6B.4 WHAT DOES THE BRIGHT BAND TELL US ABOUT THE Z-R RELATIONSHIP?

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1. INTRODUCTION

It is well known that the spatial and temporal variability of the Drop Size Distribution (DSD) has a strong impact on the transformation of radar measurements of reflectivity, *Z*, into rainfall rate, *R*, and consequently is a factor limiting the quality of radar rainfall estimates.

This variability has been characterized in some previous studies, which showed how physical processes in snow result in characteristic DSDs. On the other hand, these processes have also an impact in the characteristics of the bright band.

The main purpose of the presented work is to relate the characteristics of the bright band to the resulting *Z-R* relationship and to investigate the applicability of the information given by the bright band intensity to improve rain-rate estimates from radar reflectivity.

2. THE RELATION BETWEEN THE PHYSICAL PROCESSES AND THE Z-R RELATIONSHIP

Zawadzki and Lee (2004) and Lee and Zawadzki (2005) have shown the impact of the dominant physical processes in the snow in the resulting *Z-R* transformation.

$$Z = aR^b \tag{1}$$

In particular, for the typical Marshall-Palmer situation (where the dominant processes are deposition and aggregation), the resulting DSDs pivot around N_0 with intensity and the exponent of the Z-R relationship is close to 1.5 (see figures 1a and 2a).

On the other hand, heavily rimed snow result in uniform growth of size with intensity (i.e. small and big growth at similar rate), and, therefore giving *Z-R*s with low exponents (see figures 1b and 2b).

Finally, aggregation of snow through a deep layer of temperatures T>-6°C results in DSDs pivoting around mass flux and exponents of the Z-R relationship b>1.5 (see figures 1c and 2c).

3. THE BRIGHT BAND

On the other hand, Zawadzki et al. (2001); Zawadzki et al. (2005) have also shown the relation between the riming degree and the bright band intensity: the higher the riming degree, the less intense the bright band (see figure 3). Fabry and Zawadzki 1995 proposed to characterize the bright band intensity as the difference (in dB) between the reflectivity at peak, dBZ_{peak}, and the reflectivity in rain, dBZ_{rain} as:

$$\Delta_{ptor} = dBZ_{peak} - dBZ_{rain} \tag{2}$$

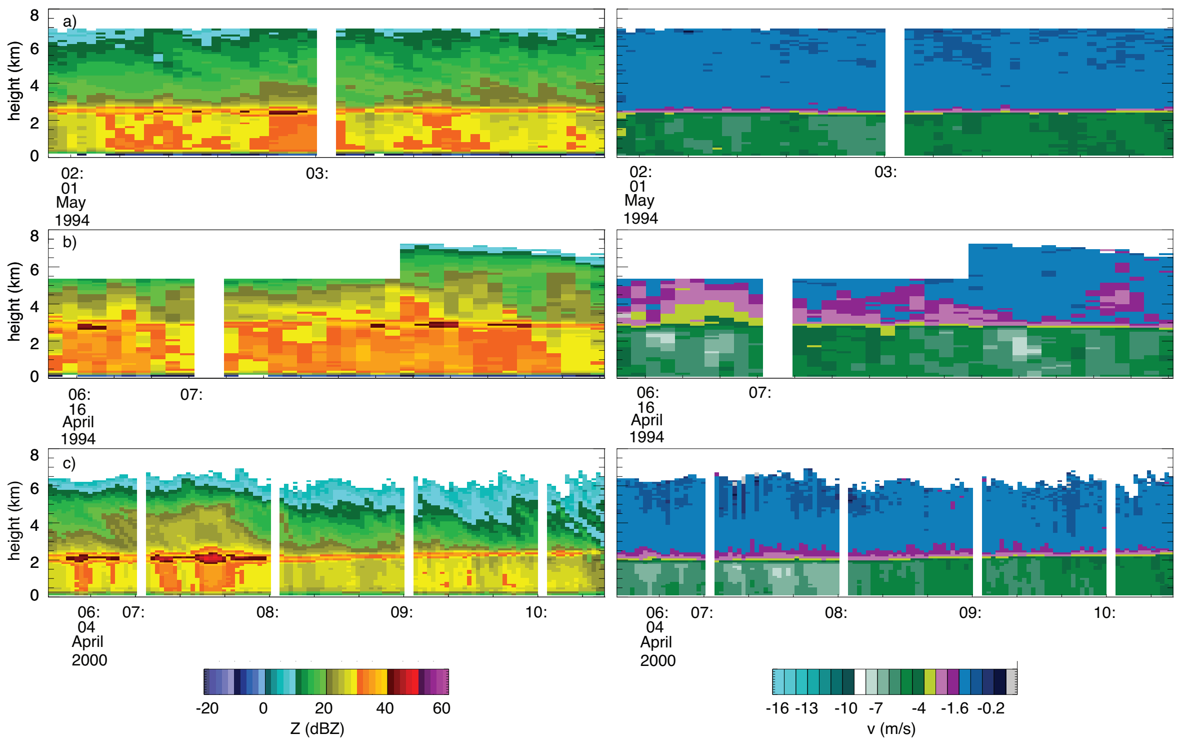

Fig. 1. Series of UHF observations (reflecitivity -left- and Doppler velocity -right-) corresponding to: (a) 1 May 1994 between 0200 UTC to 0400 UTC, (b) 16 April 1994 between 0640 UTC and 0800 UTC and (c) 04 April 2000 between 0620UTC and 1030 UTC.

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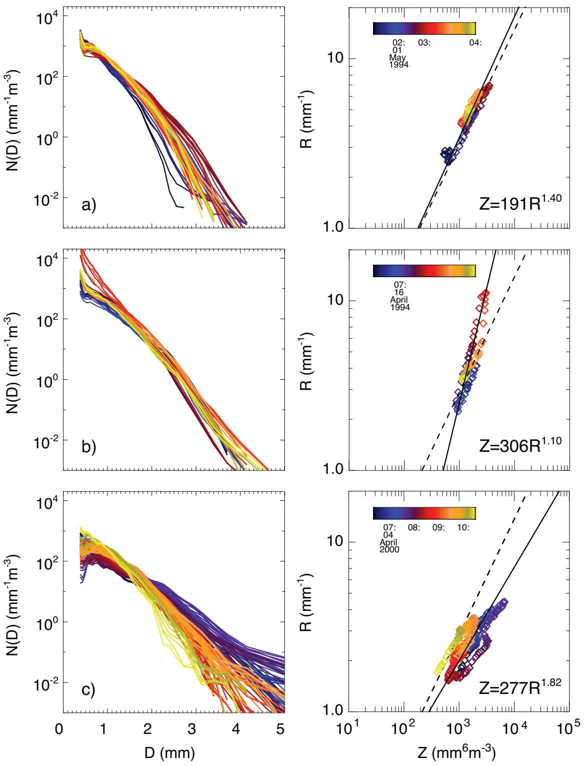

Fig. 2. DSDs (left) and Z-R scatter plots (right) corresponding to the events showed in figure 1. The dashed line correspond to the climatological Z-R

4. THE Z-R RELATIONSHIP AND THE BRIGHT BAND

This two-fold dependence of the bright band intensity and Z-R relationship with the microphysical processes in the snow, suggests some correlation between the bright band intensity and the Z-R.

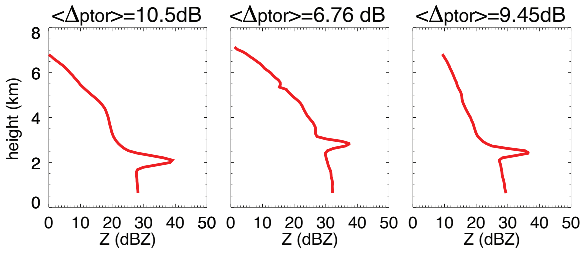

Fig. 3. Mean vertical profiles of reflectivity for the events showed in figure 1.

4.1 Data used

The data used in this section corresponds to a particular event occurred in Montreal, Quebec (Canada) on 26 April 1994 between 0140 UTC and 1620UTC.

The bright band intensity was observed from the measurements of a UHF wind profiler (see figure 4a).

On the other hand, DSD observations were obtained with a Precipitation Occurrence Sensing System (POSS, Sheppard 1990) collocated with the UHF wind profiler (figure 4b shows a good agreement between the series of reflectivity obtained with both instruments).

