A Hydrometeor Classification Method and Its Applications for X-band Dual-polarization Radar Measurements

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1. INTRODUCTION

Compared to conventional Doppler weather radars, dual-polarization radars are capable of transmitting and receiving electromagnetic waves in both horizontal and vertical polarization states. The dual-polarization radar can not only obtain the intensity and phase information (Z_H, Z_V, V, W), but also obtain the difference information (Z_{DR}, Φ_{DP}, K_{DP}, ρ_{HV}) of the intensity and phase from the two differently polarized electromagnetic wave (Bringi and Chandrasekar, 2001). These dual-polarization radar parameters are sensitive to the type, shape and size of the hydrometeor particles. Therefore, the dual-polarization radar has the ability to identify hydrometeor particles in the cloud. Hydrometeor classification is one of the most important applications of the dual-polarization radar(Liu and Chandrasekar, 2000; Dolan and Rutledge, 2009).

2. METHODOLOGY

In this paper, based on quality-controlled observations of the IAP-714XDP-A X-band dual-polarization radar, the radar reflectivity and differential reflectivity are corrected by the Slide Self-Consistency Correction (SSCC) method. Texture parameters SD(Z_H) and SD(ϕ_{DP}) are used to distinguish meteorological echoes from non-meteorological echoes. The definitions of SD(Z_H) and SD(ϕ_{DP}) are as follows (Park et al., 2009; Snyder et al., 2010).

$$SD(Z_H) = \sqrt{\frac{\sum_{1km}[Z_H - mean(Z_H)]^2}{n_Z}}$$

$$SD(\phi_{DP}) = \sqrt{\frac{\sum_{2km}[\phi_{DP} - mean(\phi_{DP})]^2}{n_\phi}}$$

A fuzzy logic hydrometeor classification method is established for the X-band dual-polarization radar observations based on Z_H, Z_{DR}, K_{DP}, ρ_{HV}, atmospheric temperature T, combining with texture parameters SD(Z_H) and SD(ϕ_{DP}).

3. RESULTS

The classification of the meteorological echoes and non-meteorological echoes using SD(Z_H) and SD(ϕ_{DP}) is verified against low-elevation observations in Beijing on 7 August 2016. The results show that the combination of SD(Z_H) and SD(ϕ_{DP}) can effectively distinguish meteorological and non-meteorological (ground cluster) echoes.

