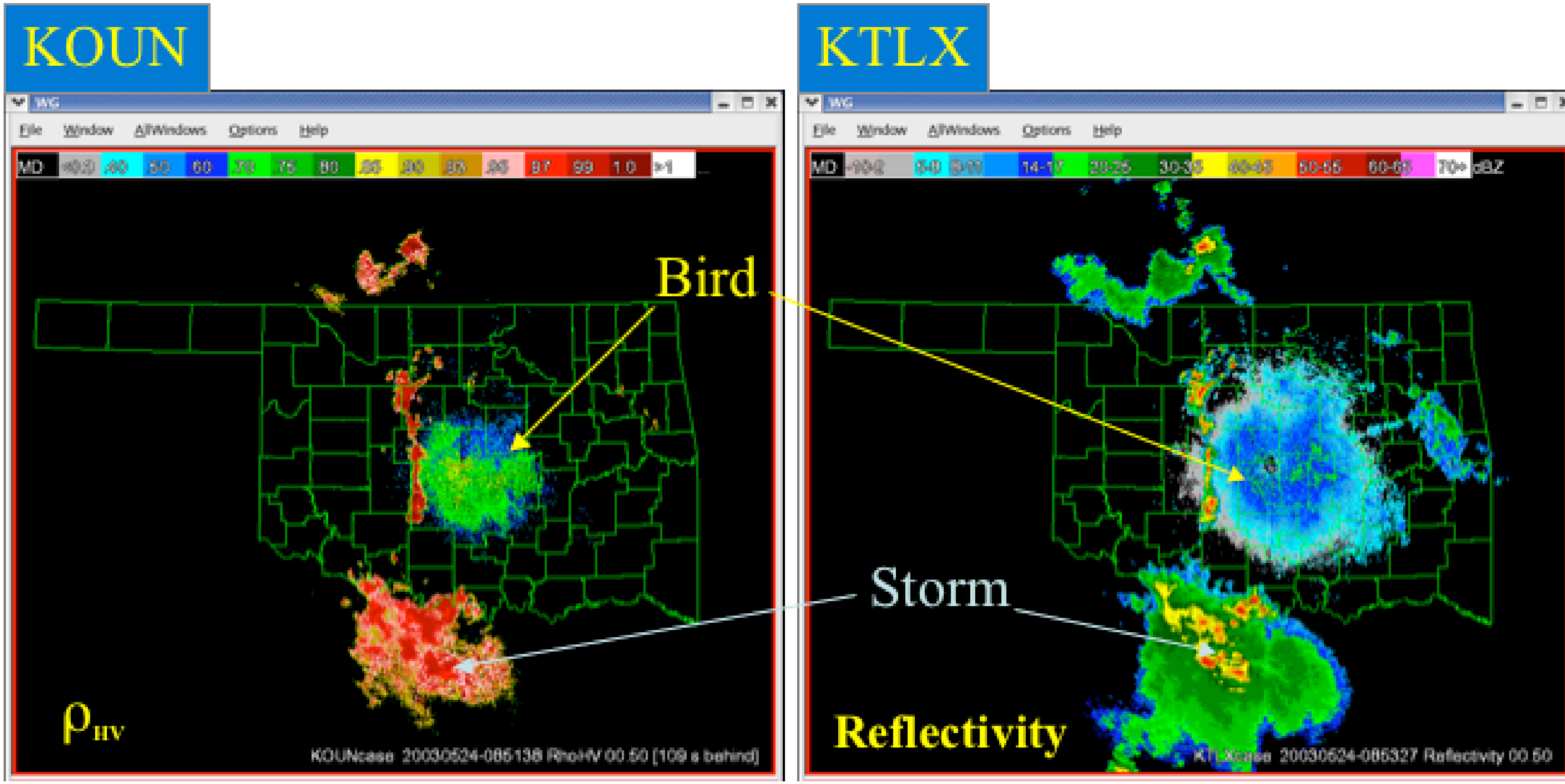




More information about polarimetric radar research:

http://www.cimms.ou.edu/~schuur/dualpol/

Polarimetric (KOUN) vs WSR-88D (KTLX)



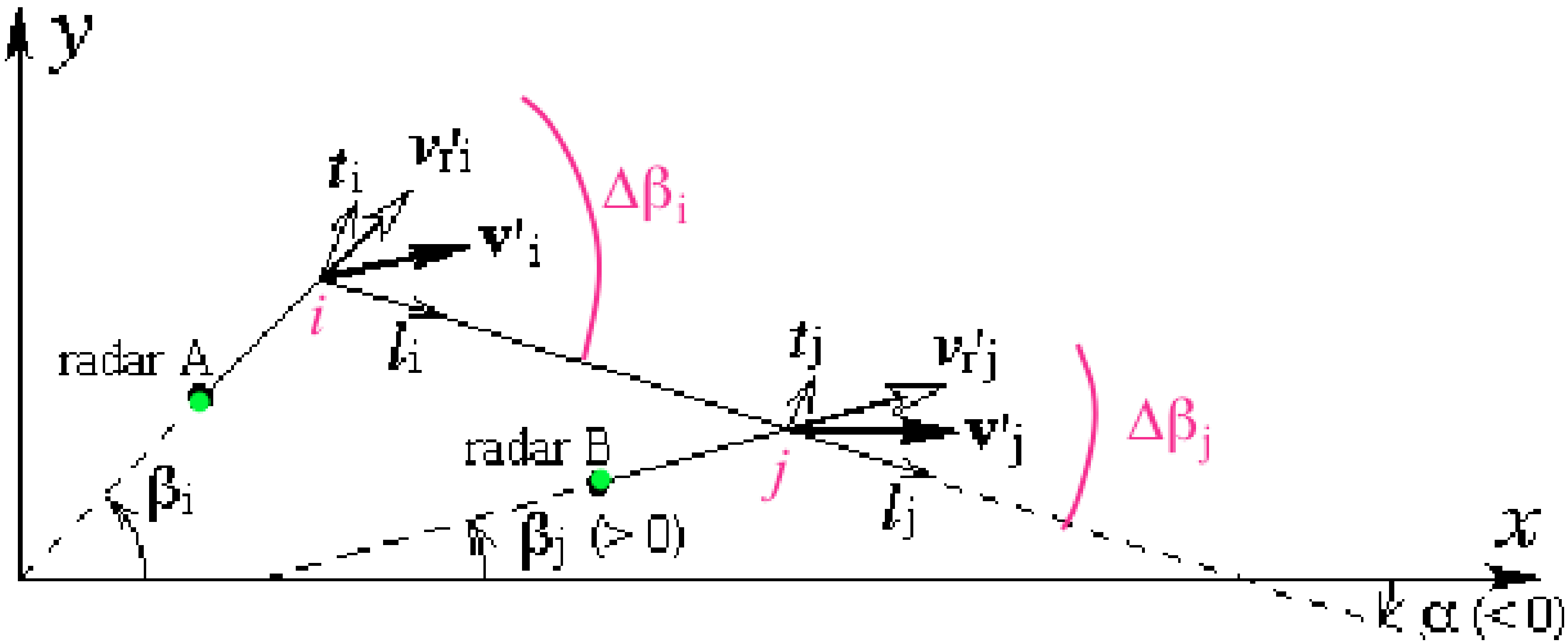
May 24 2003 0852UTC

Covariance Formulation for v_r:

Radial-velocity covariance (Xu and Gong 2003) is extended:

$$C_{vr} = 0.5(C_+ \cos\beta_- + C_- \cos\beta_+),$$

where $C_+ = C_{ll} + C_{tt}$, $C_- = C_{ll} - C_{tt}$, $\beta_- = \Delta\beta_i - \Delta\beta_j$, $\beta_+ = \Delta\beta_i + \Delta\beta_j$, $C_{ll} = \langle l_i l_j \rangle$ and $C_{tt} = \langle t_i t_j \rangle$ are functions of the distance r between points i and j.

