NON-STANDARD BLOCKAGE MITIGATION FOR NATIONAL RADAR QPE PRODUCTS

Lin Tang*[1,2], Jian Zhang[2], Youcun Qi[1,2], Carrie Langston[1,2] and Kenneth W. Howard[2]

[1]Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, OK, U. S. A.

[2]Natioanl Severe Storms Laboratory, Norman, OK, U.S.A.

1. INTRODUCTION

For the radars located in a region of complex terrain, the low-elevation angle radar beams could be partially or completely blocked by the intervening terrain, which would cause a low bias in radar reflectivity (Z) measurements (Germann and Joss 2003), and lead to an underestimation of the rainfall rate. In the application of single-polarization radars, digital elevation models (DEM) are used for the identification of blocked rays and power loss correction (e.g., Kucera et al. 2004, Bech et al. 2003, and etc.). In the National Mosaic and Multi-Sensor Quantitative Precipitation Estimation (QPE) (NMQ) system, a power compensation approach developed by Langston and Zhang (2004) was implemented to mitigate the low bias in reflectivity fields. The echoes with less than 50% of blockages are corrected. When the blockage exceeds one half of the radar beam, data from the higher tilt where the blockage drops below 50% is used for rainfall rate estimation. Standard "terrain based" hybrid scans have shown their effects in correcting the significant blockages in the operational WSR-88D precipitation process system (Fulton et al. 1998). However, blockages from trees and man-made objects (e.g., buildings, telecommunication towers, or wind farms) cannot be derived from the terrain data. Here we refer this type of power obstruction as non-standard blockage (NSB). These man-made objects near radars would block the radar beam propagation and lead to narrow or wide beam blockage wedges in the reflectivity field. As a result, the radar-derived QPE field appears artificially discontinuous. In this work, a method of non-standard blockage mitigation (NSBM) is developed for the WSR-88D radar to reduce such discontinuity artifacts.

2. METHOD

Mitigations of discontinuities due to NSB are carried out in two steps. The first step is to identify the NSB sectors by defining their azimuth and range boundaries. The second step is to determine the mitigation procedures to be applied. Three procedures (actions) are developed depending on the size of the NSB sectors.

Corresponding author address: Lin Tang, Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, Oklahoma 73072; e-mail: lin.tang@noaa.gov

2.1 Identification of NSB

Discontinuities from NSB are observed from the plan position indicator (PPI) plot of radar data and related radar products. Inaccurate/outdated terrain files or anomalous propagation (AP) could be the causes for the discontinuities. Azimuthal discontinuities are often result from the NSBs, with missing data or significantly decreased values in magnitude observed in the NSB sectors. Compared to the reflectivity field, the contaminations from NSB appear distinct and easier to be identified in the accumulated reflectivity or precipitation field. An example of the QPE accumulation field suffering NSB is presented in Figure 2 (a), where the region affected by the NSB is identified with the rectangle and oval frames. Since NSB regions are largely persistent for given radars, predefining the discontinuities region caused by the NSB is possible, which is the first step in the mitigation method. Examining the accumulated reflectivity or rainfall fields helps identify the starting and ending azimuthal angles/ranges of NSB sectors. In Figure 1, an example of the accumulated reflectivity field is presented, where apparent NSB sectors of low *Z* value can be observed as low reflectivity stripes. The NSBM scheme is to create reference tables for each of radars to adjust the hybrid reflectivity or hybrid scan precipitation rate field. Based on the non-standard blockage sector size, the NSBM scheme uses a set of rules in different scenarios.

2.2 NSBM Actions

After identifying the NSB regions, three different actions were designed to mitigate the artificial discontinuities.

Firstly, it is observed that man-made single object causes narrow and long wedges of distinct gap in the accumulated reflectivity/QPE field. The intensity reduction caused by this type of blockage is normally less than 5 degrees in azimuth width and the power propagation along neighboring azimuth radians are rarely affected. The spatial variation of a precipitation system across a narrow wedge (< 5 degrees) is considered small. In the NSBM scheme, the first action is for narrow NSB sectors (with azimuth width < 5 degrees, a configurable parameter), a process of cross-azimuth interpolation is applied as demonstrated as Eq 1.

$$Z_{AZ} = Z_{AZ1} + \frac{Z_{AZ2} - Z_{AZ1}}{|AZ2 - AZ1|} \times (AZ - AZ1) \qquad (1)$$

where *AZ* is the azimuthal angel between *AZ1* and *AZ2*, and Z_{AZ} is the corresponding reflectivity/rainrate value.