4.2 Comparison of bright band intensity and Z-R residuals

The bright band intensity, Δ_{ptor} (equation 2), has been compared with the residuals (in dB) between the rain rate estimated from reflectivity, $R^*(Z)$, and the actual rain rate defined as:

$$\delta R = 10\log\left[R^*(Z)\right] - 10\log(R) \qquad (3)$$

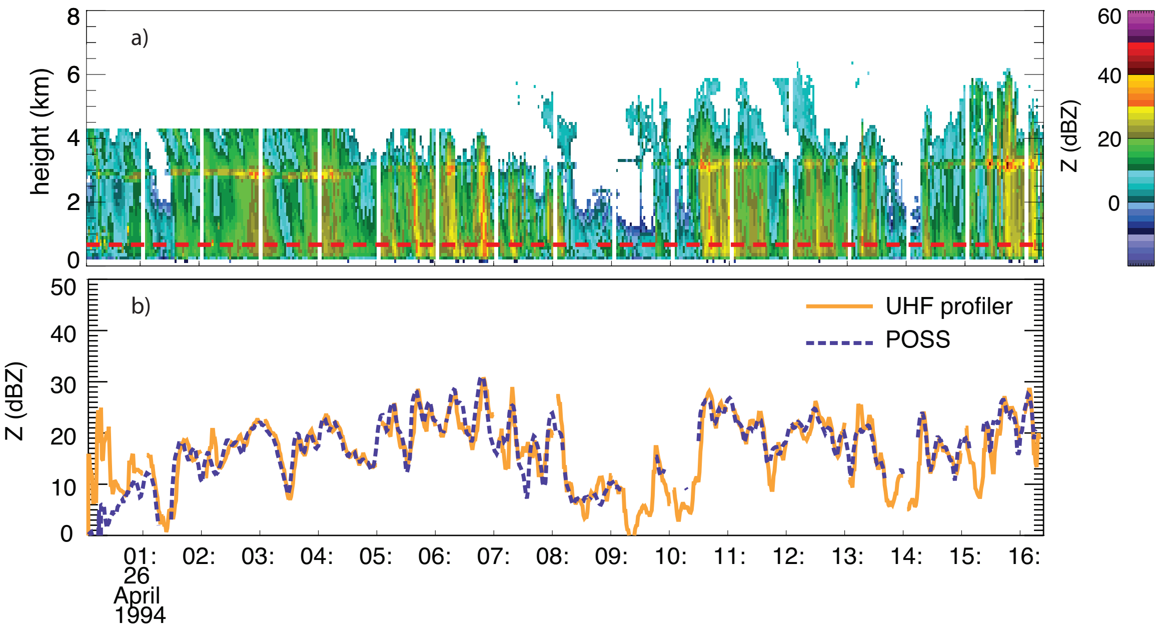

Fig. 4. Top: Series of UHF time-height reflectivity profiles measured on 26 April 1994 from 0000 UTC to 1620 UTC. Bottom: comparison of the reflectivity measured with the UHF profiler at 1100m (orange line) and the reflectivity obtained from POSS observations (blue dashed line).

Where $R^*(Z)$ is estimated with equation 1 using the climatological Z-R relationship:

$$R^*(Z) = \left(\frac{Z}{a}\right)^{1/b} \quad (4)$$

Lee and Zawadzki 2005 estimated the climatological Z-R parameters for Montreal, from long-term DSD measurements (a=210; b=1.47).

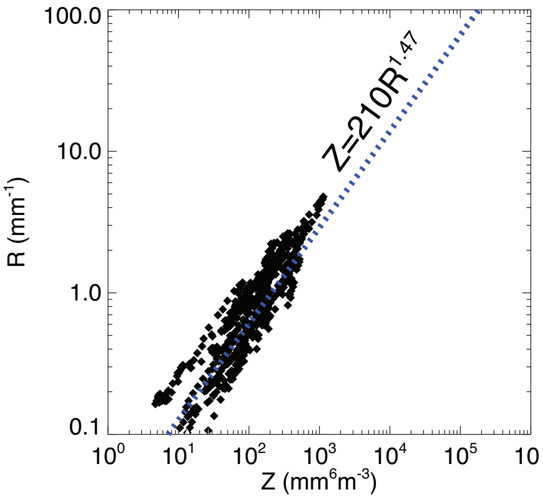

Fig. 5. Z-R scatterplot from POSS observations from 0000 UTC to 1620 UTC 26 April 1994. The dashed blue line corresponds to the climatological Z-R relationship ($Z=210R^{1.47}$).