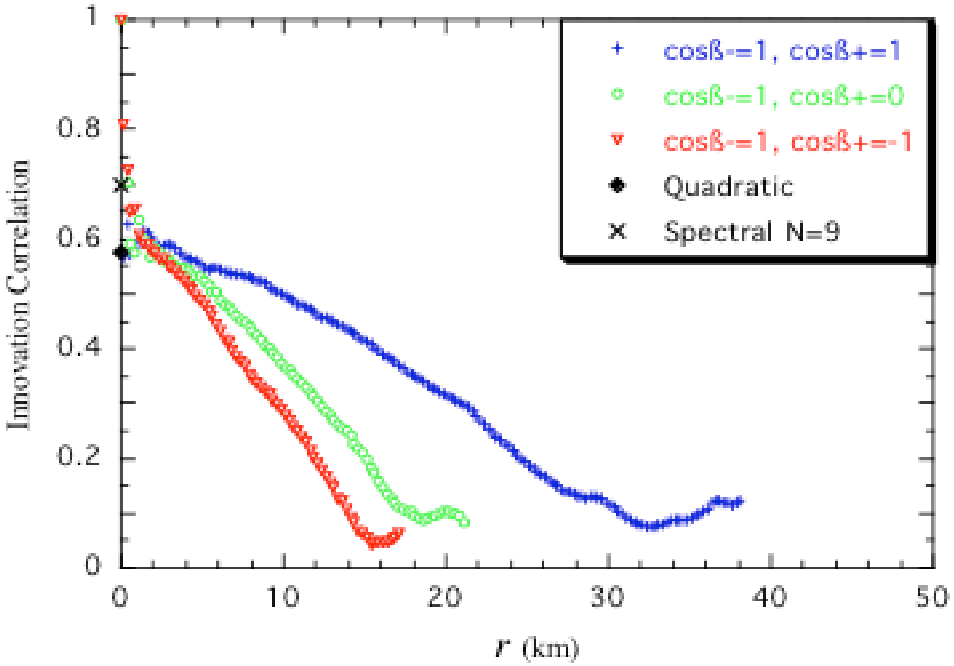


Innovation (v_{ri}^{d} = obs - back) Covariance Partition:

$$\langle v_{ri}^{d} v_{rj}^{d} \rangle = \begin{cases} C_{vr}^{b} & \text{for } r \geq r_o \\ C_{vr}^{o} + C_{vr}^{b} & \text{for } r < r_o, \end{cases}$$

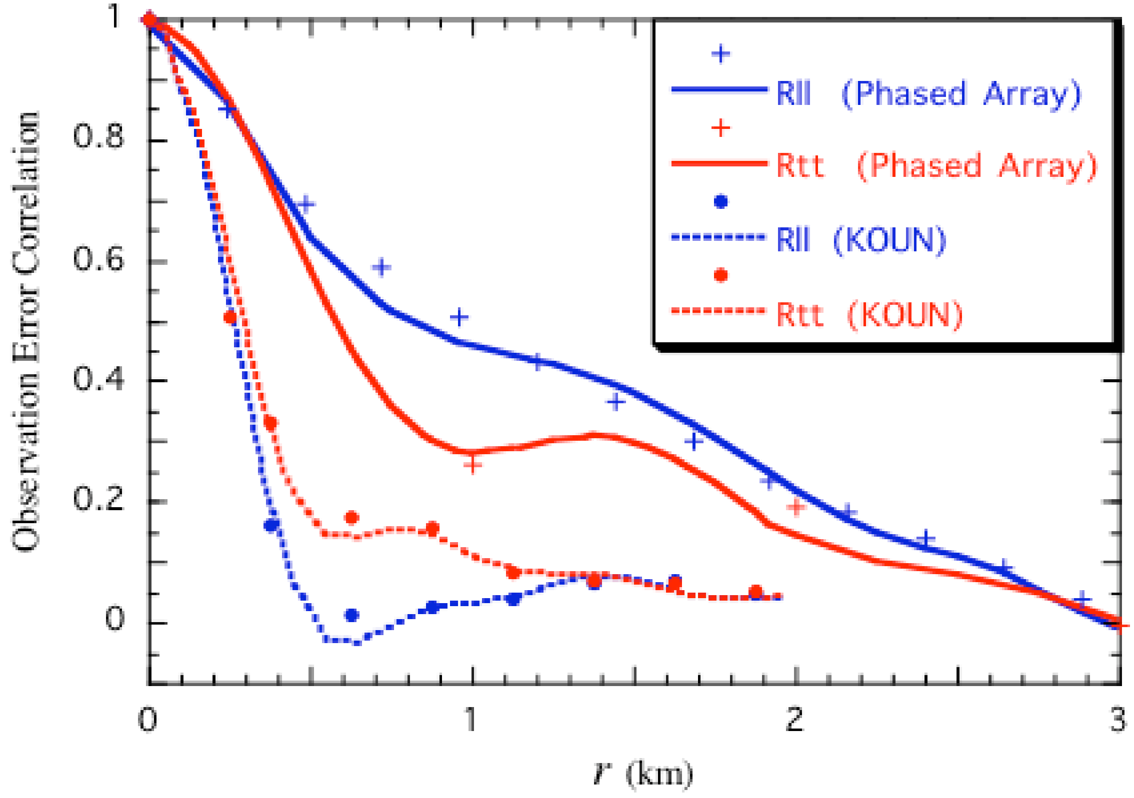
where C_{vr}^{o} and C_{vr}^{b} are obs and background error covariances modeled by (1), and r_o is the range of obs error correlation.

Previous Single-Radar Results:



Obs: phased-array 25 volumes (every 2 min, 21-22 UTC 6/2/04). Back: COAMPS predictions.

Binned innovation correlation data points over the range of $0 \leq r \leq 50$ km for three sets of bin intervals in the vicinities of $\cos\beta_- = 1$ and $\cos\beta_+ = 1, 0, -1$, respectively.



Obs error correlation data points:

+ for phased-array radar with 1.6^0 beam, stormy weather;

• for KOUN (Xu et al. 2006) with 1^0 beam, calm weather.

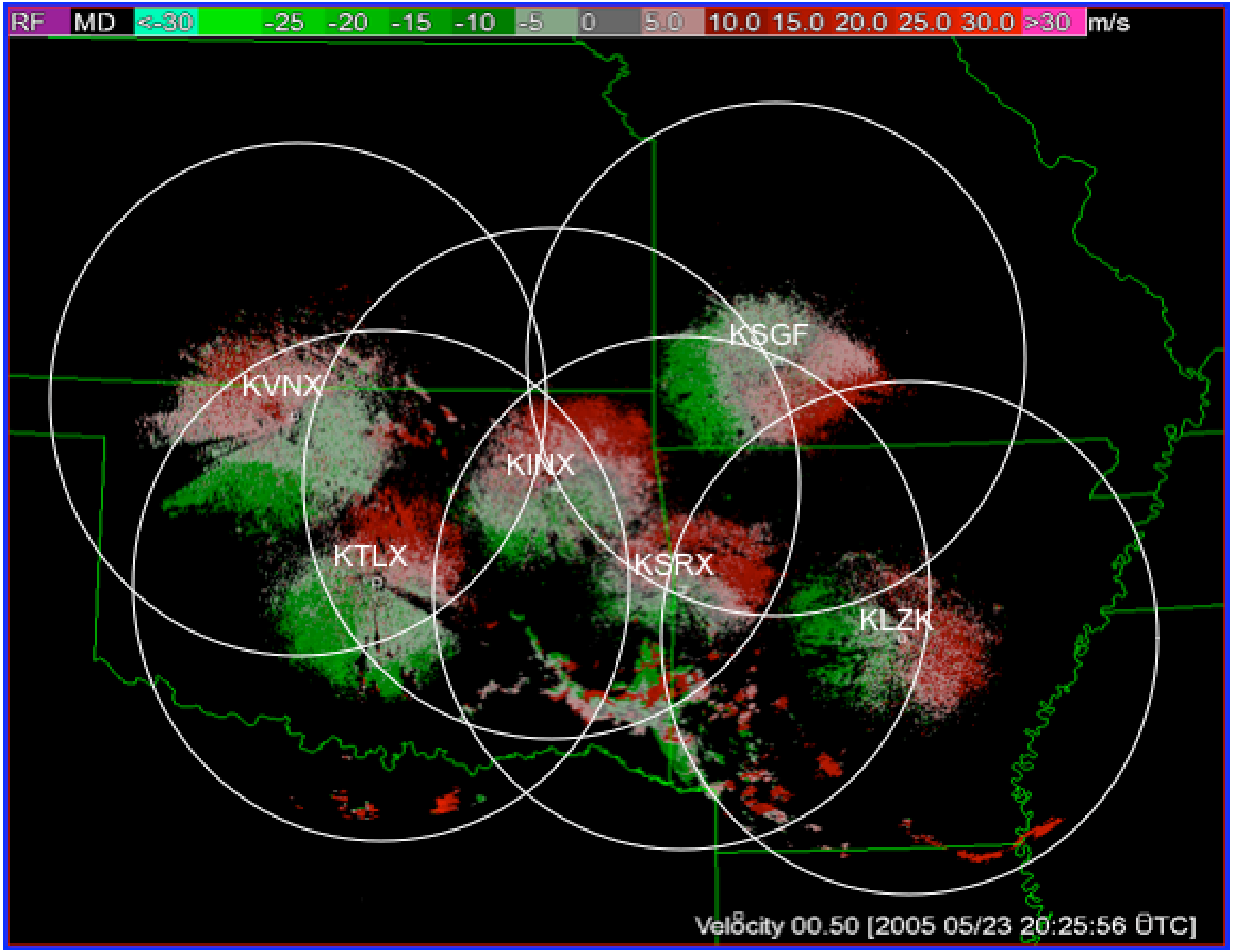
Estimated correlation functions: $R_{ll}(r)$ and $R_{tt}(r)$.

Applications to Multi-Radars and NCEP WRF

Background winds from WRF-NMM 3-hour forecasts on a 321x321x61 E-grid with Δx = 8 km over the central US, and interpolated onto 55 time levels in synchronization approximately with radar v_r volume scans.

Obs v_r from six radars: on 21 (clear) & 23 (rainy) May 2005.