Another type of power drop due to the non-standard blockage has wider spread in azimuth direction. When the terrain information is outdated or inaccurate, for example flourish plants near the radar in summer, the wave propagation suffer more severe partial blockage than the standard correction. This type of blockage leads to large section of biased QPE, and the spatial variation in the large horizontal domain cannot be ignored. Normally the echoes from the low elevation heights have more contribution to the QPE. But when the blockage exceeds one half of the beam width, the data at the lowest tilt is not reliable. Where non-standard blockage contaminates the low tilt data, the precipitation rate fields from higher tilts are adopted in the hybrid scan. The rain rate variation in vertical direction is ignored in a few low tilts but it is adjusted in the later process of vertical profile reflectivity (VPR) correction (Zhang and Qi, 2010) in this NMQ system (Zhang et al. 2011). The second action is to replace the data in the NSB sector with the data (reflectivity, rainfall rate, etc.) from the next higher tilt, shown as Eq.2. This action is for wide NSB sectors.

$$Z^{e}_{AZ} = Z^{e+i}_{AZ} \qquad (2)$$

where *AZ* is the azimuthal angle between *AZ1* and *AZ2*, *e* is the current elevation angle, and *e+i* is the adjacent high elevation angle not affected by the NSB.

The boundaries between different tilts of data adoption often appear as artificial edges/steps. The third action was to apply a smoothing across the azimuthal boundaries when data from two different tilts are used to generate the hybrid scan. Such boundaries in hybrid scan could be from the standard hybrid scan procedure based on terrain data, or from the second action in the mitigation of NSBs (Eq.2). They are smoothed with a method of linear-weighted running average using +/- 5 neighboring points (*N*=5) in the azimuthal direction, shown as Eq. 3.

$$Z_{AZ} = \frac{\sum_{j=-N}^{N} W_j \times Z_{Az+j}}{\sum_{j=-N}^{N} W_j} \qquad (3)$$

$$W_j = N + 1 - |j|$$

where $N = 5; -N \le j \le N$; *AZ* is the azimuth angle of the NSB's boundary, *j* is the neighbor azimuth of *AZ*; *Wj* is linear weight.

For each of the WSR-88D radars, the NSBM reference table contains the information of blockage sectors and the action code for each of the sector. Each sector is defined with the starting azimuth angle AZ1, ending azimuth angle AZ2, starting range R1 and ending range R2 (please refer Table1 as an example). Based on the sector size, the correction action has three options: 1) cross-azimuth interpolation, 2) replacing current data with those from the higher tilt, and 3) apply azimuthal smoothing across tilt boundaries. The reference table can be applied either in the hybrid reflectivity field or QPE products.

Since the non-standard blockage is sensitive to the scanning height, the reference tables might be different for different volume coverage patterns (VCPs). Based on the elevation angles of the five lowest tilts, the current operational VCPs are divided into two groups: G1) 11, 121, 211, 221, 21, 31, 32; G2) 12, 112, 212. For each of the operational radars, two NSBM reference tables are created, one for each group.

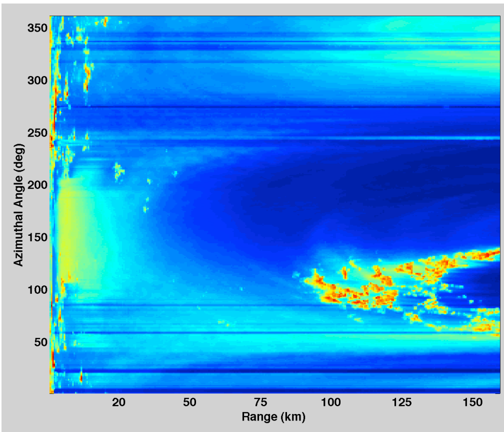
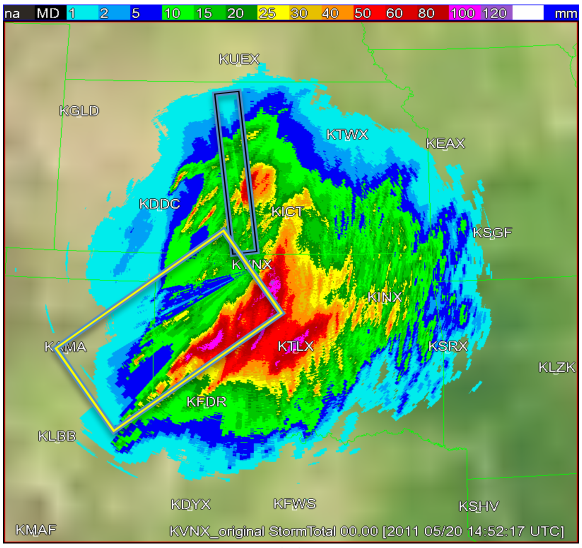