Figures 6 and 7 show the comparison between Δ_{ptor} (observed with the UHF profiler) and δR (from POSS DSD observations). In these figures, a significant correlation between them can be observed (note that they were measured with independent instruments).

A similar result was found out by Huggel et al. 1996. In a similar experiment and assuming an exponential DSD distribution they showed the correlation between the bright band intensity and the 2 parameters of the DSD, N_0 and Λ.

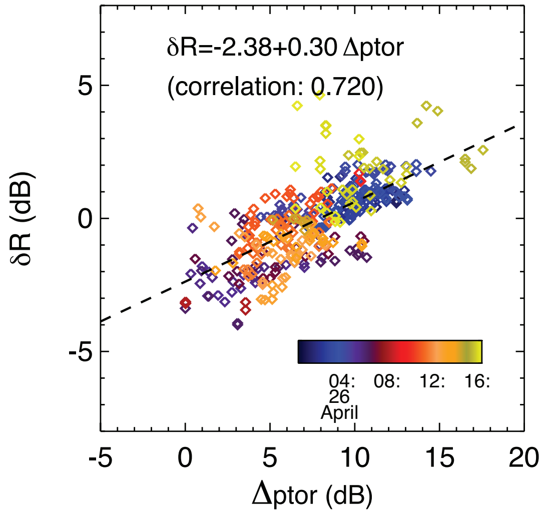

Fig. 6. Scatter plot between Δ_{ptor} and δR for the case of 26 April 1994 between 0000 UTC to 1620 UTC shown in figure 4.

5. DOES THIS CORRELATION ALWAYS EXIST?

The purpose of this section is to analyze the dependence of this correlation on the dominant physical processes.

Figure 8 shows the scatter plots Δ_{ptor}-δR for the cases analyzed in Section 2 (see also figure1). It can be seen that the correlation for the Marshall-Palmer case and the case with strong aggregation is significant, while for the case dominated by heavy riming, this correlation is significantly low. These results (illustrated here with individual cases only) have been repeatedly found.

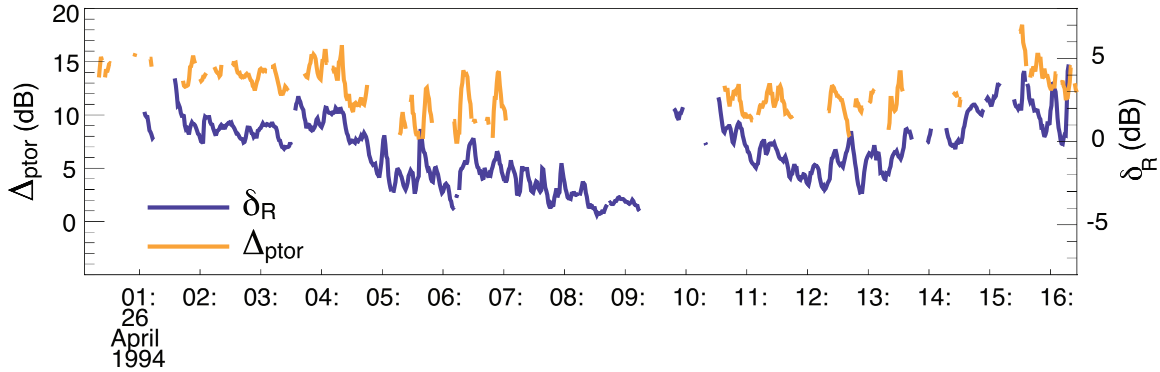

Fig. 7. Time series of the evolution of the bright band intensity, Δ_{ptor}, (orange line) and the residuals of the Z-R relationship, δR (blue line).