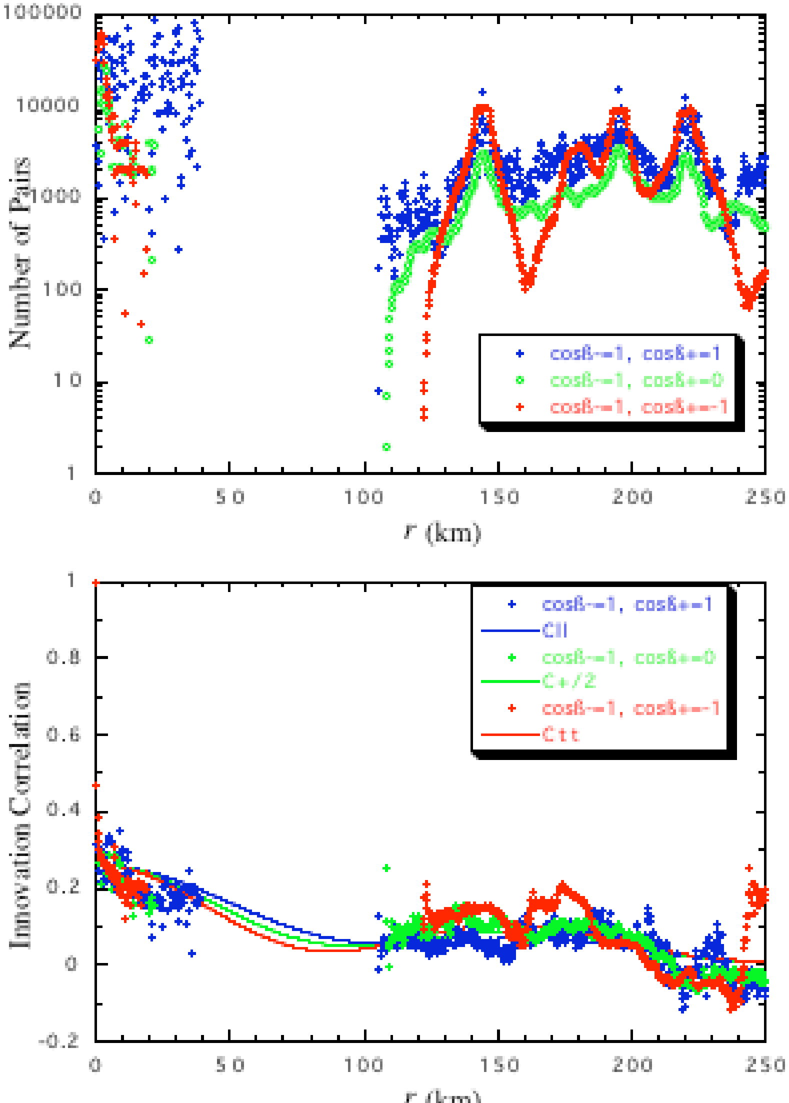
Since migrating-bird contaminations are detected for the nighttime scans, only daytime scans (13:00 to 24:00 UTC) are used. After dealiasing and quality control, radial-velocity volume scans are selected at 55 time levels.



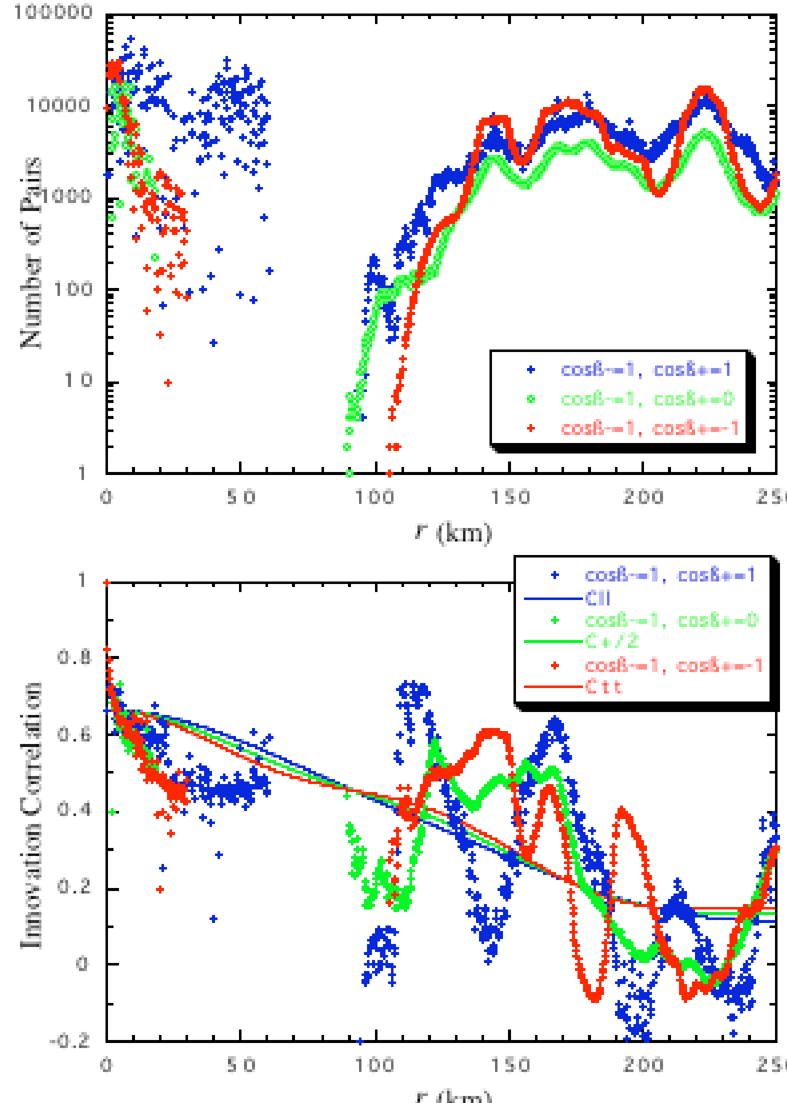
RF
MD
<-30
-25
-20
-15
-10
-5
0
5.0
10.0
15.0
20.0
25.0
30.0
>30
m/s
KVNX
KSGF
KINX
KTLX
KSRX
KLZK
Velocity 00.50 [2005 05/23 20:25:56 UTC]

Number of data pairs & Binned innovation correlation

May 21 (clear) z = 400 m



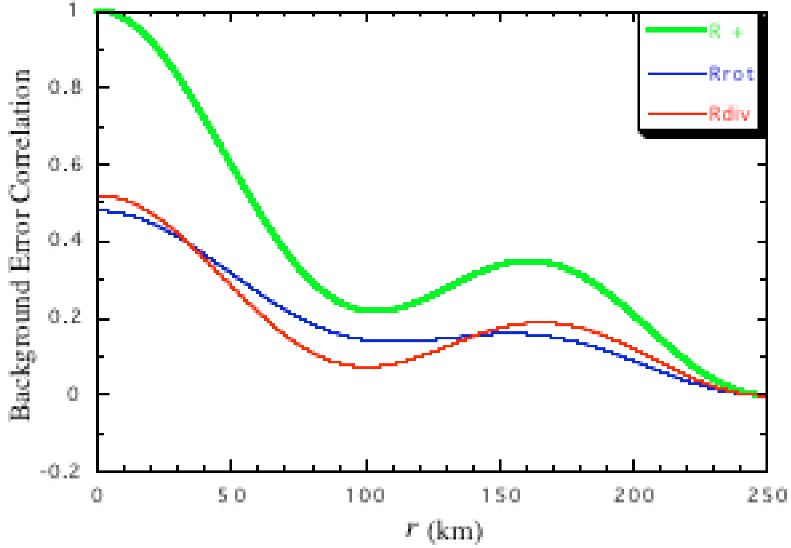
May 23 (rainy) z = 800 m



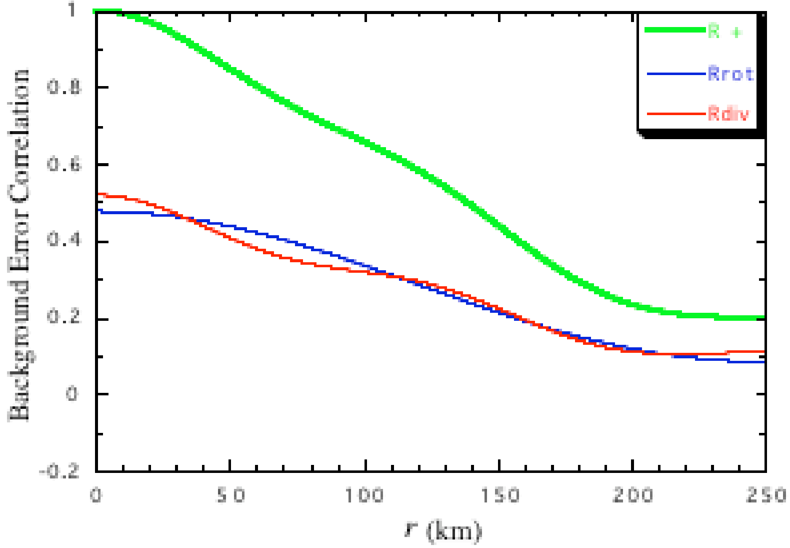
Background Error Correlation Functions:

The total R_+ is partitioned into rotational part R_{rot} and divergent part R_{div}.