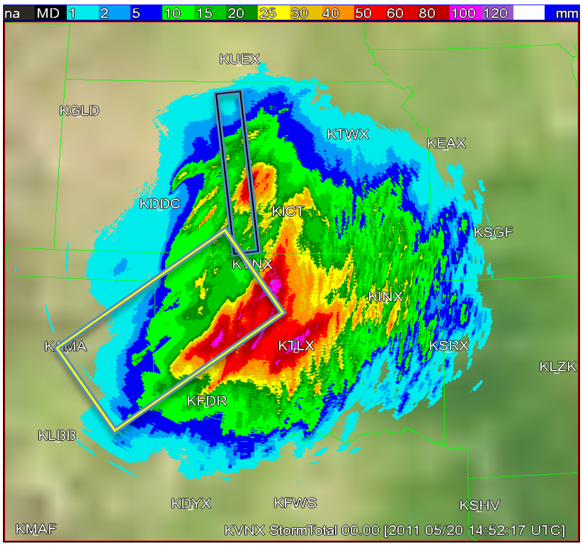
Figure 1. Accumulated reflectivity field.

3. EXAMPLES AND DISCUSSIONS

To demonstrate the performance of NSBM scheme, Figure 2 provides an example of 10-hour QPE accumulation (20110520 05:00- 20110520 14:59 UTC) observed by radar KVNX: (a) the accumulated rainfall field without NSBM and (b) the field after NSBM adjustment. In Figure 2(a), a ground object near the KVNX causes narrow wedge at about 350 degree azimuth angle shown with the black frame; outgrowing trees or changed landscape causes the outdated terrain information in the domain shown with the yellow rectangle. These non-standard blockage leads to low bias in the precipitation estimation. In Figure 2(b), it is shown the discontinuities of QPE accumulation due to the non-standard blockage are mitigated. Table is the corresponding NSBM reference table applied in Figure 1(b). In the table, 6 sectors of the field are defined, where AZ1 and AZ2 have the unit of degree; R1 and R2 use the unit of kilometer. The parameter "Tilt" is the tilt number (counted from low to high) where the data is adopted, and "0" tilt represents the data is from the regular hybrid scan without adoption. The "action codes" are defined in section 2.



(a)



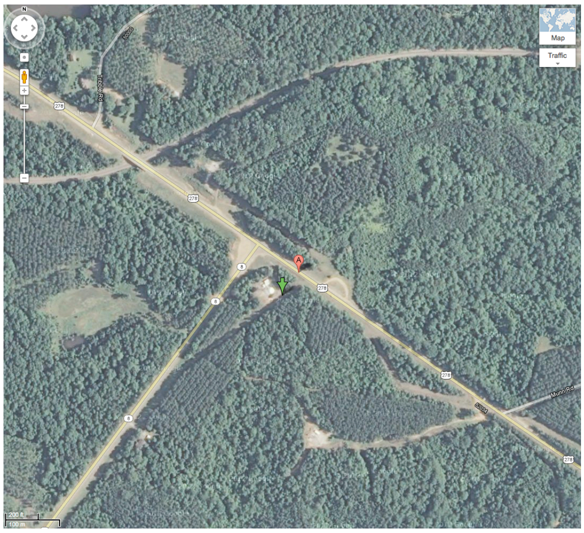
(b)

Figure 2. The 10-hour accumulated QPE (a) before and (b) after NSBM observed by radar KVNX.

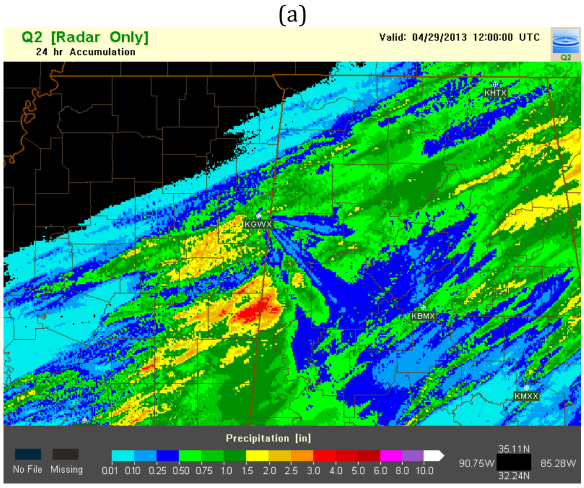
The NSBM approach has been implemented in a real-time NMQ system that integrates over 130 radars in the CONUS. It was shown the scheme is able to effectively alleviate/remove various blockages discontinuous in the national precipitation products. Figure 3 shows an example observed in the NMQ system. According to the cropped map image using the software of Google earth, the radar KGWX is surrounded by lush vegetation (Figure 3(a)). The artifacts in the image of 24-hour precipitation accumulation in Figure 3(b) are most likely due to blockage from growing trees to the southeast of the radar site. Figure 3(c) shows the corrected rainfall accumulations after the NSBM and VPR correction (Zhang and Qi, 2010).

