11B.7 THE EFFECTS OF ORIENTATION OF HYDROMETEORS ON THE ESTIMATION OF DIFFERENTIAL PROPAGATION PHASE

Enrico Torlaschi* and Gaël Durand
Université du Québec à Montréal

1. Introduction

When simultaneous or alternate transmission and reception of both horizontal and vertical polarization is used, it is common practice to assume a medium of equioriented hydrometeors for the interpretation of the radar polarization measurements. Such precipitation model leads to the description of negative values of radial gradients of the differential propagation phase in terms of backscattering phase. Torlaschi and Gingras (2000) have demonstrated theoretically that these negative radial gradients can also be due to radial variations of the degree of common orientation of the hydrometeors when the radar beam moves from a region of well oriented particles to a region of less oriented ones. Data from the S band Doppler and polarimetric weather radar at McGill University in presence of the melting layer are analyzed to illustrate in practice the effects of the orientation of the hydrometeors on the estimation of the differential propagation phase.

2. Theory

Torlaschi and Gingras (2000) have shown that

$$Z_{DR0} \approx \rho_2 Z_{DR} , \quad (1)$$

$$\Delta Z_H = Z_{H0} - Z_H \approx -\frac{1-\rho_2}{2} Z_{DR} , \quad (2)$$

$$tg(\Phi_0) = \rho_2 \; tg(\Phi) , \quad \text{and} \quad (3)$$

$$\frac{\rho_{HV0}}{\rho_{HV}} \approx \left[1-(1-\rho_2)\sin^2\Phi\right]^{1/2} \left[1+(\rho_2^2-1)\left(\frac{Z_{DR}}{8.686}\right)^2\right]^{1/2} , \quad (4)$$

where subscript 0 indicates radar polarization measurements when a priori equioriented hydrometeors with canting angle set to 0° throughout the region of precipitation are assumed, and ρ_2 is the degree of common orientation of the hydrometeors filling the backscatering volume (McCormick and Hendry 1975). The other symbols have the usual meaning. Table 1 gives values of absolute or relative error of estimate of reflectivity, differential reflectivity, differential propagation phase, and copolar correlation coefficient at zero lag time for various precipitation types.

3. Data analysis

Polarimetric radar data were provided by the J. S. Marshall Radar Observatory, McGill University, in the form of digital maps of plan position indicator (PPI) scans representing reflectivity, Z, differential reflectivity, Z_{DR}, two-way total differential phase shift, Φ_0, and copolar correlation coefficient at zero lag time, ρ_{HV}. The data are on a Cartesian grid of 1-km spatial resolution. The radar is operated at S band and employs simultaneous transmission and reception of linear vertical and horizontal polarization (Zahrai and Zrnic 1997).

On 17 September 1999 Southern Quebec was under the influence of the extratropical storm originated from Hurricane Floyd. Figure 1 shows a set of PPI' scans at 0.9° elevation, taken at 0327 UTC. In the range 100-130 km six areas displaying negative radial gradients of Φ_0 can be identified. They are numbered from 1 to 6 in Figure 1 bottom left panel. The data from McGill wind profiler located in downtown Montreal City show the presence of the melting layer above 2.5-km height. All the featured areas are then located where the radar beam interacts with the melting layer. Locations 3 and 4 are in the Appalachian Mountains, and location 6 in the Laurentians. Values of ρ_{HV} in these areas suggest ground clutter contamination. Only location 1 is considered in this paper.

Figure 2 shows the values of Φ_0 measured along a radial passing through location 1. The angle Φ_0 monotonically increases to a value of 28° at a distance of approximately 122-km. It then decreases to a value of 22° at a distance of 127-km and it increases again to a value of 28° at 135-km range. A backscattering phase up to 6° would be required to hinder the decrease in total differential phase.

We now illustrate how to describe the variations of Φ_0 in terms of the variations of the degree of common orientation of the hydrometeors, ρ_2. From Figure 2 it seems plausible to assume that the intrinsic value of the total differential phase, Φ, is constant and equal to 28° at a distance of 122-135 km. Then, form (3) and the values of Φ_0 in Figure 2 we calculate ρ_2. The results are shown in Figure 2 with full circles. The value of ρ_2 at 127-km is about 0.76 which is typical for snow. Now from (1), (2), and (4) and the values of ρ_2, Z_{H0}, Z_{DR0}, and ρ_{HV0} we obtain the intrinsic values of these last variables. From our calculations it appears that in this case the assumption of equioriented particles is a cause of an underestimation of about 0.5 dB for Z_{DR} and marginal for Z_H and ρ_{HV}.

4. Conclusions

The inspection of few radar images at coarse resolution used in this study does not permit a detailed analysis of the effects of orientation of hydrometeors on the estimation of radar polarization parameters. However, It appears from this preliminary work that negative gradients of the total differential phase shift may be observed at the rain to melting layer interface and that they are due to the variations of the degree of common orientation of the hydrometeors rather than to their backscattering phase shift.

