P11.5 POLARIMETRIC MODELLING OF FLARE ECHOES, AND COMPARISONS WITH OBSERVATIONS AT C BAND

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1. INTRODUCTION

The presence of an elongated radar reflectivity and Doppler velocity signature extending radially outward beyond a strong radar echo was firstly called a “hail spike”, as it showed a close relationship with large surface hail. After, observations in the absence of hail reports suggested it be renamed a “flare” (Wilson, 1988).

Zrnić (1987) proposed a theory in which he attributed reflectivity flares to a three-body scattering process involving, firstly, scattering of the transmitted power by large hydrometeors to the ground, secondly, backscattering by the ground to the hydrometeors and, finally, scattering from the hydrometeors back toward the radar.

More recently Lemon (1998) presented and discussed some observations taken with a WSR-88D S-Band single-polarization radar during a storm that hit Oklahoma in 1992. He showed also how the flare signature can be used operationally.

Polarimetric observations (Z and Z_{DR}) were reported by Hubbert and Bringi (2000), together with the description of an improved model of flares.

In this work a polarimetric model of flares is presented; the model has been developed on physical basis, i.e. it actually computed and integrates all the individual contributions of the three body-scattering mechanism; it is able to evaluate polarimetric signatures whichever the polarization scheme used by the radar (H-V linear, slantwise linear, etc.), starting from a given profile of reflectivity Z.

Model's predictions are then compared with observations carried out with C-band polarimetric Doppler radars, operating in Italy and Germany. The predicted profiles are in good agreement with that measured by the radars, despite the relative simplicity of the model itself.

2. EVALUATION OF Z AND Z_{DR}

The model works out its predictions starting from an initial reflectivity profile, where no flare is present.

With reference to Fig. 1, we assume that a plane wave is incident on the particles present in radar bin B_i; part of scattered energy hits the ground at point P, is (partially) reflected back to the particles in radar bin B_j, and finally back to the radar antenna. The contribution dP to the flare of an elemental area ΔS is:

$$dP = \frac{P_t G_t A_e \sigma_i(\vartheta_1)\sigma_{G,K}(\vartheta_1,\vartheta_2)\sigma_j(\vartheta_2)}{(4\pi)^4 R_i^2 R_j^2 R_{k,i}^2 R_{k,j}^2} \qquad (1)$$

where P_t is the transmitted power, G_t is the antenna gain, A_e is the effective area of the antenna, $\sigma_{i,j}$ are the scattering cross sections from the i- and j-th radar bin towards the ground, and $\sigma_{G,K}$ is the scattering cross section of the elemental ground area. The scattering cross sections depend on the polarization state of the incident wave.

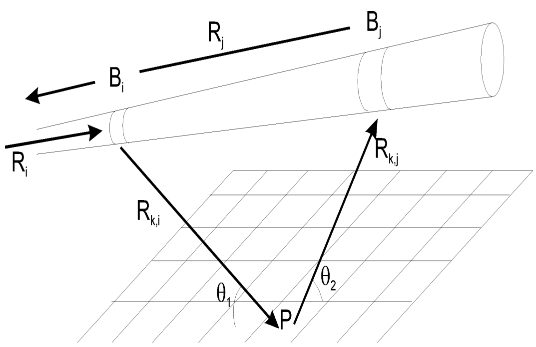

Figure 1. Three-body scattering geometry

As a first order approximation, if the scattering particles are spherical in shape, the bistatic scattering cross section shows an angular dependence (for the vertical polarisation) of the kind:

$$\sigma(\vartheta) = \sigma_b \cos^2(\vartheta) \qquad (2)$$

where σ_b is the back-scattering cross-section. The bistatic scattering cross section of the ground $\sigma_{G,K}$ can be expressed as:

$$\sigma_{G,K}(\vartheta_1,\vartheta_2) = \Gamma \Delta S (2 \operatorname{sen}\vartheta_1 \operatorname{sen}\vartheta_2)/(\operatorname{sen}\vartheta_1 + \operatorname{sen}\vartheta_2) \qquad (3)$$

where Γ is the reflection coefficient of the ground; in this respect, by comparing the absolute values of measured and predicted reflectivity in the flare region,

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we found Γ =-17 dB to be the best choice for our scenario. The energy associated with this contribution appears as coming from a radar bin located at a distance $(R_i+R_j+R_{k,i}+R_{k,j})/2$. To evaluate the complete flare profile eq. (1) must be integrated (summed) over all pairs of scatterers and all ground elemental areas, associating each power contribution *dP* to the pertinent radar bin.