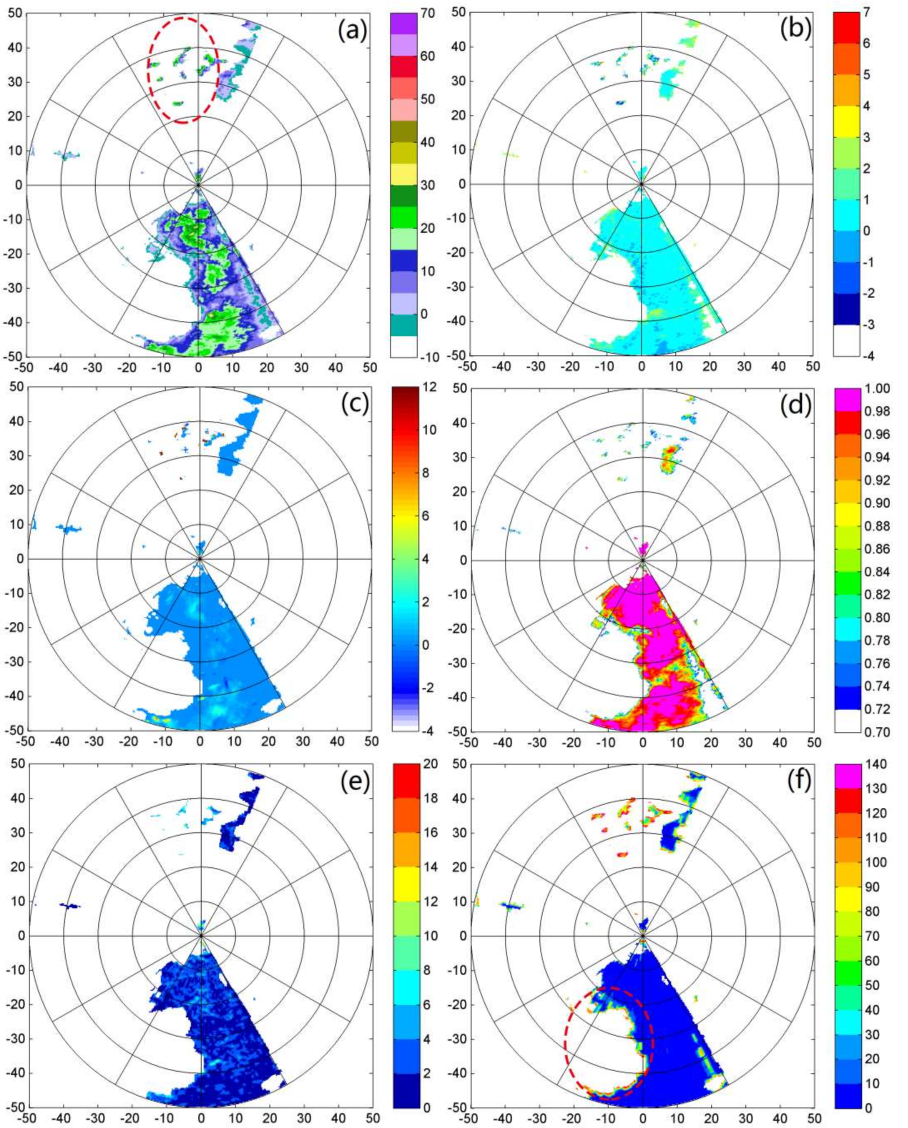

Figure 1. (a) Corrected Z_H (units: dBZ) ; (b) Corrected Z_{DR} (units: dB) ; (c) K_{DP} (units: °/km); (d) ρ_{HV}; (e) SD (Z_H) (units: dBZ); (f) SD(ϕ_{DP}) (units: degree)

(Observation time: 07:09:40 BJT, August 7, 2016; Elevation: 1°; Maximum display radius: 50km)

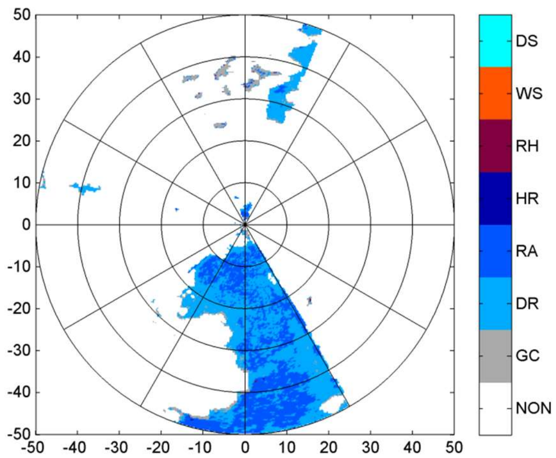

Figure 2. Classification results. DS, WS, RH, HR, RA, DR and GC represent dry aggregated snow, wet snow, a mixture of rain and hail, heavy rain, light and moderate rain, drizzle and ground clutter.

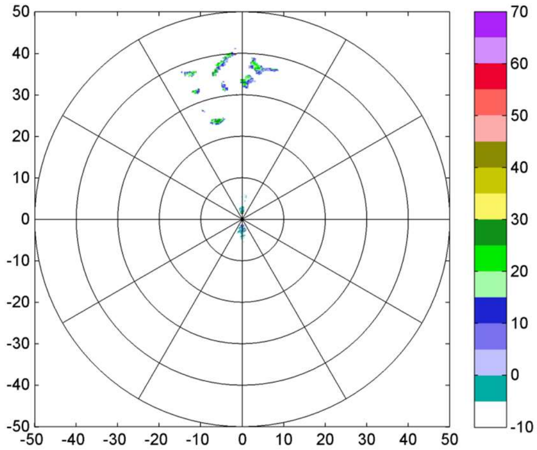

Figure 3. Reflectivity of X-band radar under clear sky condition.