6. APPLICABILITY TO IMPROVE RAINFALL ESTIMATES

The correlation shown between Δ_{ptor} and δR suggests that part of the variability of the residuals of the Z-R relationship (δR) can be explained by Δ_{ptor} using a linear relationship such as:

$$\delta R \approx A + B \cdot \Delta_{ptor} \quad (5)$$

Therefore, rain rate can be approximated from Z and Δ_{ptor} as:

$$R^*(Z, \Delta_{ptor}) = \left(\frac{Z}{a}\right)^{1/b} \cdot 10^{-0.1 \cdot (A + B \cdot \Delta_{ptor})} \quad (6)$$

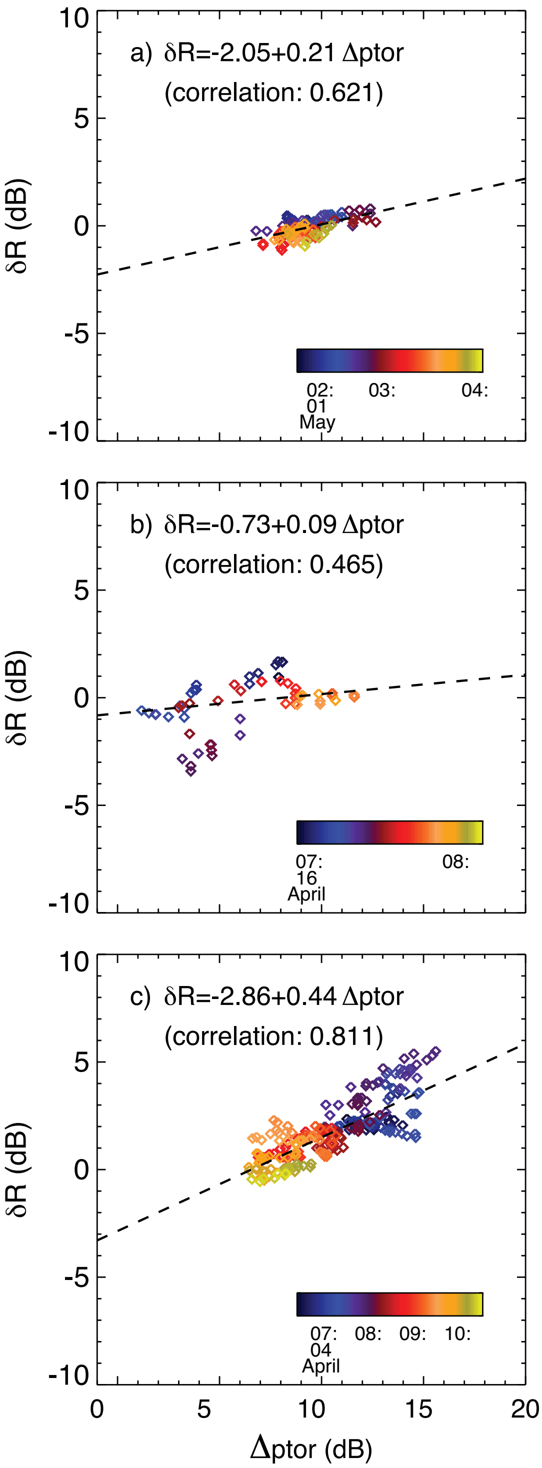

Fig. 8. Scatter plots Δ_{ptor}-δR corresponding to the events showed in figure 1.

6.1 Data used

The data used in this section corresponds to 20 events (totalizing 92 hours) of rainfall profiles measured with the UHF profiler and the DSD observations of a collocated POSS.

6.2 Improvement in rainfall estimates

Figure 9 shows the scatter plot Δ_{ptor}-δR corresponding to the data set described above. The large amount of scatter (the correlation is around 0.51) is due to the different predominant physical processes for the events considered in this data set.

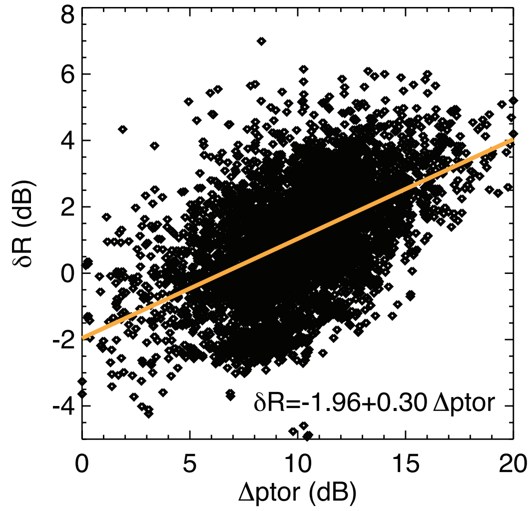

Fig. 9. Scatter plot Δ_{ptor}-δR corresponding to the events analysed in Section 6. The orange line shows the best fit.