A similar procedure is applied for horizontal polarization, with only minor changes to the equations related to different projection angles.

The received power is then converted in reflectivity *Z* through the radar equation; Z_{DR} is eventually calculated as the ratio (expressed in dB) between Z_H and Z_V.

3. COMPARISON WITH MEASURED DATA

The dataset used in this work were recorded by the C-band dual-polarization Doppler radar located near Bologna (Italy), owned and operated by ARPA-SMR. A long lasted flare occurred on 18 June 1997 when a supercell thunderstorm swept the Po Valley W-NW to E-SE; during this event an exceptional hailfall was observed over a strip 200km wide. An analysis of volumetric data highlights the continuous presence of a flare from 12:10 UTC until 15:04 UTC. During this time the system passes over the radar site and in some instants the flare identification is quite doubtful. The flare reaches a maximum tail extension of about 24km and is normally well visible at the great part of elevation recorded.

To test the model against measured data we have applied the following procedure: we have identified a section of the radar beam where hail is clearly present, and we have used the values of reflectivity coming from that region as an input for the model. Knowledge of the distance and the radar constant allows us to calculate the total back-scattering cross section σ_b relative to each radar bin. These values are then used in Eq. 1 to evaluate the power scattered back to the radar by the 3-body scattering mechanism; these values of power are eventually converted in the corresponding values of radar reflectivity Z.

In Fig. 2 the measured Z_H profile (shown as a dashed line) is plotted together with the predicted Z profile (shown as a continuous line), as a function of distance from the radar site; the selected radar ray has an elevation of 9.6° . The strong reflectivity profile from 26 to 34 km is used as input for the model; the following weaker flare echo is correctly predicted by the model; as expected, actual measurements are noisy and show a certain fluctuation around the average value.

Fig. 3 shows the measured profile of differential reflectivity Z_{DR} (dashed line), relative to the same radar ray, plotted together with the predicted Z_{DR} profile (continuous line). In the flare region there is a strong peak in Z_{DR}, that is predicted reasonably well by the model; Z_{DR} then decreases rapidly towards negative values, and this is also well predicted by the model. Beyond 43 km the measured radar echo becomes quite weak, and consequently the measured Z_{DR} becomes quite "noisy"; these fluctuations cannot be found in the simulated profile.

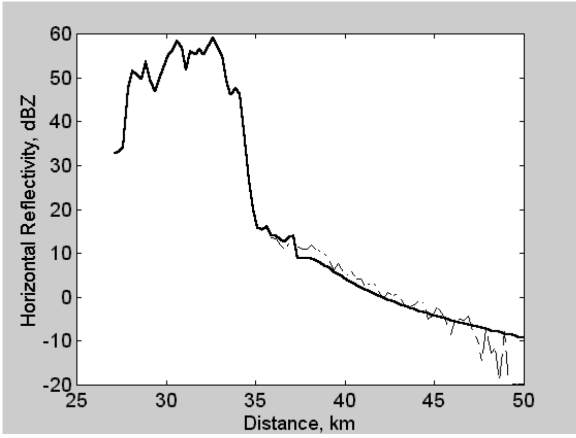

Figure 2. Predicted and measured Z_H profile

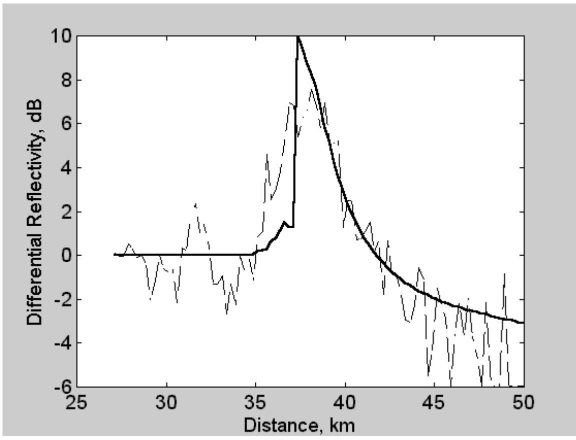

Figure 3. Measured and predicted Z_{DR} profile

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