(Observation time: 20:16:35 BJT; August 6, 2016; Elevation: 1°; Maximum display radius: 50km)

The fuzzy logic hydrometeor classification method is established for the X-band dual-polarization radar observations based on Z_H, Z_{DR}, K_{DP}, ρ_{HV}, atmospheric temperature T, combining with texture parameters $SD(Z_H)$ and $SD(\phi_{DP})$. Based on the case study of a hail event that occurred in Beijing on 7 August 2015, the fuzzy logic hydrometeor classification method is validated. The classification results of the hail are in good agreement with the ground observation results, indicating that the input parameters of different hydrometeor classification in the method are reasonable.

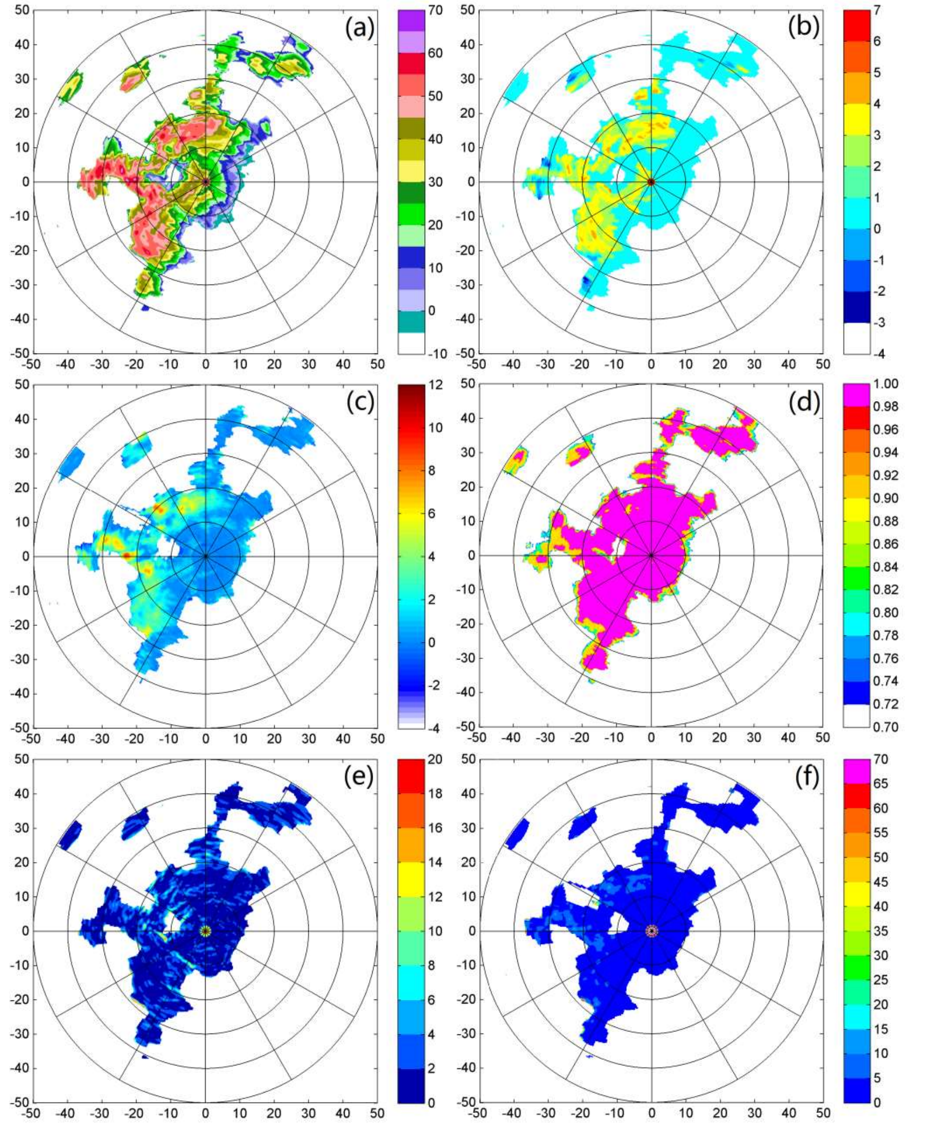

Figure 4. (a) Corrected Z_H (units: dBZ) ; (b) Corrected Z_{DR} (units: dB) ; (c) K_{DP} (units: °/km); (d) ρ_{HV}; (e) SD(Z_H) (units: dBZ); (f) SD(ϕ_{DP}) (units: degree)