Figure 10 shows the comparison of rain rare obtained from POSS DSD observations and rain rate estimated using equations 4 (with climatological paramters) and 6 (in this case using Δ_{ptor} obtained from UHF observations). The figure shows that the normalized mean absolute error (*nmae*) and root mean square error (*nrmse*) are reduced with respect to the usual *Z-R* transformation (figure 10a) after introducing the information of the bright band intensity, Δ_{ptor}, using the parameters A and B, either fitted to the whole data set (orange line in figure 9) or individually fitted to each event (figures 10b and 10c, respectively).

7. CONCLUSIONS

In this study we investigated the correlation between the residuals in the Z-R relationship and the bright band intensity in stratiform precipitation using measurements of a UHF profiler and a collocated disdrometer.

Significant correlation has been found between these two variables, especially in the cases not dominated by heavy riming.

This correlation can be used to partly explain the variability of the *Z-R* residuals. This issue has been studied using 92 hours of observations and significant improvement with respect the usual Z-R transformation has been obtained when observations of the bright band intensity have been introduced.

An open question is the applicability of these results to improve rainfall estimates obtained with a scanning radar in a more operative framework. This issue is still under study using the observations of the McGill S-band radar.

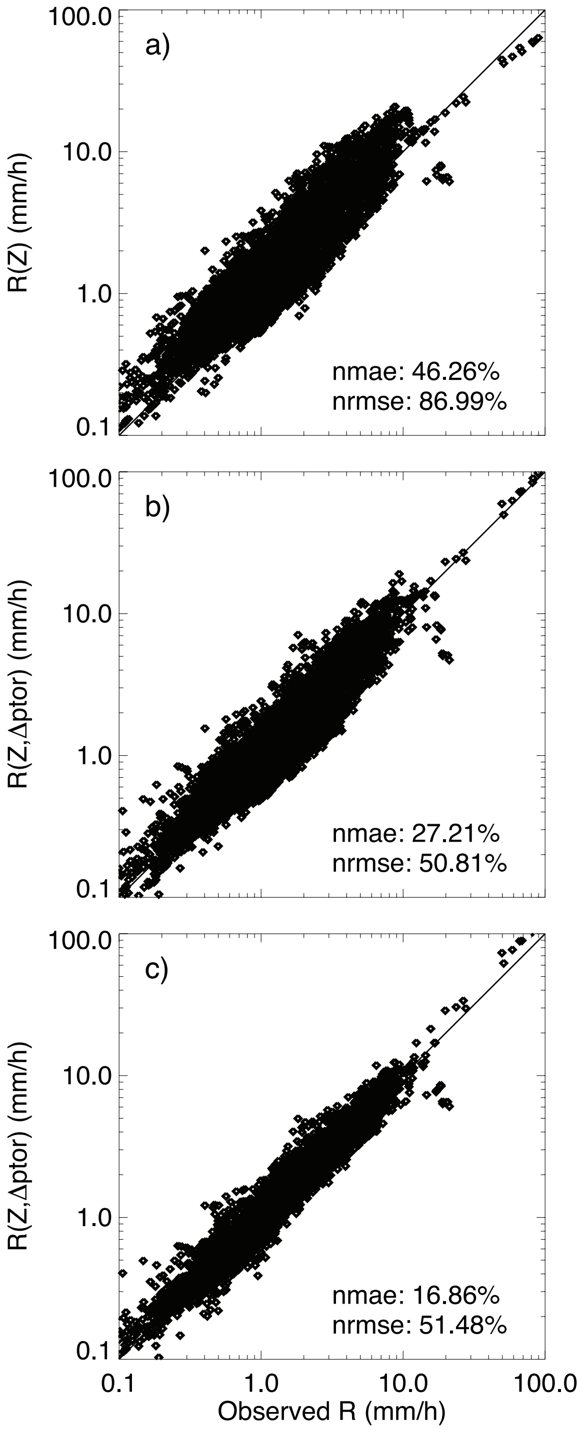

Fig. 10. Scatter plots of actual vs estimated rain rate (R) corresponding to the events analysed in Section 6. Rain rate is estimated from: (a) relflectivity only, (b) reflectivity and Δ_{ptor} using climatological A and B in equation 5, and (c) reflectivity and Δ_{ptor} using event-adjusted A and B in equation 5.

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