May 21 (clear) z = 400 m

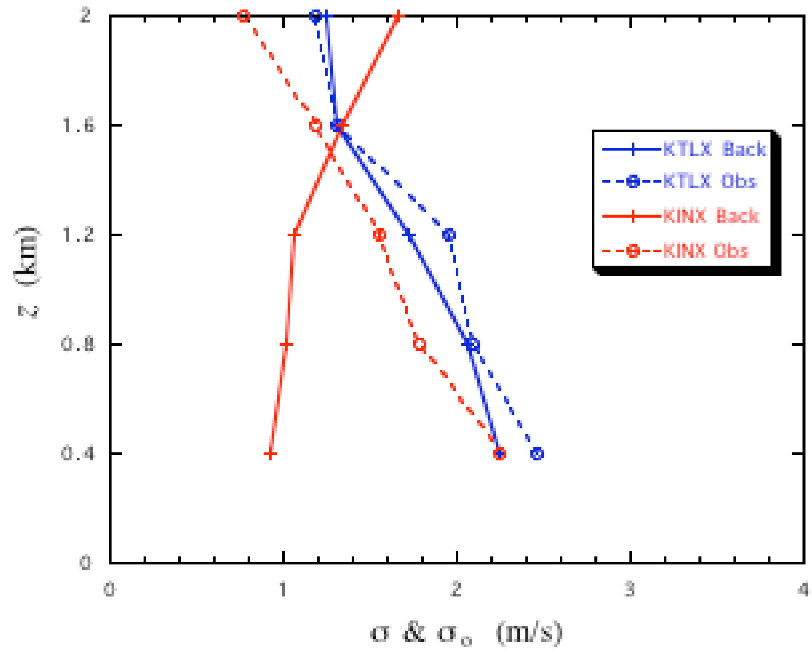


May 23 (rainy) z = 800 m

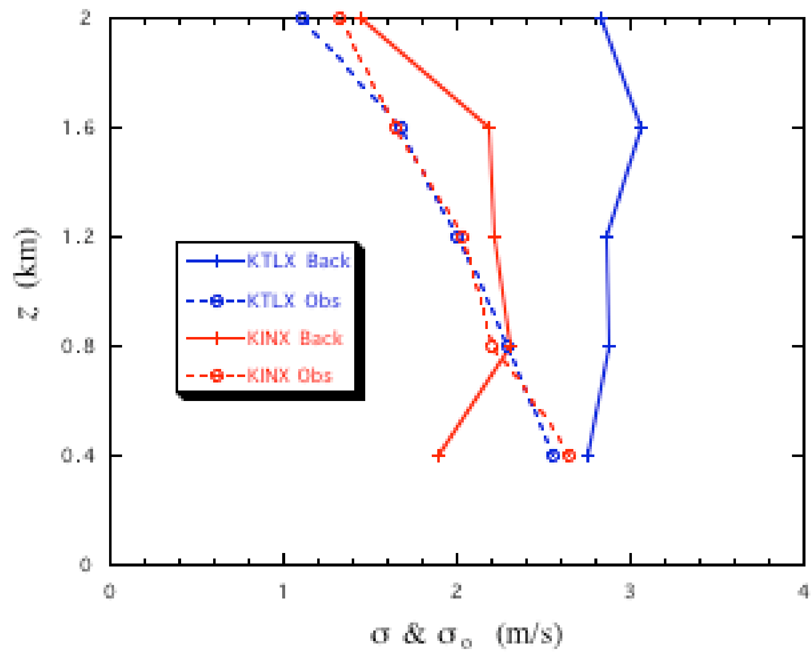


Background (solid) & Obs (dashed) error standard deviations at KTLX & KINX.

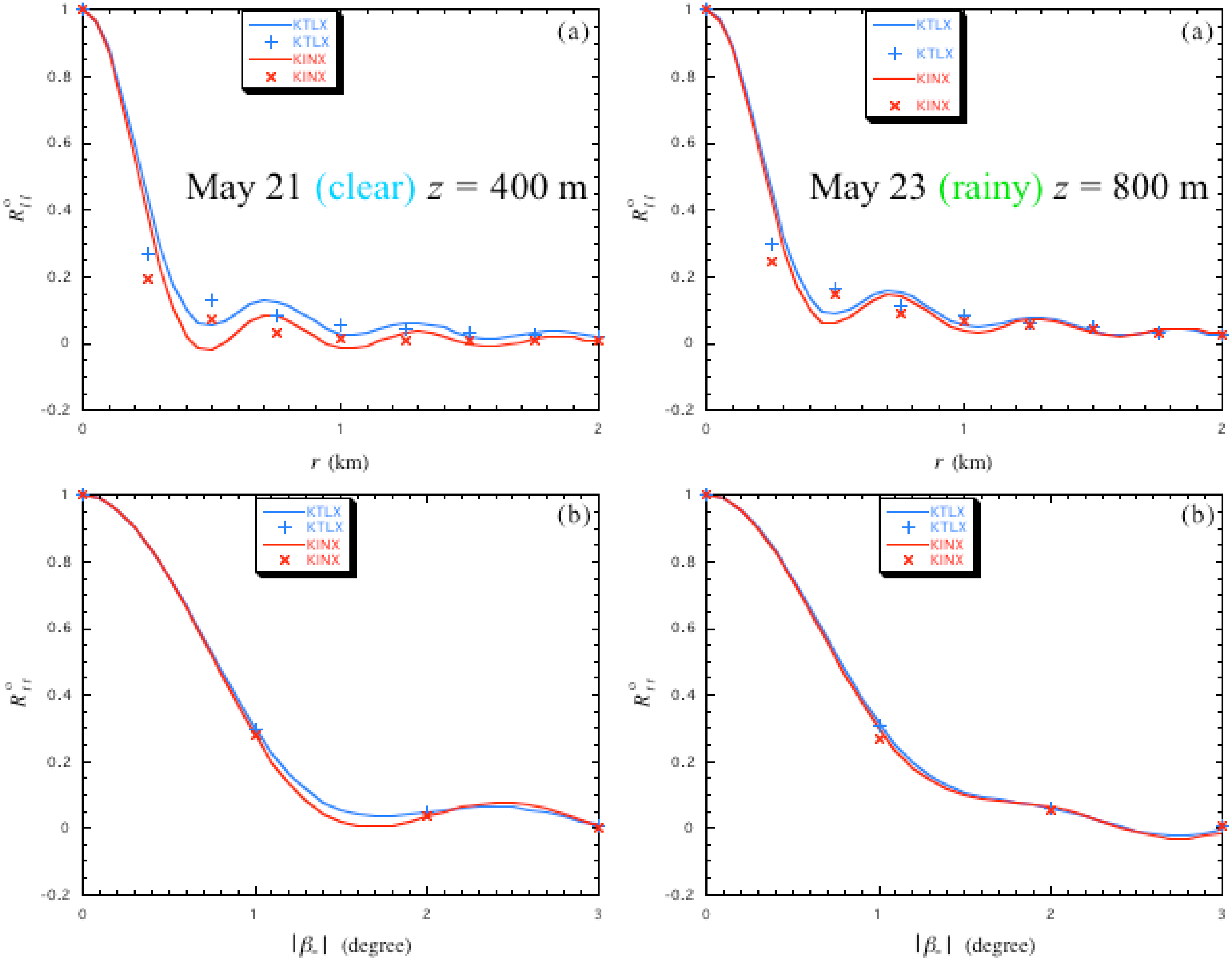
May 21 (clear)



May 23 (rainy)