(Observation time: 17:37:42 BJT, August 7, 2015; Elevation: 5°; Maximum display radius: 50km)

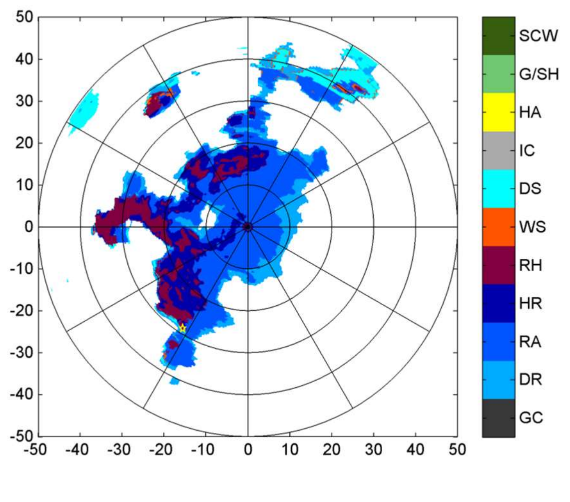

Figure 5. Classification results from the observation data in Figure 4. SCW, G/SH, HA, IC, DS, WS, RH, HR, RA, DR and GC represent supercooled water, graupel or small hail, hail, ice crystal, dry aggregated snow, wet snow, a mixture of rain and hail, heavy rain, light and moderate rain, drizzle and ground clutter, respectively.

