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
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
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 ($\geq 10$ m/s) from the air velocities in the presence of migrating birds.
Radar data QC at NCEP

1. Input $V_r$, $Ref$, $Sw$
2. Ground or sea clutter removal
3. Radial velocity dealiasing
4. Sunbeam removal
5. Calculate QC parameters
6. Migrating bird detection
7. Statistics-based QC
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° elevation angle

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

Input raw data
- Perform preprocessing sub-steps 1-3 to remove isolated data points and empty circles

- Perform preprocessing sub-step 4 to remove near zero $V_r^o$ areas ($5\Delta r \times 21^\circ$) and circles

- Perform alias-robust VAD analysis to estimate $(a_0, u_0, v_0)$ on qualified vertical levels

- Check vertical continuity of $(u_0, v_0)$ by using (1)

Perform reference check to complete step I
- Perform block-to-point check clockwise
- Perform block-to-point check counterclockwise

Compare the two check results, and complete step II

Output
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 $X_i$.

$$P(H_0 \mid x_i) = p(x_i \mid H_0)P(H_0)/p(x_i),$$
$$P(H_1 \mid x_i) = p(x_i \mid H_1)P(H_1)/p(x_i).$$

$$p(x_i) = p(x_i \mid H_0)P(H_0)+p(x_i \mid H1)P(H1)$$

$$P(H_0)=N_0/(N_0+N_1)$$
$$P(H_1)=N_1/(N_0+N_1)$$
Posterior Probability distributions of MRF (a), VDC (b) and VSC (c)
Statistics-based QC

KFWS 200909110605

SN (%) 23%

KFWS 200909110605

SN (%) 6%
Performance of radar data QC

Observation (m/s) before QC

Observation (m/s) after QC
Radar Reflectivity Mosaic
Flowchart of reflectivity data processing

1. raw radar data decoding
2. Radial velocity QC
3. Reflectivity QC
4. Single Radar Cartesian (coordinate transformation)
5. Output ref in Cartesian grid
6. Reflectivity 3D mosaic
Fig. 1. Raw reflectivity from KATX radar at 0.5 deg elevation at radar coordinate and zoom-in area
Fig. 2. Reflectivity after SRC at Cartesian grid at 1500 m and zoom in area
Domain setup

Figure is from NSSL
## Domain Specifications

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<th>ctrllon (°W)</th>
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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

\[
J = \frac{1}{2} [x^T B^{-1} x + (Hx - y) R^{-1} (Hx - y)]
\]

- Forward model

\[
V_r (\theta, \alpha) = u \cos \alpha \cos \theta + v \cos \alpha \sin \theta + [w \sin \alpha]
\]
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
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)
- SUPLON | 006197 | LONGITUDE OF RADIAL WIND SUPEROB (COARSE ACCURACY)
- DIST | 006210 | DISTANCE (FROM ANTENNA TO GATE CENTER)
- 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 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

Summary of input data

0: nradials_in= 2815600
0: nradials_fail_angmax= 668391
0: nradials_fail_time= 1403832
0: nradials_fail_elb= 0
0: nobss_in= 127634068
0: nobss_badvr= 7264458
0: nobss_badsr= 12975
0: nobss_lrbir= 199

Summary of super-obs for each station

0: for radar KAKQ nsuper= 4241
0: vrmin,max= -24.39374924 24.13636398
0: ermin,max= 0.2636067569 25.28617668
current vfit of radar wind data, ranges in m/s

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<th>900.0</th>
<th>800.0</th>
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| 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 | 0.00 | 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 | 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 | 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 | 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 | 0.00 | 1.54 |
| 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 | 0.00 | 1.96 |
| 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 | 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 | 0.00 | 1.96 |
| o-g 01 | rw rej | 999 0000 | count | 0 | 0 | 0 | 0 | 0 | 1 | 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 | 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 | 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 | 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 | 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 | 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 | 0.00 | 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 | 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 | 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 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

num(r) = 58 at lev 1 pen, qcpen, cpen, qcpen = 60.728 60.728 1.0470 1.0470
num(r) = 55 at lev 2 pen, qcpen, cpen, qcpen = 43.509 43.509 0.79107 0.79107
num(r) = 61 at lev 3 pen, qcpen, cpen, qcpen = 101.79 101.79 1.6687 1.6687
num(r) = 80 at lev 4 pen, qcpen, cpen, qcpen = 157.71 157.71 1.9714 1.9714
num(r) = 44.601 44.601 0.59469 0.59469
num(r) = 205 at lev 6 pen, qcpen, cpen, qcpen = 422.71 422.71 2.0620 2.0620
num(r) = 249 at lev 7 pen, qcpen, cpen, qcpen = 1449.6 1449.6 5.8219 5.8219
num(r) = 275 at lev 8 pen, qcpen, cpen, qcpen = 484.49 484.49 1.7618 1.7618
num(r) = 303 at lev 9 pen, qcpen, cpen, qcpen = 456.83 456.83 1.5077 1.5077
num(r) = 340 at lev 10 pen, qcpen, cpen, qcpen = 1565.3 1565.3 4.1084 4.1084
HiRes Initialization with radial wind

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

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