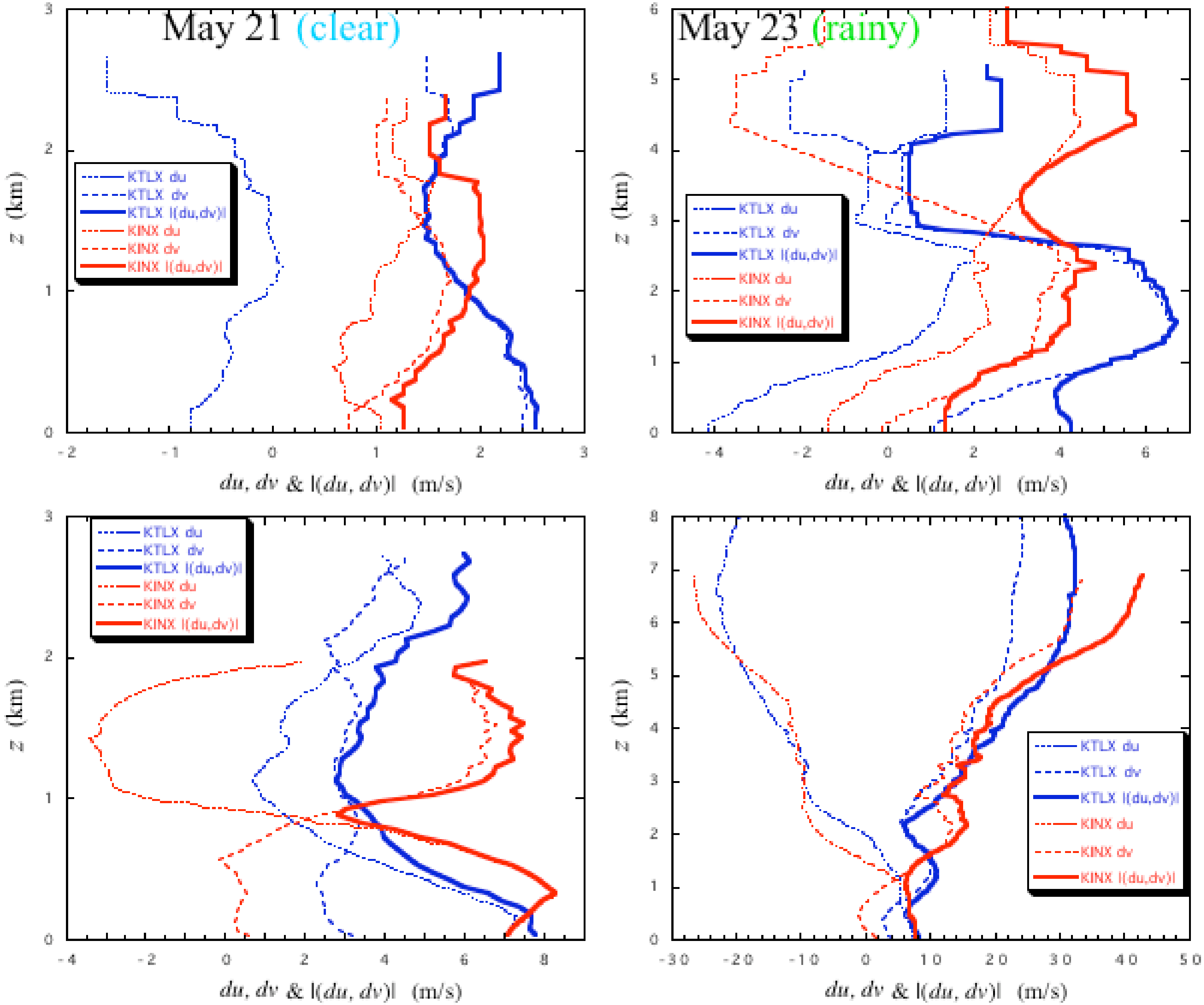


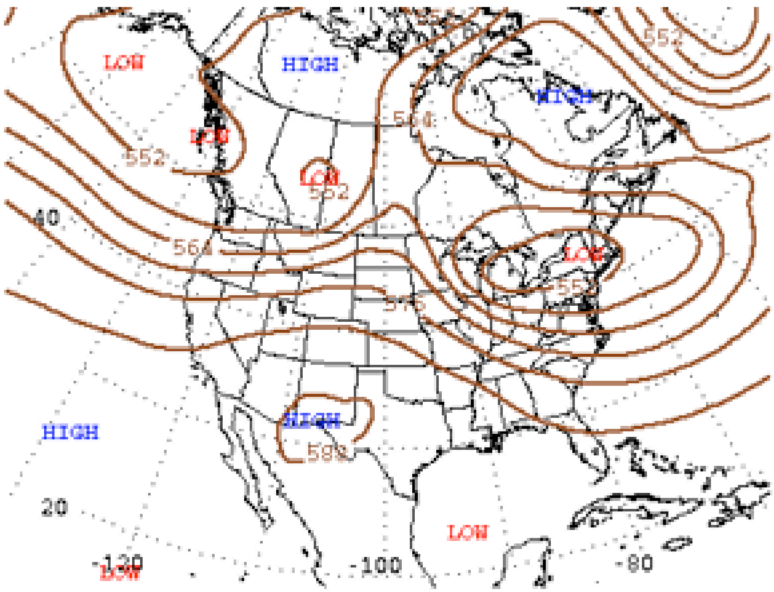
Obs Error Correlation



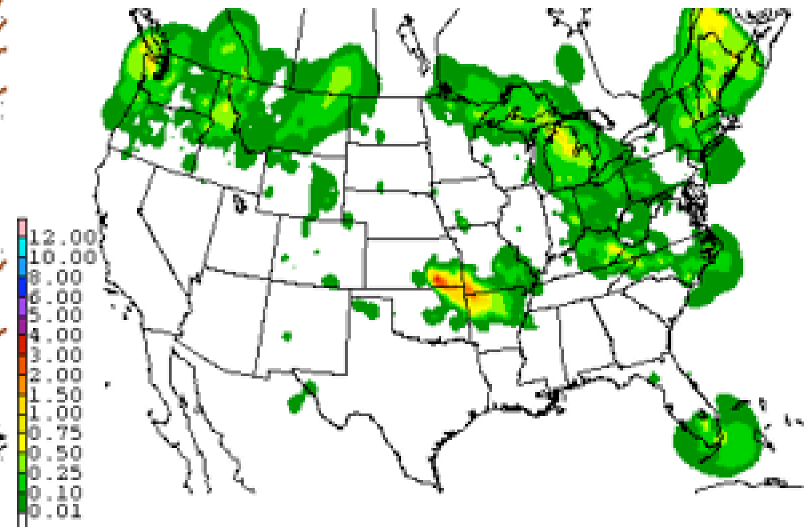
Bias diff at KTLX & KINX

VAD - back at KTLX & KINX

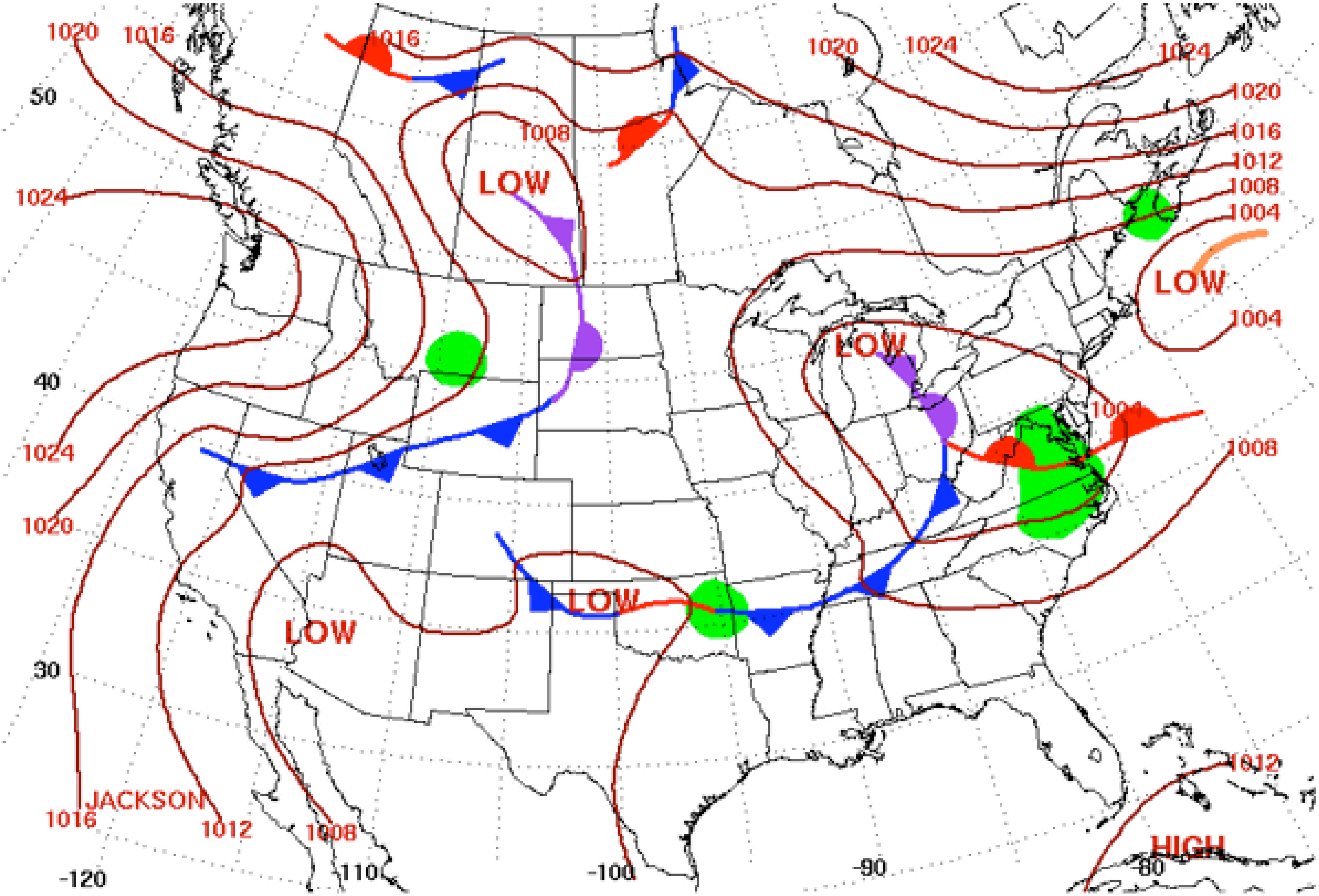