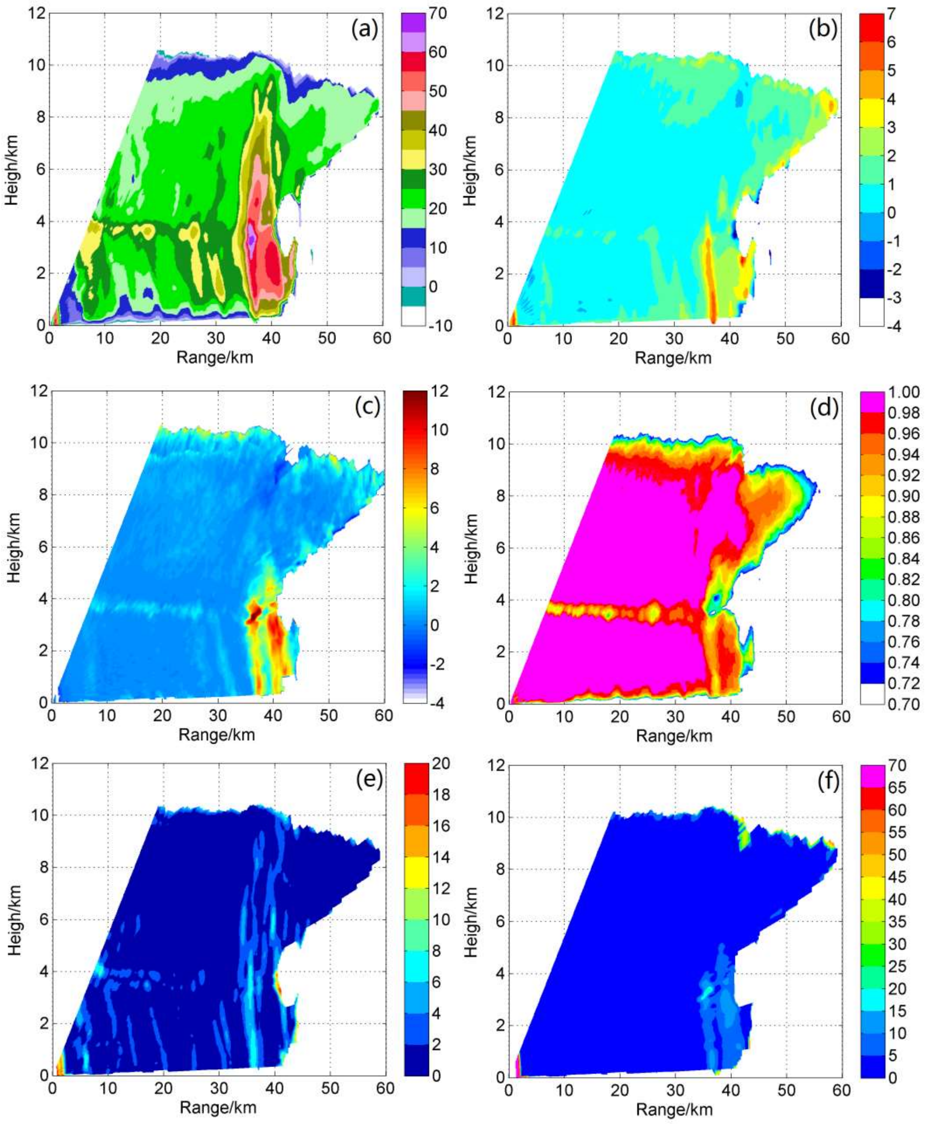

Figure 6. (a) Corrected Z_H (units: dBZ) ; (b) Corrected Z_{DR} (units: dB) ; (c) K_{DP} (units:°/km); (d) ρ_{HV}; (e) SD(Z_H) (units:dBZ); (f) SD(ϕ_{DP}) (units: degree)

(Observation time: 20:14:19 BJT, August 7, 2015; Azimuth: 148°)

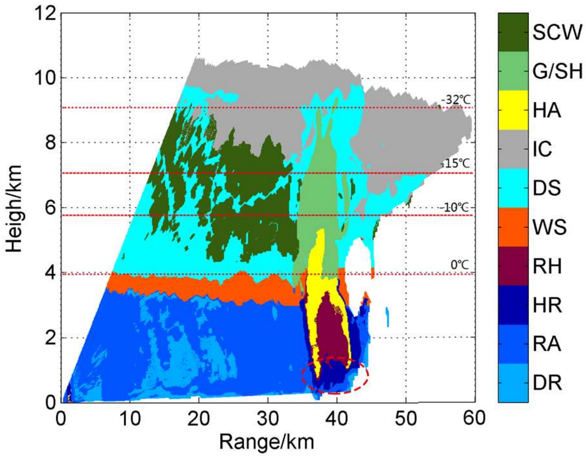

Figure 7. Classification results from the observation data in Figure 6. The signs like SCW, G/SH, HA and so on are the same as those in Figure 5.

The method is also used to classify hydrometeors in convective clouds that were in the developing stage on 14 September 2016. It is found that the strong updraft could bring low-level raindrops up into the layer above the freezing level. These raindrops then became supercooled rain and froze to hail embryos that can further develop into hailstones.

