Quantitative Precipitation Estimation Using C-band Dual-polarization Radar: A Case study for July 21, 2012 Flood in Beijing

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Abstract

A historical severe rainfall case in the metropolitan area of Beijing was studied using a C-band dual-polarization radar system. The QPE results from the evaluation was then validated using 5-min resolution gauge observation from an operational national weather station where is in the severe rainfall area. Results show that the rainfall estimation is more consistent with the surface rain gauge observation compared with the S-band single polarization observation and the algorithm of R(KDP): Brandes (2002) is the best for this case.

1. Introduction

A historical heavy rainfall hit Beijing, the Capital of China, on July 21, 2012, which caused severe flash flooding in the metropolitan area of Beijing, and 79 people, especially those in the suburb area were lost in this event from the official statistics. This extreme rainfall lasted nearly 16 hours and produced more than 300mm of rain accumulation at 18 rain gauge stations in the southwest area of Beijing. Although more than 200 Automatic Weather Stations (AWS) with rain gauges included in the mesoscale observation network, some of the precipitation data were false or missing due to the rain gauge malfunction or damage in the flooding.

Based on the 5-min resolution precipitation data integrity statistics and in-situ checking, there are about 77% rain gauges worked properly during this event, and 23% rain gauges had trouble in different degree during this period. Thus, weather radar can give a reasonable estimation and played a crucial role in quantitative precipitation estimation (QPE) for this extreme heavy rainfall event. Using the C-band radar with dual-polarization capacity and the operational S-band Doppler radar, which is one of the CINRAD (CHinese New-generation RADar network) system, both operated by Beijing Meteorological Bureau (BMB), this paper try to present a summary evaluation for the QPE results.

2. Method

The C-band radar in BMB was updated to Dual-Polarization in 2011. It operates in simultaneous transmit/receive mode for H and V channels and runs in VCP21 mode during rainy seasons. With the C-band dual-polarization radar located on the top of BMB office building, which is surrounded by several higher buildings, the radar observation is suffered from some severe blockage at lower elevations and ground clutter contamination which consists of normally propagation (NP) ground clutter and anomalous propagation (AP) ground clutter at the same time. In order to remove these non-precipitation echoes from the rain fall the fuzzy logical algorithm is applied in this study.

Addition to reflectivity (Z) and radial velocity (V) which Kessinger (2003) [1] used in Radar Echo Classifier (REC) for single-polarization radar, several dual-polarization measurements are selected in this paper which include differential reflectivity (Z_{DR}), differential propagation phase (Φ_{DP}), cross-correlation coefficient (ρ_{HV}). Conventional unfolding algorithm and estimation of the specific differential phase (K_{DP}) procedure described by Wang and Chandrasekhar (2009) [2] is employed in this work. The Finite-Impulse Response (FIR) filter of Hubbert and Bringi(1995) [3] is used to remove the differential backscattering phase δ_{HV} . And self-consistent method proposed by Bringi et al. (2001) [4] is adopted for Z and Z_{DR} attenuation-correction.

Rain-rate estimations from C-band dual-polarization radar are derived from different dual-polarization algorithm and its coefficients. We also retrieve the rainfall rate estimation from S-band single-polarization radar by the traditional Z-R relationship. The rain gauge data measured from national (with credible data quality) AWS station No.54596 maintained by operators for 24 hours every day is selected to evaluate the radar derived rainfall accumulation.

Root-mean-square error (RMSE), normalized mean bias (NMB), normalized standard error (NSE) and Pearson correlation coefficient (CORR) are calculated to access the performance of the radar QPE results.

3. Results and Discussion

The C-band dual-polarization radar derived hourly rainfall accumulation (based on R(KDP):Brandes et al., 2002) and its counterpart from the matched surface rain gauge observed at the station No.54596 is shown in Figure 1.

And the performance of each algorithm compared with total surface rainfall accumulation is listed as Table 1.

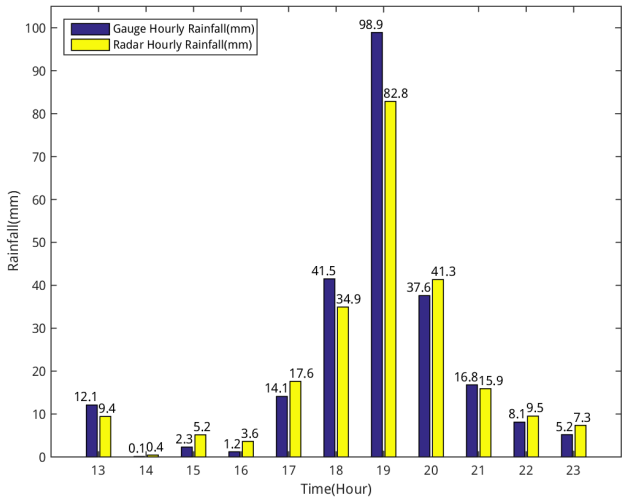

Figure 1. C-band dual-polarization radar derived hourly rainfall accumulation (yellow bar) vs. 54596 AWS rain gauge observed (blue bar).

Table 2. Performance of each algorithm compared with 54596 AWS total rainfall accumulation (mm)

Algorithm	RMSE (mm)	NMB (%)	NSE	CORR
C-band-R(Z): M-P(1948)	37.04	-36.04	1.14	0.309
C-band-R(Z): Fulton et al. (1998)	39.07	-21.84	1.24	0.289
S-band-R(Z): M-P(1948)	30.97	-65.07	0.89	0.859
S-band-R(Z): Fulton et al. (1998)	28.89	-61.33	0.83	0.856
R(KDP): Bringi et al. (2006)	22.37	-14.33	0.691	0.796
R(KDP): Brandes et al. (2002)	21.99	-2.98	0.693	0.797
R(KDP): Bringi et al. (2011)	24.14	-27.58	0.710	0.797
R(Z,ZDR): Bringi et al. (2011)	80.43	21.36	2.315	0.139
R(KDP,ZDR) : Bringi et al. (2011)	27.34	-6.52	0.762	0.751

It's obvious from Figure 1 that except for the most severe hourly rainfall at 18:00 and 19:00, which shows a slight underestimate of radar QPE compared to gauge observation, most of the other hours with less hourly rainfall are very close to the gauge observation with a little overestimate. And among the different QPE algorithms in Table 1, the RMSE, NMB and NSE for R(KDP): Brandes et al. (2002) is the best in this case study.

4. Conclusion

A severe rainfall event in Beijing area was studied using C-band dual-polarization radar for the rainfall estimation with different algorithms. The results are compared with operational S-band single polarization radar, also with the matched surface rain gauge observation as well.

Results show that the rainfall estimation using R(KDP) is more consistent with the surface observation with the matched rain gauge observation, and it shows a good competitiveness than S-band single polarization observation with the traditional Z(R) relationship. And especially in this case, the algorithm of R(KDP): Brandes (2002) is the best one among others.

Considering the scanning strategy and blockage, more work in the future will focus on the matching of the surface observation with the radar coverage.

5. Acknowledgements

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6. References

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