Table. NSBM reference table for radar KVNX VCP12.

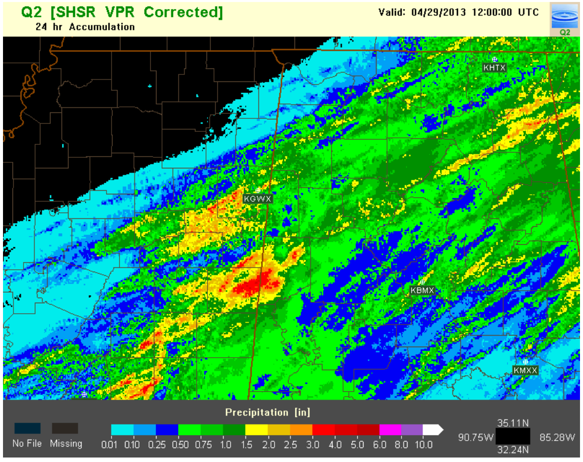
KVNX	VCP12					
S_ID	AZ1	AZ2	R1	R2	Tilt	Action code
1	209	235	0	460	2	2
2	217	217	0	460	0	3
3	219	225	0	460	0	1
4	235	256	0	460	3	2
5	276	323	0	460	2	2
6	350	351	0	460	0	1



(a)



(b)



(c)

Figure 3. (a) The image of environment around radar KGWX; (b) radar derived 24-hour precipitation accumulation in NMQ system without correction; (c) the image of precipitation accumulation (same as (b)) after NSBM and VPR correction

4. SUMMARY

A scientifically straightforward algorithm for mitigating non-standard blockage artifacts in weather radar rainfall fields was developed. It is effective in mitigating discontinuities in the radar derived precipitation field due to man-made tall objects near the radar and inaccurate terrain information used to define the “standard” hybrid-scan field. The NSBM is able to fill in the blocked sectors with neighboring data that has no blockages or with higher tilt data when there is little vertical variation in the precipitation system. However, the capability of this method is limited when the precipitation system is shallow such that the higher tilt, even though unblocked, is partially or completely overshooting the precipitation cloud top. The NSBM reference tables also need to be updated timely to account for changes in the sources of non-standard blockages.

5. ACKNOWLEDGEMENT

Major funding for this research was provided under the agreement between National Severe Storms Lab and the National Weather Service’s Radar Operations Center. Partial funding was provided under NOAA–University of Oklahoma Cooperative Agreement NA17RJ1227.

6. REFERENCES

Fulton, R. A., J. P. Breidenbach, D.-J. Seo, D. A. Miller, and T. O'Bannon, 1998: The WSR-88D rainfall algorithm. Wea. Forecasting, 13, 388-395.

Germann, U., and J. Joss, 2003: Operational measurement of precipitation in mountainous terrain. Weather Radar: Princi- ples and Advanced Applications, P. Meischner, Ed., Springer- Verlag, 52–77.

Langston, C., and J. Zhang, 2004: An automated algorithm for radar beam occultation. Preprints, 11st Conf. on Aviation, Range, and Aerospace Meteorology. Hyannis, MA,
Amer. Meteor. Soc. CD-ROM, P5.16.

Kucera, P. A., W. F. Krajewski, and C. B. Young, 2004: Radar beam occultation studies using GIS and DEM technology: An example study of Guam. J. Atmos. Oceanic Technol., 21, 995–1006.

Bech, J., B. Codina, J. Lorente, and D. Bebbington, 2003: The sensitivity of single polarization weather radar beam blockage correction to variability in the vertical refractivity gradient. J. Atmos. Oceanic Technol., 20, 845–855.

Zhang, J., and Y. Qi, (2010), A real-time algorithm for the correction of bright band effects in radar-derived QPE, J. Hydrometeor, 11, 1157–1171.

Zhang, J., K Howard, C. Langston, et al., 2011:
National Mosaic and multi-sensor QPE (NMQ) system: description, results and future plans. *Bull. Amer. Met. Soc.*, 92, 1321-1338.