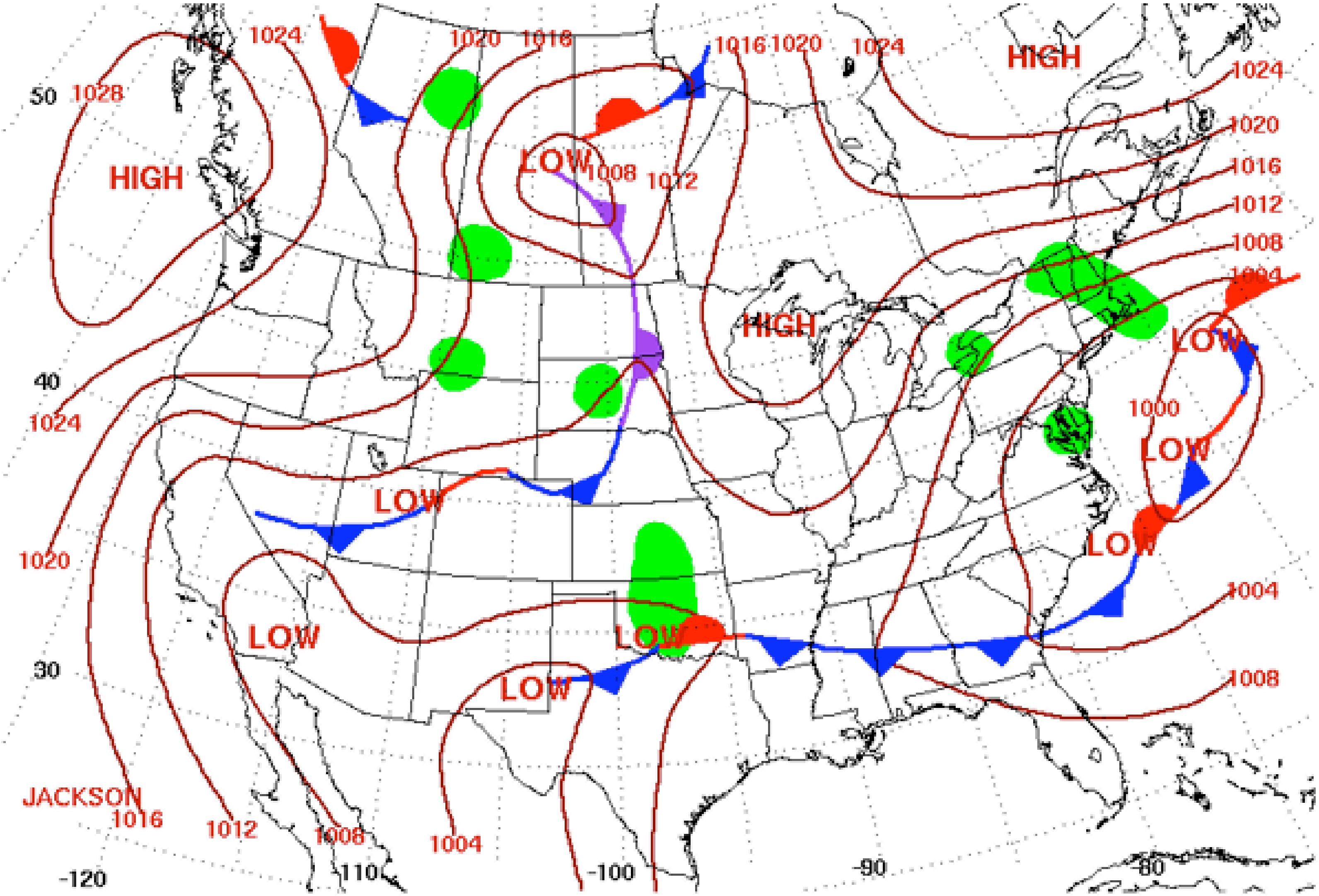
500-Millibar Height Contour at 7:00 A.M. E.S.T.



24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.

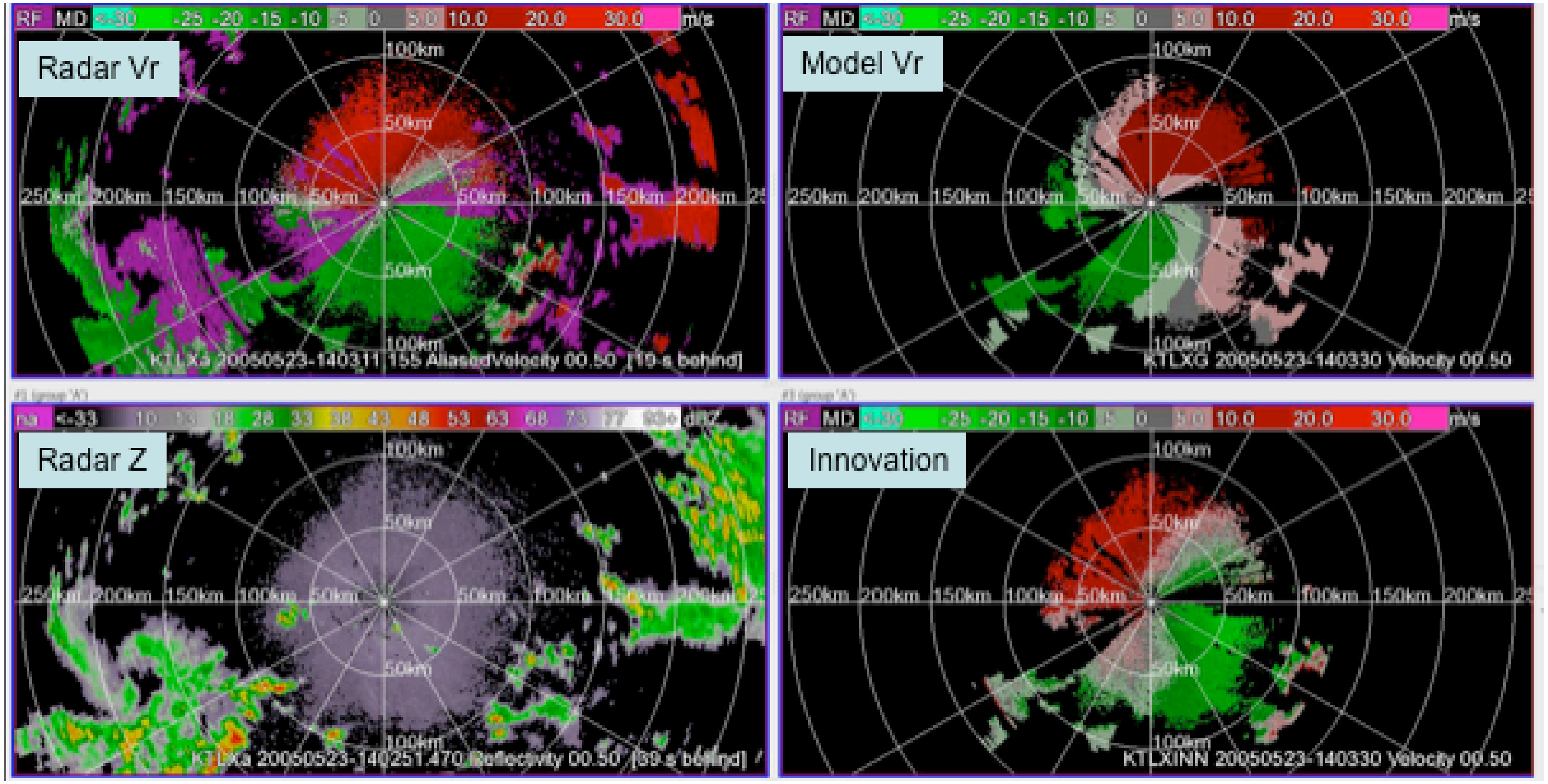


Surface Weather Map at 7:00 A.M. E.S.T.