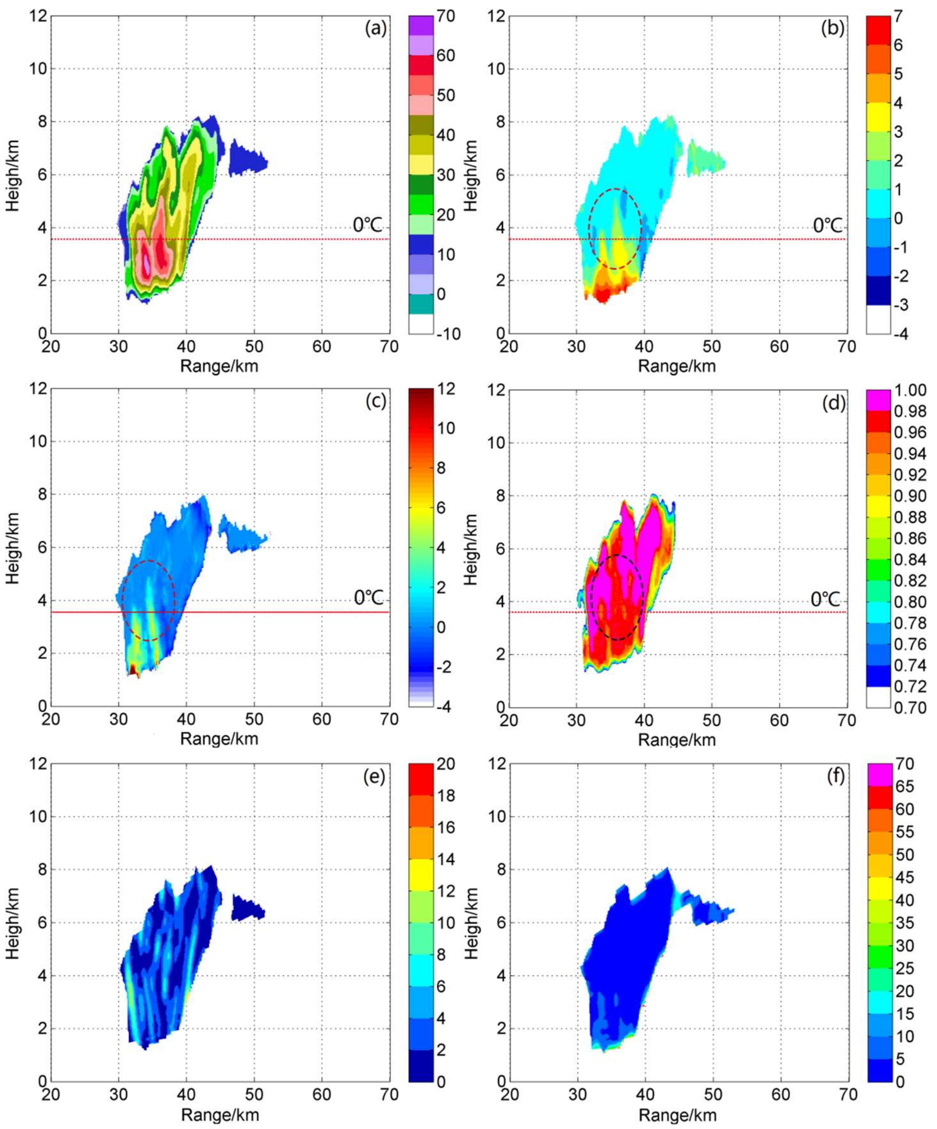

Figure 8. (a) Corrected Z_H (units: dBZ) ; (b) Corrected Z_{DR} (units: dB) ; (c) K_{DP} (units: °/km); (d) ρ_{HV};

(e) SD(Z_H) (units: dBZ); (f) SD(ϕ_{DP}) (units: degree)

(Observation time: 20:04:25 BJT, September 14, 2016; Azimuth: 92°)

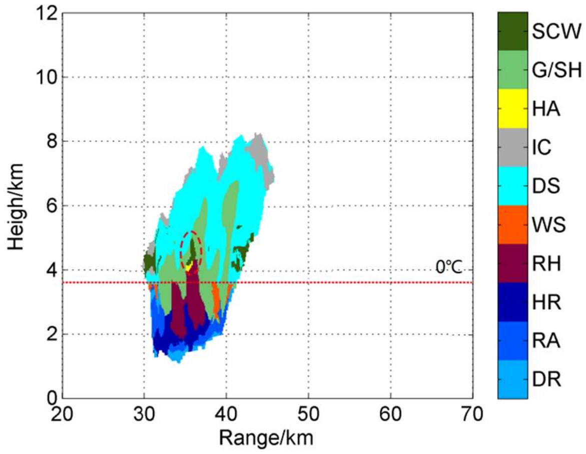

Figure 9. Classification results from the observation data in Figure 8. The signs like SCW, G/SH, HA and so on are the same as those in Figure 5.

4. CONCLUSIONS

Through the identification of meteorological echoes and non-meteorological echoes and the identification of precipitation particle types, this paper verifies that the classification results of the established recognition algorithms are accurate and reasonable. However, it should be noted that direct detection in the convective cloud is often very dangerous. Therefore, it is a difficult task to verify the classification results based on the polarization parameters of the dual polarization radar. This paper only analyzes the identification algorithm of the X-band dual-polarization radar based on a hail case happened in Beijing. A more accurate verification method is to verify the classification results by means of direct detection of the aircraft into the cloud and coordinated observation of the dual-polarized radar. In addition, the established recognition algorithm for X-band dual-polarization radar also needs more examples of precipitation process to test its universality.

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