Real-time Quality Control of Phased Array Weather Radar Data Observed Every 30 Seconds

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38th Conference on Radar Meteorology @Chicago IL, 01 Sept. 2017
Introduction

The X-band (single-polarization) Phased Array Weather Radar (PAWR) measures 3D fine structure of precipitation with 100 m range and 100 EL angles every 30 seconds. The PAWR produces Big Data which is 100 times larger than traditional radar.

Real-time quality control (QC) processing of the PAWR data is essential for data assimilation and nowcasting for weather forecast. The real-time data is also published on a web-page [http://pawr.nict.go.jp](http://pawr.nict.go.jp) and is used in a smartphone application.

In this study, faster and general-purpose data QC algorithm is developed for use in real-time applications.
“Big Data Assimilation” Revolutionizing Severe Weather Prediction (PI: Takemasa Miyoshi)

Pinpoint (< 100-m resol.) forecast of severe local weather by updating 30 min forecast every 30 sec!

(Miyoshi et al. BAMS, 2016)
Real-time demonstration of 3D nowcasting

30-second update nowcasting for 10 minutes started on July 3, 2017.


http://weather.riken.jp
Data quality control (QC) such as clutter removal is essential in order to use PAWR observation data for data assimilation and nowcast.

The Ruiz 's QC algorithm (SOLA, 2015) used for the BDA experiment requires calculation time of 40 seconds. However, it is necessary to develop a faster and general-purpose QC algorithm to perform real-time processing on the various observation data.

Perform QC calculation and data transfer within 10 seconds for 3D nowcast

Ruiz et al. SOLA, 2015
Clutter echoes and interference noise

Surface clutter echoes

Clutter echoes by ships

Airplane echo + RangeSL

Interference echoes

Surface clutter

Kobe PAWR (fine weather)

Suita PAWR (fine weather)

Add another data at 2016/12/01, 10:03:30
Contents and overview of QC flag file

QC flag < 8 bit >


- A new file of 1-byte QC flag data is provided in the same format of the same polar-coordinates as Ze and Vr data.
  (e.g. 20150808-160021.all_pawr_qcf.dat, kobe_20150808160000_A08_pawr_qcf.dat)
- The QC flag file will be created in NICT Koganei in real-time (within 10 sec.)

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[0] Valid data: if (Ze > -327.68 & Vr > -327.68) then (1)
[1] Shadow: if (ASL(Dem) > beamHT using 4/3 equiv. earth radius) then (1)
[2] Clutter possible (clutter map): if (statistical Ze_PD > 20%) then (1)
[3] Clutter certain: if (Ze_PD > 20% & -1.5 < Vr < 1.5ms⁻¹ & ZeText > 3.0) then (1)
[4] Noise (Interference): if (rng_num > 500 & Ze_std/Ze_avg < 0.5) then (1)
[5] Rain attenuation: if (Ze_inetg > 50 dBZ & delta_Ze < -2 dB/km) then (1)
[6] Range Side Lobe: if (Ze > 40 dBZ & ZeText < 1.5 & ZrTextAz < 0.8) then (1)
[7] (Reserve): future use (e.g. abnormal Vr., uncorrected aliased velocity)
Shadow flag and Stratiform rain echo

Compare DEM altitude (GSI 10m) with radar beam height using equiv. earth radius (4/3*R)

Shadow of a neighboring building
/* Building (GSE com-east)*/
if (i == 1 && 255.6 < az[k][j] && az[k][j] < 267.6){
asldem = asl[jlat][ilon]+64.5;
}

<consider beam width>
sinel=sin((el[k][j]+0.45)*RAD); /* consider half beam (diffraction)*/
cosel=cos((el[k][j]+0.45)*RAD);
sinaz=sin((az[k][j]+0.6)*RAD); /* because az[] is the start angle */
cosaz=cos((az[k][j]+0.6)*RAD);
Identification of surface clutter is done with Ze PD $> 20\%$.
Vertical gradient of bldg vs rain echoes

- **Probability Density of Ze (bldg. #5 AH)**
  - 2015/08/08, 00:00-11:59JST
  - **no rain**

- **Probability Density of Vr (bldg. #5)**
  - **no rain**

- **PD Ze (strat@#5)**
  - 2015/07/17, 07:00-08:59JST
  - **Strat rain**

- **PD Vr (strat@#5)**
  - **Strat rain**

- **PD Ze (conv@#5)**
  - 2015/08/08, 15:00-16:59JST
  - **Conv rain**

- **PD Vr (conv@#5)**
  - **Conv rain**

→ Vertical gradient information is not used anyway...
Seasonal variation of surface clutter (Ze)