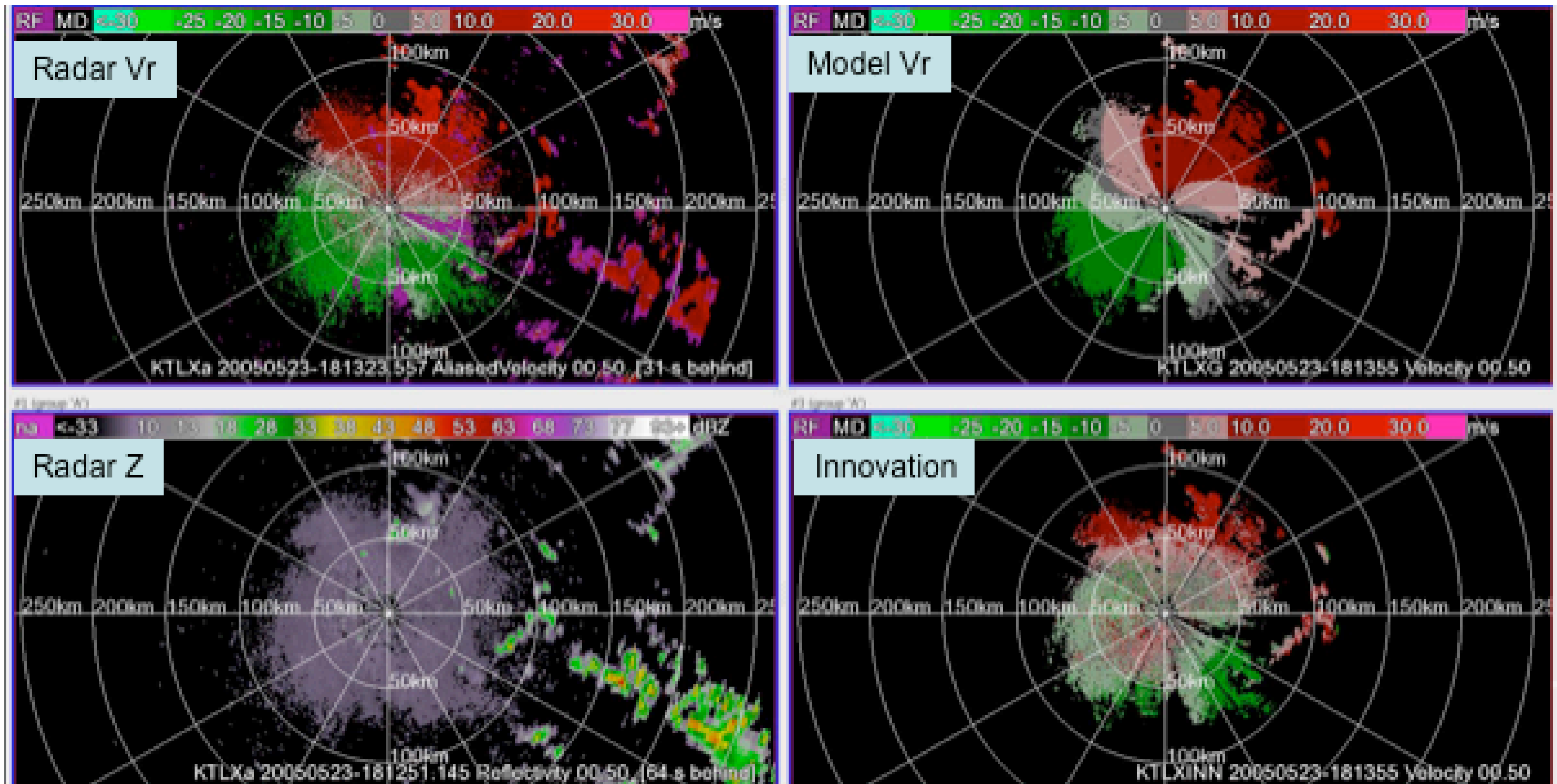
Surface Weather Map at 7:00 A.M. E.S.T.

KTLX 20050523 14 UTC



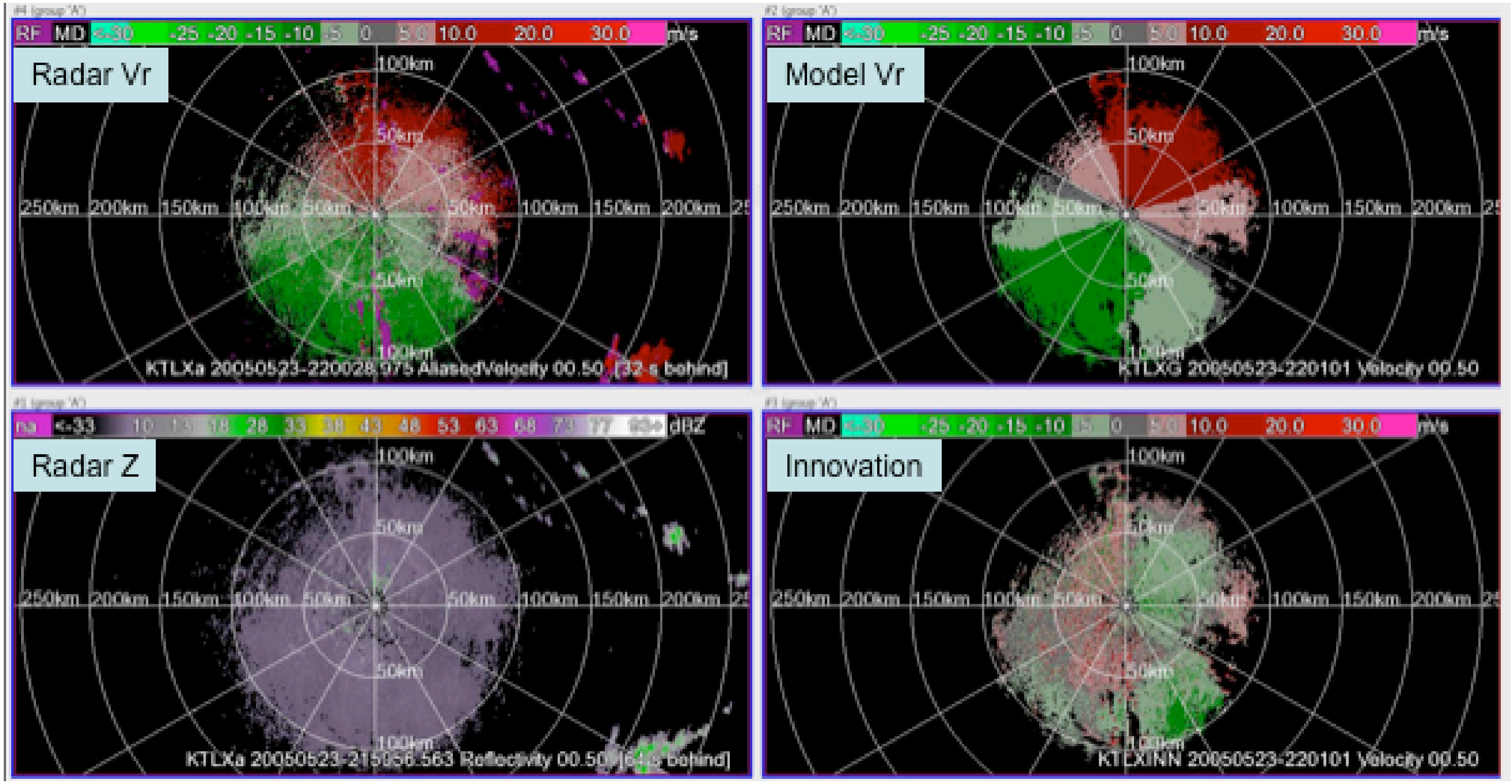
Innovation=(Radar Vr)-(Model Vr)

KTLX 20050523 18 UTC



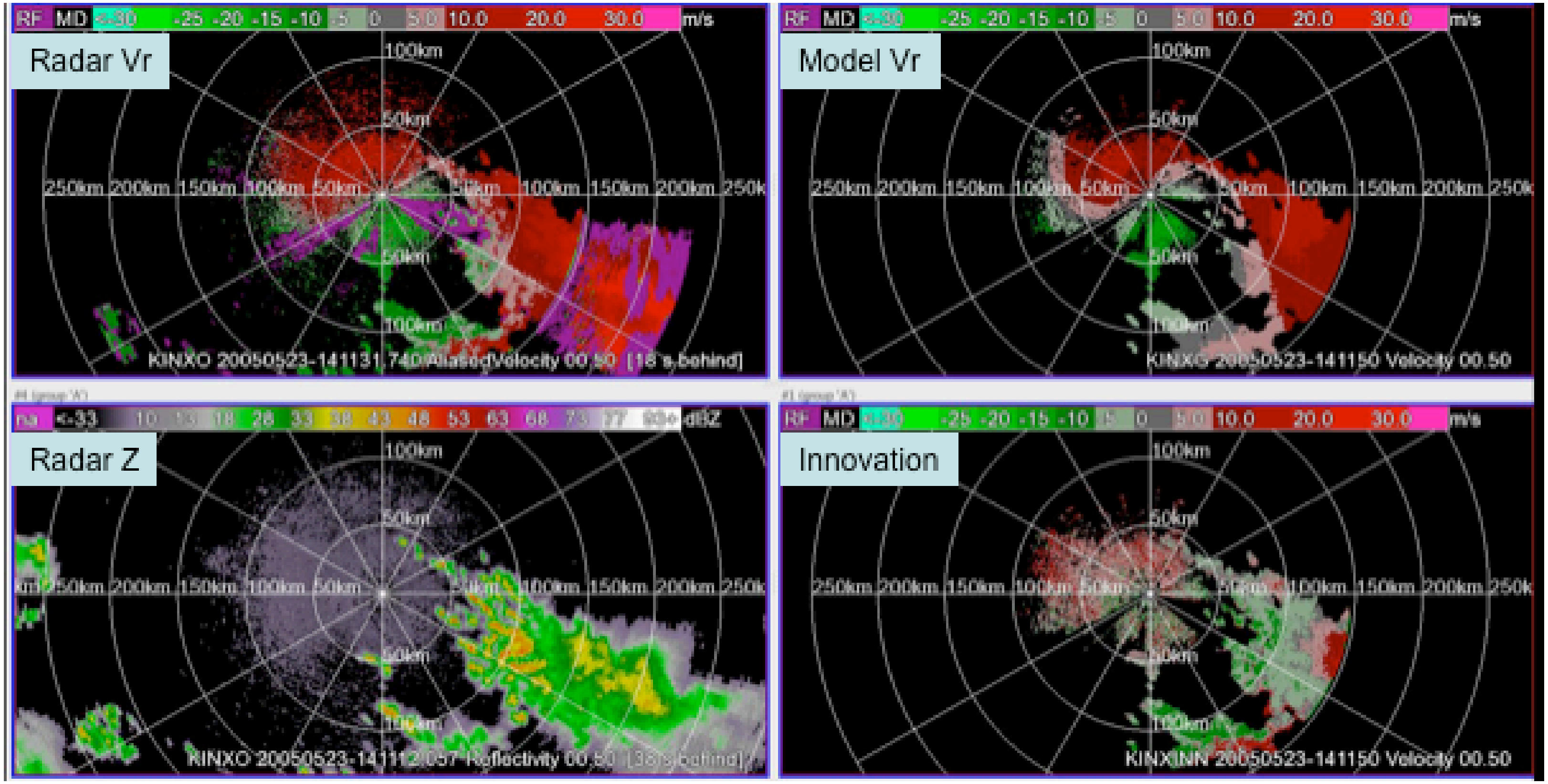
Innovation=(Radar Vr)-(Model Vr)