* *Corresponding author address:* Enrico Torlaschi, UQÀM, Département des Sciences de la Terre et de l'atmosphère, Case postale 8888, succursale Centre-Ville, Montréal, QC Canada, H3C 3P8; e-mail: torlaschi.enrico@uqam.ca

Acknowledgments. Our thanks are due to Prof. I. Zawadzki from J. S. Marshall Radar Observatory, McGill University, Montreal, Canada, for providing the radar data.

REFERENCES

Color Figure 1:
http//people.sca.uqam.ca/~enrico/RADAR01/Figure1.jpg

McCormick, G. C., and A. Hendry, 1975: Principles for the Radar Determination of the Polarization Properties of Precipitation. *Radio Sci.*, **10**, 421-434.

Torlaschi, E., and Y. Gingras, 2000: Alternate Transmission 0f +45° and - 45° Slant Polarization and Simultaneous Reception of Vertical and Horizontal Polarization for Precipitation Measurement. *J. Atmos. Oceanic. Technol.*, **17**, 1066-1076.

Zahrai, A., and D. S. Zrnic, 1997: Implementation of polarimetric capability for the WSR-88D (NEXRAD) radar. Preprints, 28th Conference on Radar Meteorology, Austin, Amer. Meteor. Soc., 284-285.

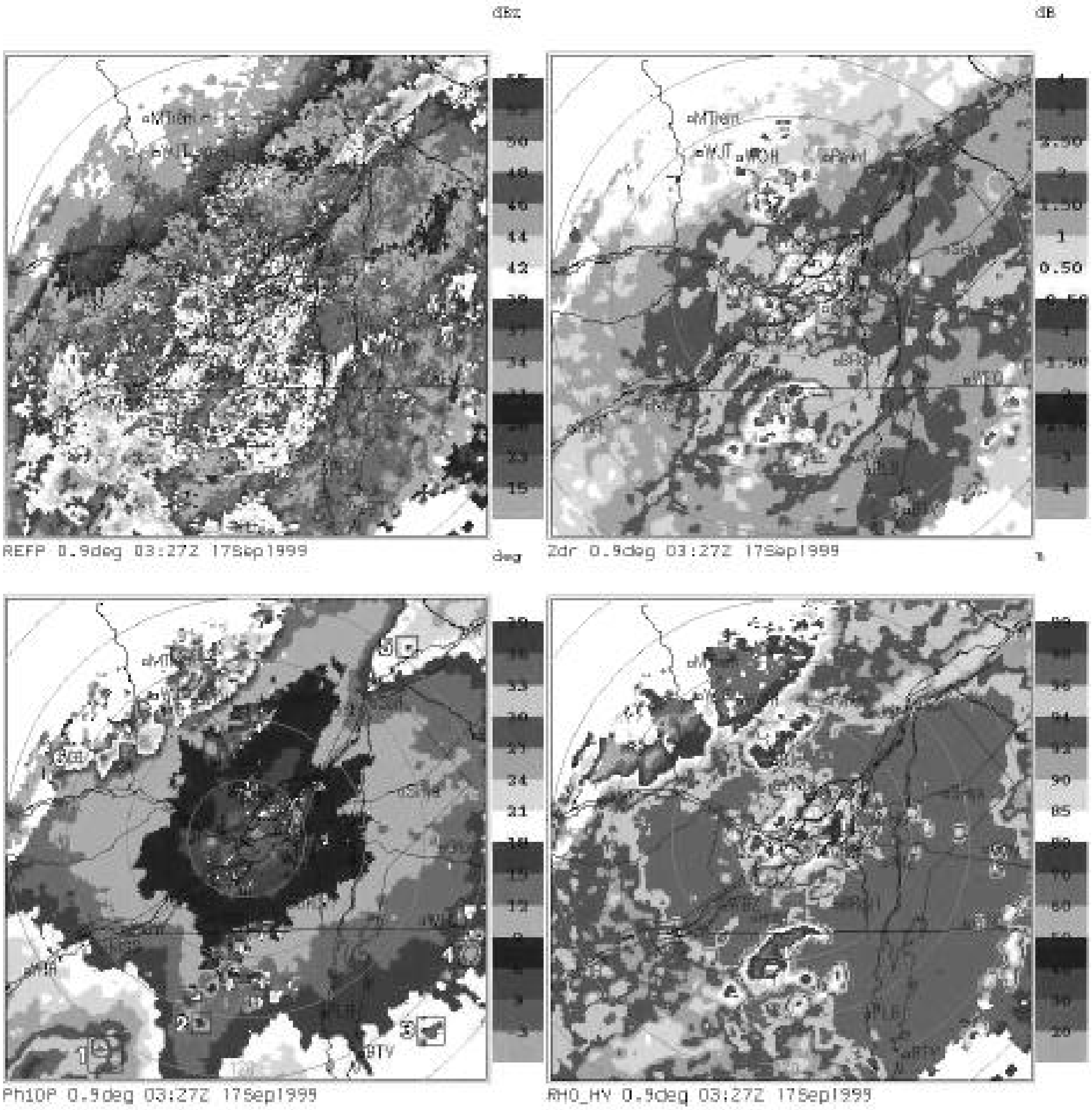

Figure 1. Plan position indicator displays at elevation 0.9° of reflectivity (top left panel), differential reflectivity (top right panel), two-way total differential phase shift (bottom left panel), and copolar correlation coefficient at zero lag time (bottom right panel) on September 17, 1999, at 0327 UTC. Range circles are at 30-km intervals. In the bottom left panel are indicated the locations 1 - 6 of negative radial gradients of two-way total differential phase shift.