2015/08/08, 00:00 – 12:00 JST

Ze AVG

EL=2.0 deg

Averaged reflectivity (dBZ)

Ze PD

Probability Density (%)

Contour map (100, 200, 400, 600, 800 m)

2016/01/26, 00:00 – 12:00 JST

Ze AVG

EL=2.0 deg

Averaged reflectivity (dBZ)

Ze PD

Probability Density (%)

→ Statistical clutter maps are created every 2 or 3 months
QC flag of Stratiform Rain echo

Ze

Vr

PPI
(EL=1.0 deg)

2015/07/17
08:30:19JST

Ze Texture

1/n Σ [Ze(i,j)-Ze(i-1,j)]
in 11 range x 5 az

QC flag

Valid >1
Shadow >2
Clutter map >4
Clutter certain >8

120 km

120 km

dBZ

dB

ms⁻¹
QC flag of Convective Rain echo

2015/08/08 16:00:21JST

Valid >1
Shadow >2
Clutter map >4
Clutter certain >8
Ze and QC flag in PPIs (EL=2.0 deg)

2015/07/17, 08:30:19 JST

Ze

2015/08/08, 16:00:21 JST

Ze

2015/12/18, 10:40:34 JST

Ze

QC flag

2015/07/17, 08:30:19 JST

Stratiform Rain

QC flag

2015/08/08, 16:00:21 JST

Convective Rain

QC flag

2015/12/18, 10:40:34 JST

Interference Noise (fine weather)
determined by ZeStd/ZeAvg < 0.5

Valid >1
Shadow >2
Clutter map >4
Clutter certain >8
Interference noise >16
Range side-lobe contamination

False echoes at the forth and back of a strong echo

RangeSL flags are determined by ZeMax, ZeText, and ZeTextAZ
Computation time for creating QC flag

< Convective case >
## Input file: 20150808-154021.all.10000000.dat, 20150808-154021.all.20000000.dat
## data_size=379200, elnum=110, aznum=300, rnum=600 lat=34.82, lon=135.52, alt=119.0

# Total                  real time = 10.000  proc time =  8.890
# Total make qc flag     real time =  6.000  proc time =  5.660
#   Input data read:     real time =  1.000  proc time =  0.420
#   Calc Ze_ave, rinteg: real time =  0.000  proc time =  0.170
#   Calc Ze_texture:     real time =  4.000  proc time =  3.870
#   Make QC flag:        real time =  1.000  proc time =  1.180
#   Output QC flag:      real time =  0.000  proc time =  0.020
# PPI make & output      real time =  4.000  proc time =  3.230

real 0m9.186s       user 0m8.343s       sys 0m0.555s

< Stratiform case >
## Input file: 20150717-083019.all.10000000.dat, 20150717-083019.all.20000000.dat
## date & time: 2015/7/17, 8:30:19 - 2015/7/17, 8:30:48
## data_size=379200, elnum=110, aznum=300, rnum=600 lat=34.82, lon=135.52, alt=119.0

# Total                  real time = 11.000  proc time = 11.400
# Total make qc flag     real time =  7.000  proc time =  7.890
#   Input data read:     real time =  0.000  proc time =  0.550
#   Calc Ze_ave, rinteg: real time =  1.000  proc time =  0.500
#   Calc Ze_texture:     real time =  5.000  proc time =  5.250
#   Make QC flag:        real time =  1.000  proc time =  1.570
#   Output QC flag:      real time =  0.000  proc time =  0.020
# PPI make & output      real time =  4.000  proc time =  3.510

Real 0m11.704s       user 0m10.241s       sys 0m1.190s

This is the result of using single a CPU core, which enables faster calculation by parallel computation (MPI)
Summary

- The X-band phased array weather radar (PAWR) produces 3D big data (100 m, 100 EL angles) every 30 seconds. The real-time data QC is essential for data assimilation and nowcasting.

- The statistical features of surface clutter echoes in both clear and rainy days were investigated to use for surface clutter removal.

- 8-bit QC flag in the radar coordinates was designed. It includes shadow, surface clutter, interference noise, range side-lobe contamination etc.

- The QC flag in both stratiform and convective echo was verified. The computation time for creating the QC flags was within 10 seconds.