KTLX 20050523 22 UTC



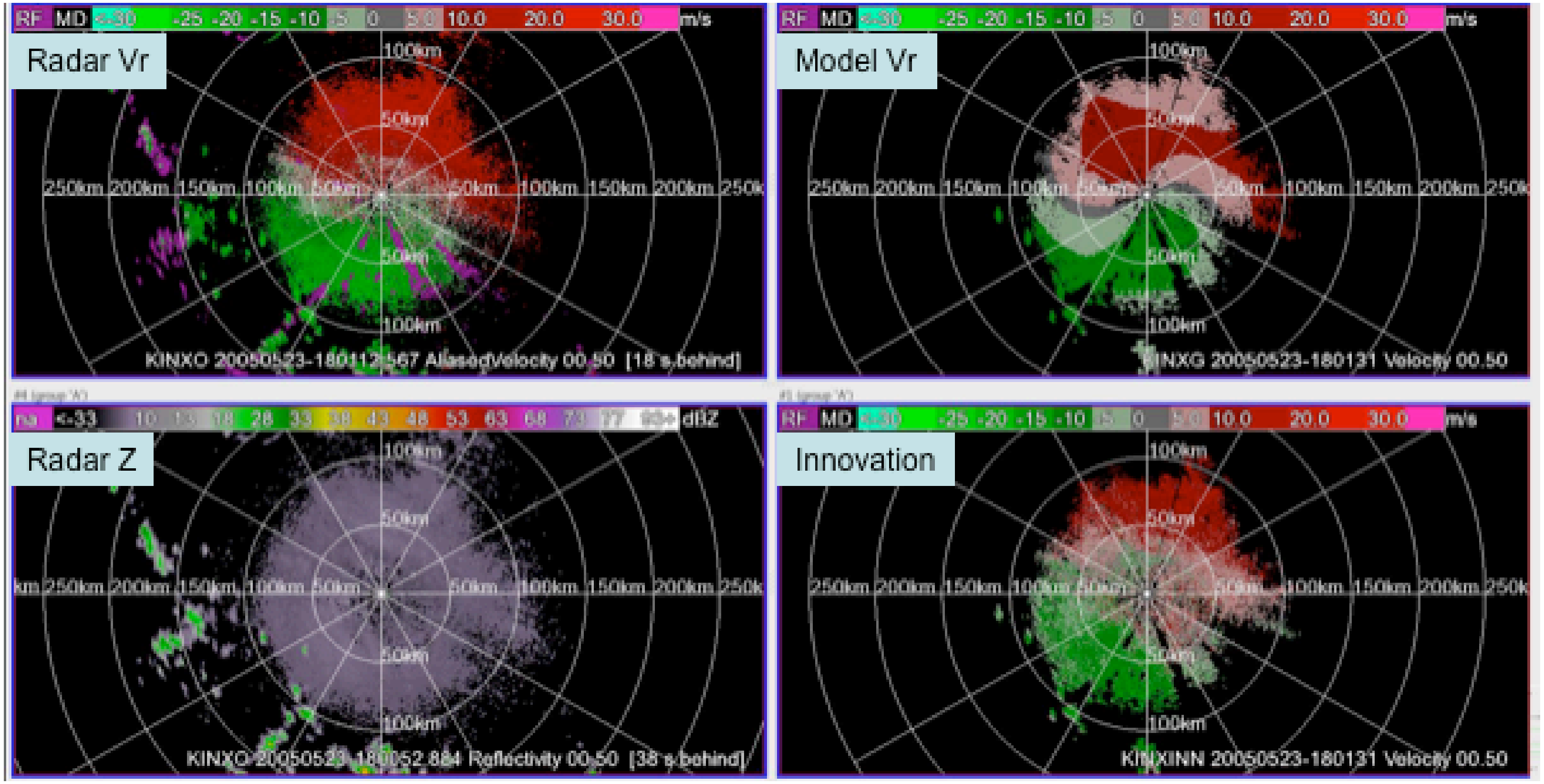
Innovation=(Radar Vr)-(Model Vr)

KINX 20050523 14 UTC



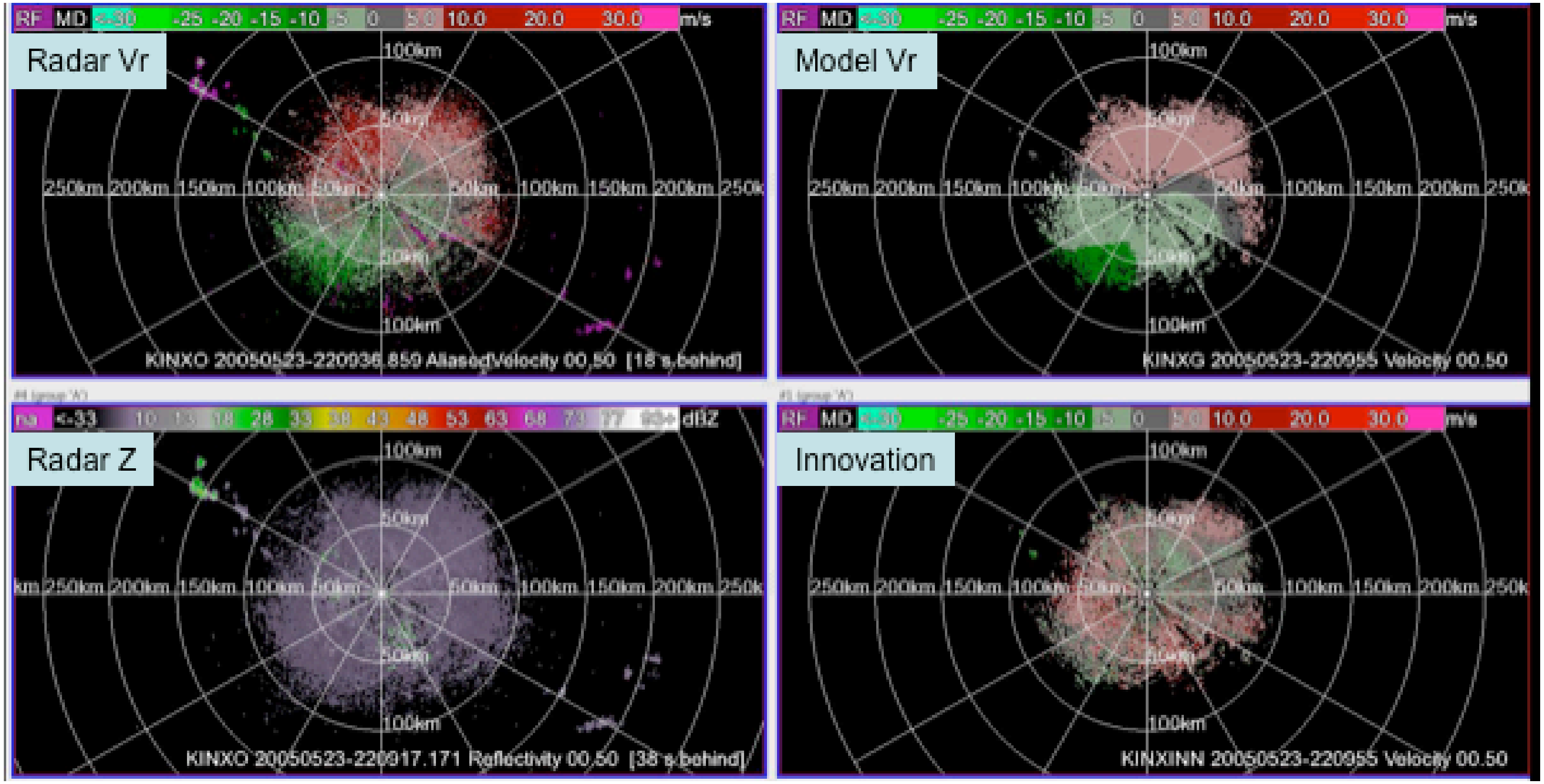
Innovation=(Radar Vr)-(Model Vr)

KINX 20050523 18 UTC



Innovation=(Radar Vr)-(Model Vr)

KINX 20050523 22 UTC



Innovation=(Radar Vr)-(Model Vr)

Conclusions

- Radar obs and background wind error covariances can be estimated, but the background correlation estimates are limited or harmed by data coverage gaps.
- Obs error sd ≈ 2 m/s and decreases with z in PBL.
- Obs errors are correlated in two different ways between neighboring range gates and between neighboring beams.
- Bias difference varies with z & radar site (mainly due to background bias variations).
- VAD minus background profile does not really estimate bias difference and is subject to large errors (if used in radar data quality control).