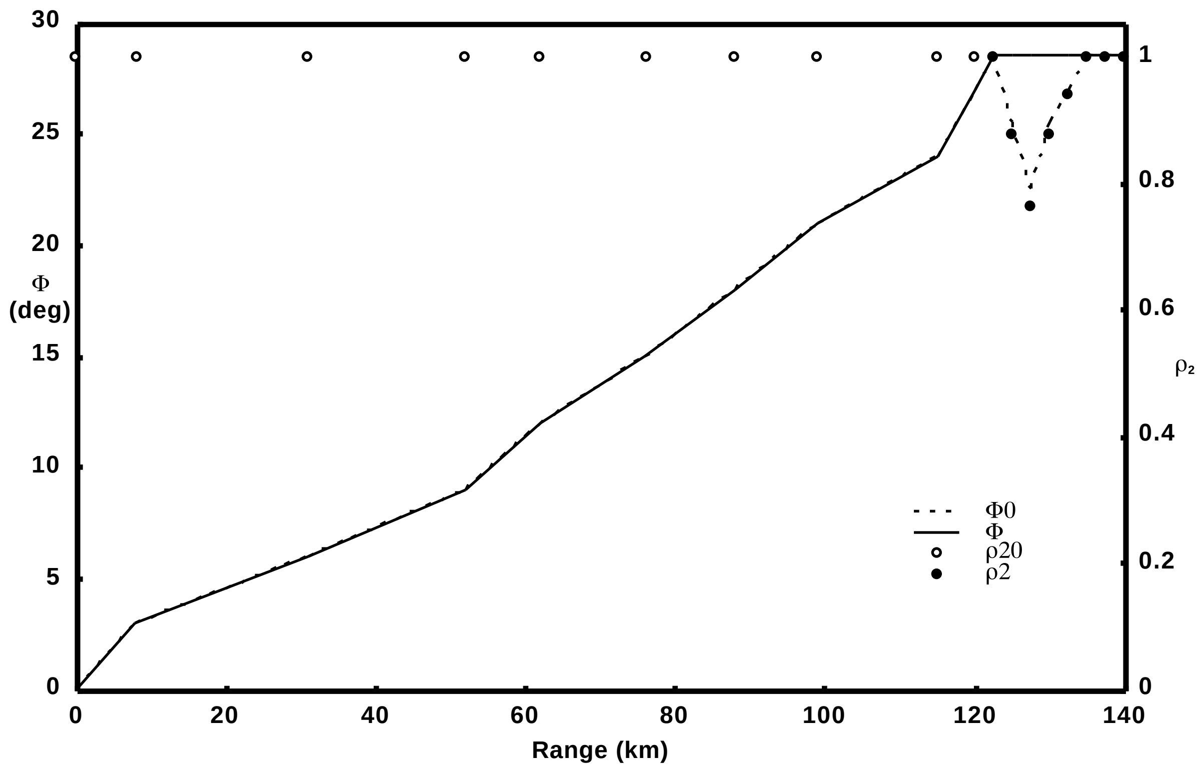

Figure 2. Total two-way differential propagation phase shift, Φ, and degree of common orientation of the hydrometeors, ρ_2, as function of range. Dashed line and open circles indicate data when a medium of equioriented hydrometeors is assumed. Solid line and full circles show the calculated values when the orientation of the particles is considered.

TABLE 1. Values of ρ_2, Z_{DR}, ΔZ_H, $\Delta Z_{DR}/Z_{DR}$, $(\Delta\Phi)_{Max}$, and $(\Delta\rho_{HV}/\rho_{HV})_{Max}$ for various precipitation types.

	ρ_2	Z_{DR} (dB)	ΔZ_H (dBZ)	$\Delta Z_{DR}/Z_{DR}$ (%)	$(\Delta\Phi)_{Max}$ (deg)	$(\Delta\rho_{HV}/\rho_{HV})_{Max}$ (%)
Rain	0.9 to 1	0.5 to 4	-0.2 to 0	0 to -10	-3	-5 to -7
Snow	0.75	0 to 5	-0.6 to 0	-25	-8	-13 to -20
Melting Layer	0.65	0 to 3	-0.5 to 0	-35	-12	~ -20
Hail	0.35	-0.5 to 0.5	-0.2 to 0.2	-65	-30	~ -40